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LIBERIA

INITIAL NATIONAL COMMUNICATION

2013

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GEF UNEP

FORWARD

On behalf of the Government and people of the Republic of Liberia, it is indeed a profound pleasure for me to present this Initial National Communication Report of Liberia to the United Nations Framework Convention on Climate Change (UNFCCC) in fulfilling its reporting commitments under Articles 4.1 and 12.1 of the Convention.

This National Report of Liberia covering thematic areas such as national Greenhouse Gas Inventories, Impacts, Vulnerability and Adaptation Assessment, and Greenhouse Gas Mitigation Analysis was prepared by a team of national and international experts with financial assistance from the GEF and technical and project management support from UNEP. Some degree of technical capacity of the local experts drawn from the University, Government Ministries and Agencies in the area of climate change has been developed and will be sustained to ensure that the Republic of Liberia would be able to meet its obligations under the UNFCCC

The report, which focuses mainly on four key economic sectors such as Energy, Forestry, Agriculture, and Waste, has not only contributed to a better understanding of the sources emissions of greenhouse gases within Liberia, but also identified some important sectors of the national economy that could be adversely affected by climate impacts such as coastal zones and agriculture. The report has therefore come up with potential projects which when implemented will help build Liberia's resilience and strengthen its national efforts in tackling the threats of climate change.

The report is truly a synthesis of the outcomes of several sensitization conferences and technical workshops organized by the Climate Change Office of the Multilateral Environmental Unit of the Environmental Protection Agency of Liberia (EPA). The draft report produced out of the validation workshop has been reviewed by imminent national experts whose comments are highly considered.

The report serves a useful resource material to provide the needed information and data for a wide range of stakeholders, including policy-makers, academics, civil society, non-governmental organizations and private entities working generally on climate change and climate related issues. More besides, the report also demonstrates the commitment of the Government of Liberia to work collaborately with the international community to find a win-win solutions to address the multifaceted challenges posed by global phenomenon of climate change.

Finally, with adequate and predictable national and international support, Liberia will be in the position to fully implement the adaptation and mitigation projects listed in Annex 2 of the report.

Anyaa Vohiri

EXECUTIVE DIRECTOR
Environmental Protection Agency of Liberia

ACKNOWLEDGEMENT

Liberia's Initial National Communication (INC) is in compliance with decision 17 CP/8; guidelines for the preparation of national communications from Parties not included in Annex I to the Convention from 23 October to 1 November 2002. The project of creating the INC was executed by the Environmental Protection Agency (EPA) of Liberia under the title: Liberia's First National Communication under the UN Framework Convention on Climate Change. A process of participation and consultation with various consultants and technical teams, the project ensures that Liberia fulfills its obligation under Articles 4.1, 4.2, and 12 of the United Nations Framework Convention on Climate Change (UNFCCC).

Liberia's INC is the second national climate change document seeking to address key issues for Liberia such as national circumstances, national greenhouse gas (GHG) inventory, vulnerability and adaptation measures, mitigation of GHG emissions, and other broad issues. The first document was the National Adaptation Program of Action (NAPA), which addressed the need for urgent and immediate adaptation actions.

On behalf of the project management staff, I wish to congratulate the team leaders and members of the GHG Inventory, Mitigation Analysis Study, and Vulnerability and Adaptation teams. I also thank our international consultants, Prof. Francis K. Allotey, Bubu Jallow, and Audace Ndayizeye, for taking the lead in supporting the work of our local consultants.

I would also like to extend our thanks and appreciation to the United Nations Environmental Programme (UNEP) for providing able guidance for the successful completion of this project. I thank especially Dr. George Manful of UNEP for his maximum cooperation, assistance, and understanding. Liberia has challenges in its institutional systems and human-resource capacities, and Dr. Manful undertook several missions to the country to ensure that the project was on track and completed.

Finally, I must thank past executive directors and the present executive director, Madam Anyaa Vohiri, of the EPA for the support and confidence they have shown in allowing me to coordinate this important project.

Benjamin S. Karmorh, Jr

National Project Coordinator

EXECUTIVE SUMMARY

LIBERIA

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Liberia is located on the West Coast of Africa, bordered by Sierra Leone on the west, Guinea on the north, Côte d'Ivoire on the east, and on the south by the Atlantic Ocean. Covering an area of 111,370 square km, the Liberian landscape is mostly flat to rolling coastal plains containing mangroves and swamps, rising in the northeast to a rolling plateau and low mountains. The highest point wholly within Liberia is Mount Wuteve, which rises to 1,440 meters above sea level in the northwestern Liberia range of the West Africa Mountains and the Guinea Highlands. Mount Nimba near Yekepa is higher at 1,752 meters above sea level, but it is not wholly within Liberia as Mount Nimba shares a border with Guinea and Côte d'Ivoire.

Liberia has a tropical climate with heavy rainfall from May to October, with a short interlude in mid-July to August. The dry season extends from November to April, although there has been gradual change in both seasons over the last 30 years. The coastal areas are wetter and except for highland areas where air is forced to rise, causing aerographic rains, reduced moisture in the atmosphere toward the interior causes rainfall to decrease. Temperature ranges from 32°C in November to 28°C in June. Relative humidity is about 90-100% during the rainy season and 60-90% during the dry season.

Liberia gained its independence on July 26, 1847. The government is a unitary constitutional republic and representative democracy with three branches: the legislative, executive, and judiciary. In addition to the central government administration, Liberia also has a functioning local government. The country is divided into fifteen political subdivisions (counties), each of which is headed by a superintendent appointed by the president. Other levels of local administration are the chiefdoms, headed by paramount and clan chiefs.

With a population of 3.5 million in 2010, projected to increase to 10.3 million by 2058, Liberia is one of the world's poorest countries: the formal employment rate is only 15%. In 2010 the country's nominal GDP was US$974 million, while nominal GDP per capita stood at US$226. The economic growth of the country was 6.3% in 2010. The maternal mortality rate from the 2008 census was 890 per 100,000 live births. The Human Development Index of Liberia was 0.300 in 2010. Historically, the Liberian economy has depended heavily on foreign aid, foreign direct investment, and exports of natural resources such as iron ore, rubber, and timber. Richly endowed with water, mineral resources, forests, and a favorable climate, the main economic sectors of Liberia's economy are mining, agriculture, and forestry, while the main natural resources are iron ore, rubber, timber, diamonds, and gold.

NATIONAL INVENTORY OF GREENHOUSE GASES OF LIBERIA

The Environmental Protection Agency (EPA) of Liberia is the designated agency responsible for the coordination of the preparation of national greenhouse gas (GHG) inventories and compilation of the National Communication (NC) under the UNFCCC. It also serves as the UNFCCC National Focal Point (NFP).

This national inventory submitted covers the selected base year of 2000. Its development is based on the Revised 1996 IPCC Guidelines and the guidelines in IPCC Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories, 2000 (IPCC GPG). Unavailability of activity data (AD) is a big constraint due to loss of basic data during the civil wars from 1989–1996 and 1999–2003. The AD for the energy sector for 2000 was extrapolated from 1999. The AD for agriculture for 2000 was obtained from FAO statistics. IPCC default emission factors were applied.

From Table ES.1, and in the absence of Land Use, Land-Use Change and Forestry (LULUCF) emissions, the total national GHG emissions for the year 2000 amounted to 8,022 Gg CO_2 eq. The energy sector accounted for 67.5% of the total GHG emissions, followed by agriculture (31.9%) and waste (0.6%). With an uptake of 69,991 Gg CO_2 eq. from LULUCF, Liberia is categorized as a sink.

Table 2.1: GHG emissions by sector (without LULUCF), 2000.

GHG Source and Sink categories	TotalGg CO_2 eq.	Sector Share (%) (without LULUCF)
Energy	5,414	67.5
Industrial processes	NO	NO
Solvent and other product use	NE	NE
Agriculture	2,562	31.9
LULUCF	-96,811	
Waste	46	0.6
Other (please specify)	NO	NO
Total (without LULUCF)	8,022	100
Total (with LULUCF)	**-88,789**	

Note: LULUCF– Land Use Change and Forestry

MITIGATION OF EMISSIONS

Through the Mitigation Assessment, national experts and consultants conducted a national-level analysis of the technologies and practices that can either reduce the sources of GHG emissions (abatement) or/ and enhance their sinks (uptake) while supporting sustainable development. The assessment covers the identification and analysis of all measures and activities under implementation and planned at the national level that can contribute to the reduction, removal or sink of GHG emissions. It is extended to the energy, LULUCF, agriculture, and waste sectors.

ENERGY SECTOR

The assessment was based upon and informed by some baselines and targets. There has been an average 14% annual growth in diesel and gasoline consumption since 2004. However, a 10.3% growth up to 2020 and a 3.4% growth between 2020 and 2028 are considered in this study. Baseline estimates of electricity demand range from 11 to 25 MW, rising at an average of 10.3% annually by 2010 and then decreasing slightly to a 3.4% growth annually until 2020. Demand in the residential, commercial, and institutional subsectors will be within the range of 10–12% by 2015. For the industrial subsector, a growth rate of 5% is applied for a business-as-usual (BAU) scenario between 2008 and 2015 but will be followed by a more rapid growth rate of about 12% as the country attempts to restore the full industrial capacity that existed before the war.

For the energy sector the targets included reduction of GHG emissions by 10%, improvement in energy efficiency by 20%, raising the share of renewable energy to 30% of electricity production and 10% of overall energy consumption, and increasing the share of biofuels in the transport sector to 5%. The trajectory of emissions is expected to be 647 Gg in 2015, increasing to 3,435 Gg in 2038 for the residential, commercial, and institutional (RCI) subsectors and to about 32,000 Gg by 2038 for the transport subsector. The emission of CO_2 from the industrial sector is expected to grow from 229 Gg CO_2 in 2015 to 404 Gg in 2020, 711 Gg in 2025 and 1,253 Gg CO_2 in 2038.

Identified mitigation measures for the energy sector are shown in Table ES.2.

The assessment is constrained by a lack of reliable and updated information on activity, which has made it difficult to conduct a quantitative assessment of mitigation options. The GHG inventory which was supposed to be the basis for the assessment suffered from the lack of AD and was incomplete, particularly for the forestry, agriculture, and waste sectors.

FORESTRY SECTOR

The total forest cover of Liberia was estimated at 4.65 million ha in the mid-1980s and 4.52 million ha in 2001, which amounts to an annual deforestation rate of 0.2% or a cumulative 2.6% loss of forest. These changes resulted from logging, farming, hunting, settlement,

Table ES.2: Mitigation options in the energy sector.

Sector	Mitigation Options	Targets
ELECTRICITY	1. Promote hydroelectricity as in the pre-war period. 2. Promote the use of renewable energy technologies and energy-efficient appliances. 3. Declare emission standards. 4. Reduce the losses in the electricity supply system.	1. Reducing greenhouse gas emissions by 10% by 2030. 2. Improving energy efficiency by 20% by 2030. 3. Raising the share of renewable energy to 30% of electricity production and 10% of overall energy consumption by 2030.
RESIDENTIAL, COMMERCIAL, AND INSTITUTIONAL	1. Use renewable energy technologies such as solar water heaters. 2. Use energy-efficient appliances such as compact fluorescence lamp. 3. Use LPG for domestic cooking. 4. Remove the subsidy for kerosene. 5. Set up an energy-efficient use and conservation extension service. 6. Incorporate energy-efficient measures and standards in building design. 7. Audit energy use in commercial and institutional buildings.	
TRANSPORT	1. Continue to improve the public transport system. 2. Equip the police force with the resources to enforce laws and regulations. 3. Put in place a traffic management plan. 4. Ensure integrated land-use and transport planning. 5. Establish a road improvement program. 6. Create a driver awareness campaign for efficient use of vehicles.	
INDUSTRIAL	1. Use renewable energy technologies in hotels and guest houses. 2. Use low-carbon fuel for industrial boilers. 3. Use more energy-efficient and clean technology. 4. Conduct regular audits of energy use and implementation of energy management plans. 5. Declare emission standards. 6. Initiate energy education and extension services.	

Table 3.13: Possible mitigation options in the forestry sector.

Category/Technologies	Description
1. Forest protection and management	
Forest protection	Measures which increase the opportunities for harvesting and marketing of non-timber forest products such as nuts, honey, and fiber can aid forest protection. Introducing small-scale rural industries such as carpentry, brick-making, weaving, etc. may stem the rate of deforestation associated with subsistence farming.
Improvements in harvesting techniques, e.g., reduce logging impact	A good harvest selection system aims to keep all-aged stands through timber cuttings at shorter intervals and many light cuttings. Seedlings become established in small gaps. Under this system two or more intensive harvests are possible during one rotation. At periodic intervals exploitable trees are selectively felled over an area.
2. Sink enhancement	
Improvements in product conversion and utilization efficiency	Anti-log forests attempt to reverse the loss of forest cover by planting trees and lesser plants on deforested lands, regenerating the structure and functions of original forests. This is also commonly known as enhance regeneration or enrichment planting.
Reforestation	Planting trees on degraded land in forest area.
Afforestation	Conversion of non-forest area into forest area by planting trees
Timber plantation	Large-scale plantings on degraded land using short-rotation species, long rotation species, or exotic species with intensive management for wood production.
Agroforestry (social forestry)	Improving carbon sequestration and storage in both soil and biomass through planting trees intercropped with annual crops for the purpose of producing both agricultural and forest products. Long rotation systems that use trees for windbreaks, border planting, and over-storey shade can sequester carbon for many decades.
Urban forestation	Planting trees in parks and gardens, green belts, residential shade trees, and road side and demarcation trees in the rural areas. Urban tree planting offers advantages of reducing GHG through reduction in energy consumption from air conditioning.
3. Substitution	
Stoves for cooking	Replacing cooking stoves with low thermal efficiency (5-10%) with the higher-efficiency (40%) stoves.
Biogas	Biogas is a combustible gas produced by anaerobic fermentation of cellulosic materials such as animal dung, plant leaves, and waste from food processing and households.

Table ES.4: Mean temperature and precipitation scenarios in the 2020s and 2050s for Liberia using RCM ensemble simulation to downscale ECHAM5 and HadCM3 A1b scenarios.

Horizon	Precipitation (%)	Mean Temperature (°C)
2010–2019	+2.0	+0.4
2020–2029	+1.6	+0.5
2030–2039	+5.0	+0.8
2040–2049	+2.6	+1.3

mining, fuel production, plantation, and road building. With stricter enforcement of forest regulations and concessions, this loss is projected to be transformed into biomass restocking. The mitigation measures and technologies identified in the forestry sector (Table ES.3) will enable the restocking.

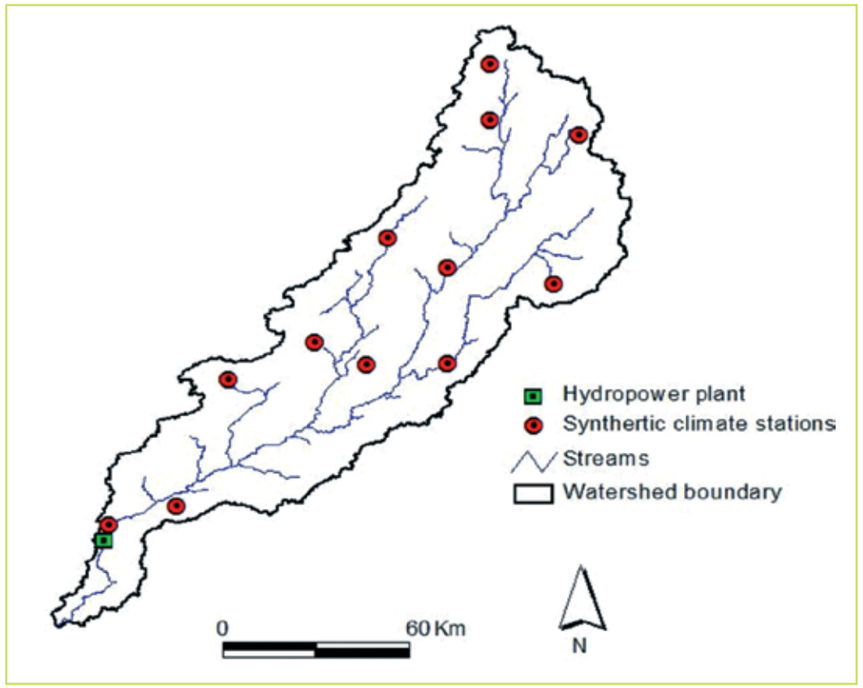
WASTE MANAGEMENT

For the waste-management sector, three waste-management systems recognized in Liberia are solid-waste disposal on land, industrial and domestic wastewater handling, and incineration. Estimated waste production for the Monrovia municipality is about 724 metric tons and is projected to increase by 2.5% every year, producing 153,009 tons/day in 2012 and about 321,000 tons/day in 2020. With this waste-generation rate for the Monrovia municipality, suggested mitigation measures are recycling, composting, incineration, and methane recovery.

Vulnerability (Impacts and Adaptation) of the Liberian Economy to Climate Change

PROJECTED CLIMATE OF LIBERIA

The projected climate of Liberia is based on an ensemble of Regional Climate Models (RCMs). The average rates of change in interdecadal rainfall and mean air temperature are provided in Table ES.4. The average increase in rainfall from 2010–2050 will be between 2.0% and 5.0%. Mean air temperature is unanimously projected to increase by 0.4°C to 1.3°C. The average increase in the 2020s for both rainfall and temperature is estimated at 3% and 0.6°C respectively.



It appears that temperature will increase by 1.3°C in the middle of the 21st century, while rainfall is expected to show great variability without a strongly increasing or decreasing trend.

IMPACTS ON THE ST. PAUL RIVER BASIN

The mean annual total precipitation and potential evapotranspiration (PET) over the St. Paul River Basin for the baseline period (1961–1990) was estimated to be 2,299.7 mm and 1,317.4 mm, respectively. Total drainage area of the basin is about 17,000 km2 (Figure ES.1 below) and the runoff value translates into 16.70 billion m3/year.

Simulations of the water balance show that the St. Paul River Basin runoff is expected to diminish by 0.7%–25% in the 2020s (Table ES.5), which will reduce the production of electricity from the Mount Coffee hydropower plant located in the basin. The supply of raw water to the city of Monrovia also could be seriously affected.

IMPACTS ON AGRICULTURE AND SUGGESTED ADAPTATION

The increase in rainfall could damage rubber production as it will be more difficult to keep the soil in plantations adequately drained. Excess rain during sudden storms with very heavy rainfall and high winds over short periods could lead to broken rubber trees. Significant loss of rice production will occur due to lodging, i.e., rice plants bending over and collapsing.

Identified potential adaptation options in agriculture include development of an agricultural database-management system for data archiving, accessing, and dissemination; planting varieties of rice that are resistant to droughts, flooding, major pests, and diseases; replacement of inorganic fertilizers with soil- enriching (and carbon-absorbing) crop production inputs, processing crops to minimize post-harvest losses, and decreasing animal stock.

IMPACTS ON HEALTH AND SUGGESTED ADAPTATION

Wetter environments in the future will lead to rises in the sea level, making Monrovia and other coastal cities vulnerable to flooding. It has been estimated that a one-meter rise in sea level will place 230,000 people at risk and cause the loss of 2,150 km2 of land, including the infrastructure and much of Monrovia, valued at US$250 million. Increased rainfall and flooding will lead to a greater vulnerability to epidemics of malaria, cholera (likely to increase by 10% by 2100), and diarrheal diseases, increased incidences of Lassa fever, schistosomiasis, lymphatic filariasis, yellow fever, hepatitis A, and intestinal worms. Current expansion of the geographical range of dengue fever could include Liberia since the vectors (Aedes spp. mosquitoes) are present and the disease has been identified in neighboring Côte d'Ivoire.

With warmer environments and associated land-use changes, the savannah form of onchocerciasis will likely spread, insect vectors of disease such as mosquitoes and tsetse flies will complete their life cycles faster and thus their populations will increase, and more breeding sites for mosquitoes will become available, thus exacerbating the transmission of malaria, lymphatic filariasis, etc. Higher temperatures will also lead to higher rates of measles amongst the community.

Suggested adaptation options for the health sector are the development of a health database-management system, development and implementation of policy and strategic initiatives, and strengthening of effective capacity.

ADAPTATION AND MITIGATION TECHNOLOGIES

Technology transfer is a broad set of processes covering the flow of know-how, experience, and equipment for mitigating and adapting to climate change. The broad and inclusive term "transfer" encompasses diffusion of technologies and technology cooperation

Table ES.5: RCM (HadRm 3P and REMO) projected mean annual total runoff (mm) for the St. Paul River Basin, Liberia.

Scenario	Daily Mean Temperature (oC)		Mean Annual Total Precipitation (mm)	
Baseline (1961–1990)	24.6		2,299.7	
	HadRM 3P	REMO	HadRM 3P	REMO
2020s (2011–2040)	26.0	25.7	2,217.2	2,345.7
Change	1.3	1.1	-3.6%	2.0%

Table ES.6: Main barriers to technology uptake and policy options to lift the barriers.

TECHNOLOGIES	BARRIERS	POLICY OPTIONS
1. Hydroelectricity 2. Energy-efficient appliances 3. Retrofitted electricity transmission and distribution lines and equipment 4. Solar home systems for lighting and heating 5. Energy-efficient, compact fluorescent lamp 6. LPG for domestic cooking 7. Renewable fuel sources (solar, wind, and biomass) 8. Industrial water heaters 9. Energy-efficient lighting equipment 10. Sprinkler and drip irrigation systems 11. Improved rice varieties 12. Post-harvest technologies 13. Food processing and preservation technologies 14. Aquaculture 15. Energy-efficient and wood-saving cook stoves 16. Biogas plants and equipment 17. Recycling, composting, and incineration technologies 18. Methane recovery technologies	1. Non-existence of technology development and diffusion policy. 2. High initial cost associated with some of the technologies. 3. Inadequate knowledge and access to technology information. 4. Inadequate capacity to estimate and certify environmental benefits, particularly potential GHG reductions associated with the technologies. 5. Interventions distorting markets, such as subsidies for polluting industries. 6. Regulated markets, monopolies, and oligopolies that create disincentives for new technologies. 7. Sharing of incentives and limited access to capital. 8. Information barriers where, for example, potential purchasers are ignorant of new technology possibilities and/or lack access to technology information. Presented with multiple and conflicting information and limited ability/time to absorb it, purchasers may choose a known option over a new alternative. 9. Externalization of pollution costs.	1. Informing the public, responsible authorities in government and business, and development partners about the potential contribution of the identified technologies to the national economy and the improvement of the livelihoods of the citizenry. 2. Regulatory reform, including tighter regulatory standards and/or the modification of unhelpful regulations. 3. Modest financial interventions in information provision and pilot/demonstration schemes. 4. Closer cooperation and collaboration between the public and private sectors. 5. Internalization of external costs, for example, through carbon taxation, can encourage the uptake of climate-friendly technologies.

across and within countries. Transfer comprises the process of learning to understand, utilize, and replicate the technology, as well as the capacity to choose and adapt technologies to local conditions and integrate with indigenous technologies. Having identified the mitigation and adaptation measures required to respond to the challenges of climate change in Liberia, it was necessary to determine the prerequisite and accompanying technologies needed for the implementation of the identified measures. The determination of the needed technologies followed the establishment of national criteria for selecting the technology transfer priorities based on the national circumstances of Liberia.

Soft and hard technologies required for the implementation of mitigation and adaptation measures identified in preceding sections are as follows:

1 → Mitigation technologies that are categorized as energy efficient and fuel efficient, solar, wind, improved cook stoves, mini hydro, biomass biofuel, landfill-gas recovery, and composting.

2 → Adaptation technologies to include irrigation, crop types and cultivars, post-harvest handling, food processing and preservation, and coastal protection (including groynes, sea walls, revetments, off-shore breakwater, and beach nourishment or replenishment).

The range of potential barriers or obstacles to the promotion and adoption of these technologies are shown in Table ES.6. below.

Acquisition of these technologies and implementation of the adaptation options and mitigation measures will improve the wellbeing of the population of Liberia and the economy. This will be achieved through the development of appropriate investment, procurement, and implementation plans and programs.

A detailed independent study should be conducted following the full UNFCCC process for developing a Technology Needs Assessment (TNA) including detailed analysis of barriers (technical, social, and economic), cost, and sustainability of the actions. Many of the technologies identified in this study need to be adapted to the social, cultural, economic, and environmental priorities of Liberia. As technology issues are mostly in the hands of private-sector, efforts should be made to fully engage the private sector of Liberia not only in the identification and adoption of environmentally-sound technologies but also in the broader implementation of the UNFCCC in Liberia. To that end, there should be capacity-building activities, such as training major stakeholders to be engaged in future TNA processes.

RESEARCH AND SYSTEMATIC OBSERVATIONS

The UNFCCC calls on parties to promote and cooperate in research and systematic observation of the climate system, including through support to existing international programs and networks. These services are mostly provided by the national meteorological services of countries, including the Liberia National Meteorological and Hydrological Service (NMHS).

However, due to the long civil war, the Liberian meteorological service is in a deplorable state. There are no research institutions on weather, climate, or environment in the country. As far as data collection is concerned, observation stations are still not dense enough and are unevenly distributed. Liberia does not make marine-based or space-based observations due to a lack of observation networks and stations in those areas. At present there are only two meteorological stations operating in the country, and these produce land-based meteorological observations. Most of the collected data are processed and provided on a non-real time basis, and the observation equipment is already old, has exceeded its life span, and needs to be replaced. The agency has no centralized or well-managed database and no data-rescue services.

Currently there are no organized or coordinated programs for meteorological, hydrological, or climate research and observation in Liberia. Only fragmented and limited services are available. As well as non-existent observation networks, the agency suffers from inadequately-trained human resources. The Liberian National Meteorological and Hydrological Services (NMHS) currently has insufficient technical and support staff. As of 2011, there were only six meteorologists backed by fourteen meteorological technicians. These constraints also include inadequate or lack of weather and climate research, data processing and management facilities, instruments and equipment, public weather services, and early warning systems. Barriers encountered also include fragmented and limited services on meteorological/climatological and hydrological activities, no policy/legal framework, and no budget support.

As the impacts of weather-related hazards continue to unfold, there will be increasing demand for accurate and timely weather and climate forecasts and other relevant hydrometeorological information for public safety and for planning purposes. To address these demands, Liberia needs to improve and expand its meteorological services to meet the emerging needs of the various economic sectors. It is therefore necessary to put in place the basic requirements for a meteorological service to function effectively. Improved observing/monitoring systems could provide reliable data to

produce customized, accurate, and timely forecasts of great value to the various sectors and to promote sustainable economic development.

The NMS needs to be transformed into a full-fledged agency with the power to perform its mandate of advising the Government of Liberia (GOL) on climate and weather issues that have a critical impact on the socioeconomic development of the country. All sections of the NMS which were moved to other ministries or departments need to be moved back into service in line with international best practices. The NMS needs assistance in gaining the ISO 9001 certification required by the World Meteorological Organization's (WMO) Quality Management Systems for the provision of weather information.

EDUCATION, TRAINING, AND PUBLIC AWARENESS

Implementation of the climate change convention at the national, regional, and international levels depends heavily on creating and improving education, training, and public awareness and understanding of climate change issues. Accordingly, the GOL, through its Ministry of Education (MOE) and its development partners, is making every effort to provide all Liberians with the opportunity for a quality and affordable education relevant to their needs and that of the country.

There is no institution in Liberia that offers climate change education or research programs. However, the University of Liberia (UL), the oldest public higher-education institution (HEI) in Liberia, offers programs on the environment. The MOE, responsible for education and training programs in Liberia, has not incorporated climate change into its education curricula. However, climate change issues are presented within the broad framework of educational programs on sustainable development. At the higher education level, environmental protection issues, including climate change, are addressed in the training programs of the College of Agriculture and Forestry. In addition, climate change-related programs are enshrined in the curriculum of the Department of Geography in Liberia College (the College of Social Science and Humanities) at the UL.

As a commitment to the environment, the GOL established the EPA in 2003, and the agency became a fully functioning entity in 2006. Since its establishment in 2003, significant and visible progress has been made in building Liberia's environmental governance framework. These steps include a dedicated website to improve access to environmental data and information.

Education, training, and awareness of climate change are grossly inadequate in Liberia, as is the case with many countries, particularly in Africa. The major cause is low prioritization of climate change at the policy level. Connecting the scientific and technical issues of climate change to policymaking advances slowly. Many policy and decision makers consider education, health, agriculture, water, and security issues the highest priorities. However, the same policy and decision makers fail to understand that climate change can wipe out development gains in these sectors in a fraction of the time spent in developing those sectors. With better understanding of the inherent opportunities for considering climate change in our daily lives and in our planning, it is possible to develop sustainably.

Thus it is recommended that the climate change institutional framework of Liberia be revisited and coherently developed. The Liberia EPA, in its capacity as the national institution charged with the coordination of the implementation of the Multilateral Environmental Agreements (MEAs), including climate change, should be adequately supported to implement its mandate. The EPA, when adequately supported, should continue facilitating capacity-building and awareness among the Liberian population in collaboration and cooperation with national, bilateral, and multilateral development partners. The EPA should continue to make education, training, research, and public sensitization and awareness a major program of the agency and forge closer working relationships with the media, civil society organizations, and extension services of Liberia.

The print and electronic media of Liberia are engaged in environmental and climate change issues only on an ad hoc basis. The GOL and development partners should work with the Liberia EPA to continue to facilitate closer working relations with the media and civil society organizations. In the short term, the Liberian EPA should initiate a program for the development of a critical mass of "agents of communication" from the media, civil society organizations (NGOs, CBOs, etc.) and public sector extension workers. Engaging the extension services and civil society organizations will pay dividends as these agents are closer to the local communities and understand and speak the same language. Utilizing these resources can be achieved through the design and implementation of a comprehensive training program on climate change, the development and provision of media materials on climate change and environmental issues, and helping governmental and non-governmental agents sensitize the public about environmental issues, particularly climate change.

Liberia needs enhanced knowledge, skills, and partnerships on climate change issues, including cross-sectoral partnerships which are critical to dealing with climate change in a systematic manner. This can be best achieved by building partnerships between the Liberia EPA and key stakeholders mandated to carry out education, research, training, and public sensitization and awareness campaigns. The latter include the MOE, the Ministry of Information and Broadcasting (MIB), local government authorities, extension services, and civil society organizations. In the long term, the MOE, the MIB, and the EPA should work towards integrating climate change into the education curricula at the basic, secondary, tertiary, and university levels. Closer working relations with media-training institutions should be forged and supported with concrete investment over a long period for sustained growth and institutional development.

It is important to point out that during the development of the present First National Communication (INC), the EPA in collaboration with the Ministry of Gender and Development (MOGD) and the Forestry Development Authority (FDA), have conducted a participatory process to develop a gender-sensitive climate change action plan (cc:GAP).

The main objective of the cc:GAP is to ensure that gender equality is mainstreamed into Liberia's climate change policies, programs, and interventions so that both men and women have equal opportunities to implement and benefit from mitigation and adaptation initiatives in combating climate change and positively impact the outcome of Vision 2030.

The cc:GAP includes six priority sectors:

I. Agriculture and Food Security
II. Coasts
III. Forestry and REDD
IV. Health
V. Water and Sanitation
VI. Energy

Gaps, Constraints, and Financial, Technological, and Capacity-Building Needs

The development of this INC of the Republic of Liberia to the UNFCCC Conference of Parties (COP) has not been easy and has been met with a lot of challenges. A lot of data and information gaps exist that make the document comparatively incomplete. In the preceding sections of this document, constraints on and gaps in data, information, and technical and institutional incapacities have been presented and discussed. The following is a summary of the constraints, gaps and capacity deficiencies:

1 → Current policies, strategies, and regulatory mechanisms have limited or no consideration of climate change issues.

2 → There is no dedicated technical committee or task force to implement the climate change convention and its Kyoto Protocol.

3 → At the national level there is limited expertise in the assessment of mitigation and adaptation options, participation in the Kyoto Protocol process, and development of appropriate implementation strategies. The major constraint is the absence of expertise in analyzing, developing, and assessing the cost of mitigation and adaptation options and projects.

4 → The country needs to reduce uncertainties in the statistics and develop national- and/or regional-specific emission factors with the ultimate objective of improving and updating the national GHG inventory.

5 → The institutional framework and technical expertise for the development of a comprehensive and integrated vulnerability (impacts and adaptation) assessment is limited.

6 → Liberia needs sustained access to a reliable body of scientific and technical information.

These capacity constraints exist at the systemic, institutional, and individual levels. At the systemic level, the limited or non-existent enabling environments created by inappropriate policies, strategies, and regulations are constraints. At the institutional level, the Liberia EPA and its collaborating institutions are constrained by inadequate financial resources and inadequate human resources with the appropriate scientific and technical expertise. At the individual level expertise is limited. The absence of a dedicated climate change committee or task force makes it difficult to identify qualified technicians who will be available long enough to participate in the implementation of the convention and its Kyoto Protocol.

What is needed is the development of policies, measures, and opportunities for sustainable development strategies that will make climate-sensitive sectors resilient to climate variability and change and allow development to proceed on a low- or carbon-neutral path. Such policies should lead to reduced pressure on resources and enhance adaptive capacity. Liberia urgently needs to develop a climate change policy and a low-carbon development strategy.

One of the highest priorities is strengthening the Liberia EPA and its collaborating institutions to enable effective participation in the implementation of the convention and the Kyoto Protocol process. This will involve the following program of activities:

1 → Instituting a dedicated technical National Climate Change Committee (NCCC) with an open membership from all sectors of the Liberian economy;

2 → Establishing in-country or regional and international training programs to improve the expertise of the EPA and the members of the NCCC about the science, economics, and politics (negotiations) of climate change.

3 → Developing a climate change policy, a comprehensive Low-Carbon Development Strategy (LCDS), and a Climate Change Action Plan (CCAP) with an integrated implementation strategy.

In updating and improving the national inventory of GHG emissions, the members of the NCCC assigned the study will need to move beyond the mechanical use of the IPCC inventory guidelines, guidance materials, and the default emission factors contained in those guidelines.

In conducting vulnerability (impacts and adaptation) assessments, technical experts acquire rough General Circulation Model (GCM) outputs and use these to develop national-level climate and climate change scenarios. These scenarios are then used as input for computerized biophysical models such as DSSAT, WATBAL, SPUR2, GAP, etc. to assess the vulnerability of the economy to climate change. Liberian technical experts have very limited expertise in adapting the source codes to the national circumstances of their own country. For a comprehensive vulnerability assessment, the capabilities and skills of Liberian technicians need to be developed beyond those acquired through workshops.

Development and implementation of climate change programs is a process that depends on access to a reliable body of scientific information. The information is developed from raw data acquired from a national, regional, and global system of observation networks. Liberia has limited historical climate data (less than 100 years), meteorological and hydrological networks have deteriorated, and gaps in data have occurred, especially in the 1980s and 1990s. Inadequate or non-available equipment for systematic collection of long-term instrumental observation of climate system variables has the consequence of limiting the vital data required for the development of adequate and accurate input variables necessary for modeling and simulating climate and climate change. It is thus a priority in Liberia to reverse this deterioration of the observation networks and improve the availability of data and information. Improvement will entail acquiring Automatic Weather Stations (AWS) and rehabilitating and stocking meteorological stations with the required number of instruments and automatic recorders. Adequate number of replacement parts and spares should also be stocked for timely replacement. Instrument and electronic technicians should be trained to maintain the networks.

NETWORKING AND KNOWLEDGE AND INFORMATION SHARING

Knowledge sharing is the exchange of ideas and experiences through networks of relationships. Knowledge sharing only occurs when people are genuinely interested in helping one another develop new capacities for action; it is about creating learning processes. On the other hand, information sharing typically channels messages between knowledge producers and target audiences. In both cases networking is key, and the emergence of new participatory tools such as web-based social media, including Twitter, wikis, and blogs, participatory video, and mobile phones present exciting opportunities and important challenges to complex concerns such as climate change, development, and global environmental governance.

The following is a list of some sources and climate change networks that institutions in Liberia can use to access climate change knowledge and information:

1→ AfricaAdapt Knowledge Sharing Network at http://www.africa-adapt.net/

2→ GenderCC – Women for Climate Justice at www.gendercc.net

3 → Civil Society Network on Climate Change (CISONECC) at http://www.cepa.org.mw/cisonecc/

4 → Community Based Adaptation Network and Sharing at www.bcas.net/2nd.cba/index.html

5 → The Communication for Development Network (C4D) at http://c4dnetwork.ning.com/.

6 → Climate Change Media Partnerships (CCMP) at http://www.climatemediapartnership.org/

7 → The Communication Initiative Network at http://www.comminit.com/global/spaces-frontpage

8 → "Time to adapt? Media coverage of climate change in non-industrialized countries," by Mike Shanahan, International Institute for Environment and Development (IIED), June 2009, at www.iied.org/pubs/pdfs/G02512.pdf

9 → Panos London, an online resource for journalists and other media professionals seeking to provide the public with quality information about the impacts of climate change, at http://panos.org.uk/resources/

10 → BBC World Service Trust: Africa Talks Climate at http://www.africatalksclimate.com/

11 → Earth Journalism Network (EJN) at www.earthjournalism.org/

12 → Climate Change Information Network - CC:iNet at http://unfccc.int/cc_inet/cc_inet/items/3514.php

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ACRONYMS AND ABBREVIATIONS

AAU	Association of African Universities
ACCFP	Africa Climate Change Fellowship Program
ACPC	African Climate Policy Centre
AD	Activity Data
ADB	African Development Bank
AEMET	Agencia Estatal de Meteorología de España
AF	Adaptation Fund
AFL	Armed Forces of Liberia
AFTN	Aeronautical Fixed Telecommunications Network
AIDS	Acquired Immune Deficiency Syndrome
AIS	Alien Invasive Species
AMESD	African Monitoring of the Environment for Sustainable Development
AMHS	Aeronautical Message Handling System
AMPS	Aeronautical Message Processor System
ASEAN	Association of Southeast Asian Nations
AU	African Union
AWOS	Automatic Weather Observing Station
AWS	Automatic Weather Stations
BAU	Business-as-usual
BMA	Liberia Bureau of Maritime Affairs
BMC	Bong Mining Company
BRE	Buchanan Renewable Energies
BSE	Bureau of State Enterprises
C4D	Communication for Development Network
CAADP	Comprehensive Africa Agriculture Development Program
CAAS-Lib	Comprehensive Assessment of the Agriculture Sector in Liberia
CAP	Climate Action Plan
CARI	Central Agricultural Research Institute
CBA	Community Based Adaptation
CBD	Convention on Biological Diversity
CBF	Capacity Building Framework
CBL	Central Bank of Liberia
CBO	Community-Based Organization
CCA	Common Country Assessment
CCAP	Climate Change Action Plan
cc:GAP	Climate Change Gender Action Plan
CCGCC	International Competence Centre Gender & Climate Change
CC:iNet	UNFCCC Climate Change Information Network
CCMP	Climate Change Media Partnerships
CD	Commercial Department
CDKN	Climate and Development Knowledge Network
CDM	Clean Development Mechanism
CEMENCO	Liberia Cement Corporation
CEMESP	Center for Media Studies and Peace Building
CFLs	Compact Fluorescent Lamps
CFO	Central Forecasting Office
CH_4	Methane
CHP	Combined Heat and Power
CHWG	Climate and Health Working Group
CI	Conservation International
CISONECC	Civil Society Network on Climate Change
COP	Conference of Parties
CO_2	Carbon Dioxide
CSDI	Communication for Sustainable Development Initiative
CSET	Center for Sustainable Energy Technology
DARE	Data Rescue
DC TV	Ducor Broadcasting Corporation TV
DCWWH	Domestic and Commercial Wastewater Handling
DES	Development, Equity, and Sustainability
DSSAT	Decision Support System for Agrotechnology Transfer
DWEH&S	Department of Waste, Environmental Health, and Sanitation
ECHAM5	European Centre Hamburg Model 5
ECOWAS	Economic Community of West African States
ECSNCC	Ethiopian Civil Society Network on Climate Change
EE&C	Energy Efficiency and Energy Conservation
EFs	Emission Factors
EIA	Environmental Impact Assessment
EITI	Extractive Industries Transparency Initiative
EJN	Earth Journalism Network
ELTV	Eternal Love Television
EPA	Environment Protection Agency
ESP	Education Sector Plan
EU	European Union
EUMETSAT	European Organization for the Exploitation of Meteorological Satellites
EWS	Early Warning System
FAO	Food and Agriculture Organization
FCRC	Forest Concession Review Committee
FDA	Forestry Development Authority
FFI	Fauna and Flora International
FFS	Farmers Field School
FM	Frequency Modulation
FMCs	Forest Management Contracts
FRMC	Forest Reform Monitoring Committee
GAP	Global Assessment and Prognosis
GCM	General Circulation Model
GCOS	Global Climate Observing System
GDP	Gross Domestic Product
GEA	Global Environmental Assessment
GEF	Global Environment Facility
GenderCC	Women for Climate Justice
Gg	Gigagram
GHG	Greenhouse Gas
GIS	Geographic Information System
GOL	Government of Liberia
GPG	Good Practice Guidance
GSD	General Services Department
GSN	Global Surface Network
GTS	Global Telecommunication System
GUAN	Global Upper Air Network
Ha	Hectare
HadRM 3P RCM	Hadley Centre Regional Climate Model
HEI	Higher Education Institutions
HES	Household Energy Survey
HFCs	Hydrofluorocarbons

HIPC	Heavily Indebted Poor Countries
HIV	Human Immunodeficiency Virus
IAP	Industrial Attachment Program
ICOM	Integrated Communication
ICT	Information and Communication Technology
IEC	Information, Education, and Communication
IIED	International Institute for Environment and Development
IMF	International Monetary Fund
INC	Initial National Communication
IPCC	Intergovernmental Panel on Climate Change
IPCC GPG	IPCC Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories, 2000
IRRI	International Rice Research Institute
ISDR	International Strategy for Disaster Reduction
ISPs	Internet Service Providers
ITCZ	Inter-tropical Convergence Zone
ITD	Inter-tropical Discontinuity
ITK	Indigenous and Traditional Knowledge
KCs	Key Categories
LAC	Liberia Agriculture Company
LAMCO	Liberian American Swedish Minerals Company
LAMCO–JVC	Liberian American Swedish Minerals Company–Joint Venture
LASV	Lassa Virus
LBS	Liberia Broadcasting System
LCDS	Low-Carbon Development Strategy
LCN TV	Liberian Communications Network Television
L$	Liberian Dollar
LDAA	Liberia Domestic Airports Agency
LDC	Least Developed Country
LDTA	Liberia Domestic Transport Agency
LEAP	Liberia Employment Assistance Program
LEC	Liberia Electricity Corporation
LF	Lassa Fever
LFR	Liberia Forest Reassessment
LGS	Liberian Geological Survey
LHS	Liberian Hydrological Service
LISEIS	Liberia Institute of Statistics and Eco-Information Services
LISGIS	Liberia Institute of Statistics and Geo-Information Services
LLPRS	Lift Liberia Poverty Reduction Strategy
LLWAS	Low Level Windshear Alert System
LMC	Liberia Media Center
LMI	Liberia Media Initiative for Peace, Democracy and Development
LNP	Liberia National Police
LPERP	Liberia Primary Education Recovery Program
LPG	Liquefied Petroleum Gas
LPMC	Liberia Produce Marketing Corporation
LPRC	Liberia Petroleum Refining Corporation
LTA	Liberia Telecommunications Authority
LULUCF	Land Use, Land-Use Change and Forestry
LWSC	Liberia Water and Sewage Corporation
MCC	Monrovia City Corporation
MCIT	Ministry of Commerce, Industry and Transportation
MDAs	Mineral Development Agreements
MDG	Millennium Development Goals
MDTF	Multi-Donor Trust Fund
MEAs	Multilateral Environmental Agreements
MIB	Ministry of Information and Broadcasting
MICAT	Ministry of Information, Cultural Affairs and Tourism
MLME	Ministry of Lands, Mines and Energy
MOA	Ministry of Agriculture
MOF	Ministry of Finance
MOGD	Ministry of Gender and Development
MOE	Ministry of Education
MOH&SW	Ministry of Health and Social Welfare
MOPT	Ministry of Posts and Telecommunication
MOT	Ministry of Transport
MPEA	Ministry of Planning and Economic Affairs
MPW	Ministry of Public Works
MRU	Mano River Union
MRV	Measurement, Reporting, and Verification
MSG-PUMA	Meteosat Second Generation - Preparation for Use of MSG in Africa
MW	Megawatt
N_2O	Nitrous Oxide
NACUL	National Charcoal Union of Liberia
NAM	Non-Aligned Movement
NAPA	National Adaptation Program of Action
NATCOM	National Communication
NBSAP	National Biodiversity Strategy and Action Plan
NCC	National Cultural Center
NCCC	National Climate Change Committee
NCHE	National Commission for Higher Education
NCSA	National Capacity Self-Assessment
NEP	National Energy Policy
NEPAD	New Partnership for Africa's Development
NFP	National Focal Point
NFRL	National Forestry Reform Law
NGO	Non-Governmental Organization
NICOM	National Industrial Company
NIIP	National Inventory Improvement Plan
NMA	National Meteorological Agency
NMHS	National Meteorological and Hydrological Services
NMVOC	Non-Methane Volatile Organic Compounds
NOx	Nitrogen Oxides
NRM	Natural Resource Management
NWP	Numerical Weather Prediction
NWRSB	National Water Resources Supply Board
PET	Potential Evapotranspiration
PFCs	Perfluorocarbons
PMCPWA	Partnership for Media and Conflict Prevention in West Africa
PMCRWA	Partnership on Media and Conflict Resolution for West Africa
PPA	Power Purchase Agreement
PPCA	Public Procurement and Concession Acts
PRS	Poverty Reduction Strategy
PRSP	Poverty Reduction Strategy Paper
PUL	Press Union of Liberia
PV	Photovoltaic
QA/QC	Quality Assurance/Quality Control
QMS	Quality Management Systems

RADAR	
RCM	Regional Climate Model
REDD	Reducing Emissions from Deforestation and forest Degradation
REMO	Regional Model
RIA	Roberts International Airport
RPAL	Rubber Planters Association of Liberia
RREA	Rural and Renewable Energy Agency
SARS	Severe Acute Respiratory Syndrome
SBSTA	Subsidiary Body for Scientific and Technological Advice
SCCF	Special Climate Change Fund
SEAN-CC	Southeast Asia Climate Change Network
SF_6	Sulfur Hexafluoride
SHS	Solar Home System
SLM	Sustainable Land Management
SOE	State of the Environment
SOx	Sulfur Oxides
SPUR2	Grassland Ecosystem Simulation Model Software
SRES A1B	Special Report on Emissions Scenario A1B
START	Global Change SysTem for Analysis, Research and Training
SWAT	Soil and Water Assessment Tool
SWDS	Solid Waste Disposal Site
TB	Tuberculosis
TFR	Total Fertility Rate
TNA	Technology Needs Assessment
TOE	Tons of Oil Equivalent
TOT	Training of Trainer
TU	William V.S. Tubman University
TVET	Technical and Vocational Education and Training
UL	University of Liberia
UN CC:Learn	One UN Training Service Platform on Climate Change:
UNDP	United Nations Development Programme
UNDTCD	United Nations Department of Technical Co-Operation for Development
UNECE	United Nations Economic Commission for Europe
UNEP	United Nations Environment Programme
UNESCO	United Nations Educational, Scientific and Cultural Organization
UNFCCC	United Nations Framework Convention on Climate Change
UN FAO	United Nations Food and Agriculture Organization
UNFPA	United Nations Population Fund
UNICEF	United Nations Children's Fund
UNISDR	United Nations Office for Disaster Risk Reduction
UNITAR	United Nations Institute for Training and Research
UPS	Uninterrupted Power Supply
US$	US Dollar
USTC	United States Trading Company
VCP	Voluntary Cooperation Programme
VTC	Volunteer Technology Communities
WATBAL	Water Balance Biophysical Model
WHO	World Health Organization
WMO	World Meteorological Organization
WSS	Water Supply and Sanitation
WVSTCT	William V.S. Tubman College of Technology

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CHAPTER → 1

NATIONAL CIRCUMSTANCES OF **LIBERIA**

1.1: POLITICAL GEOGRAPHY OF LIBERIA

1.1.1: Location

Liberia is situated on the West Coast of Africa and is bounded by longitude 7° 18' to 11° 30' West and latitude 4° 20' to 8° 30' North. The country covers an area of 111,370 square km (see Figure 1.1) with a coastal belt 563 km long extending 149 km inward. It is bordered by Sierra Leone on the west, Guinea on the north, and Côte d'Ivoire on the east.

Fig.1.1 Geographical location of Liberia.

1.1.2: The Government of Liberia

Liberia gained its independence in 1847 and has had two written constitutions. The 1847 constitution was written by Professor Simon Greenleaf of Harvard University (USA) following the Declaration of Independence. This historic document existed for 133 years (1847–1980) and was abrogated by the military take-over (*coup d'état*) of April 12, 1980. The existing constitution of Liberia was written in 1986. The constitution guarantees the dignity of humankind, freedom of the press, freedom of association, freedom of religion, and freedom of speech. Liberia is currently governed by a multiparty, republican democracy. It is a secular state.

The government of Liberia, modeled on the government of the United States, is a unitary constitutional republic and representative democracy with the seat of government based in Monrovia, the capital city of Liberia. The country was initially made up of four provinces that were mainly along the coastal belt where the settlers were based. Later the country was subdivided into nine counties in order to include the indigenous areas. Between 1980 and 2000 the country was again subdivided into fifteen counties (Figure 1.2).

The government of Liberia has three branches: the legislative, the executive, and the judiciary. The legislative branch has two chambers – the Senate (the Upper House) and the House of Representatives (the Lower House). Members of the Senate are elected for nine- and six-year terms for senior and junior senators, respectively. Members of the House of Representatives are elected for a six-year term. Representatives of both houses can be re-elected as many times as their constituencies wish. The constitutional responsibilities of the legislative branch are, among other things, the enactment of laws, minting of currency, creation of national armies, impeachment, etc.

The second branch of the Liberian government is the executive, headed by the president, who is the chief foreign policy formulator and also commander-in-chief of the Armed Forces of Liberia (AFL). With the consent and advice of the Senate, the president appoints cabinet ministers to form the cabinet which assists in the day-to-day running of the government. The president also appoints local superintendents, ambassadors, and other officials. The executive branch is charged with enforcing the laws enacted by the legislative branch.

The third branch of government, the judiciary, is headed by the chief justice, who is assisted by four associate justices of the Supreme Court. The constitutional responsibility of the judiciary is to interpret the laws. The Supreme Court serves as the final arbiter of justice in the country. Under the Supreme Court are several lower courts such as the circuit court, criminal court, tax court, debt court, traffic court, juvenile court, magistrate court, Justice of the Peace courts, etc.

In addition to the central government administration, the country also has a functioning local government. The country is subdivided into fifteen administrative divisions (counties), each of which is headed by a superintendent appointed by the president. The counties are further subdivided into districts headed by commissioners. In addition, cities are headed by mayors. Other levels of local administration are the chiefdoms, headed by paramount and clan chiefs. There is also a traditional system, comprised of zoes and bodios (traditional healers and priests), etc., which is part of the local administration.

Liberia traditionally has maintained cordial relations with the West. China and Libya have been prominent international partners in Liberia's reconstruction since the end of the civil war. Liberia also maintains diplomatic relations with Cuba. The country is a founding member of the United Nations (UN) and its specialized agencies, and is a member of the African Union (AU), the Economic Community of West African States (ECOWAS), the African Development Bank (ADB), the Mano River Union (MRU), and the Non-Aligned Movement (NAM).

Figure 1.2 Political map of Liberia reflecting 15 counties.

1.1.3: Population

The results of five major censuses show that the population of Liberia was 1.02 million in 1962, 1.5 million in 1974 (GOL, 2008), 2.1 million in 1984 (LISGIS, 2009), 3.48 million in 2008 (LISGIS, 2009) and 3.5 million in 2010.

The 1999/2000 Liberia Demographic Survey showed a total fertility rate of 6.2, an average life expectancy of 47.7 years, an infant mortality rate of

Table 1.1: A summary of some key demographic indicators from the 2008 census report.

Total fertility rate (TFR)	5.8	4.9	3.5	3.1
Life expectancy at birth (males)	51.6	54.0	58.6	63.4
Life expectancy at birth (females)	53.9	66.2	60.9	65.5
Life expectancy at birth (both sexes)	52.7	55.0	59.7	64.4
Dependency ratio	0.82	0.74	0.6	0.56

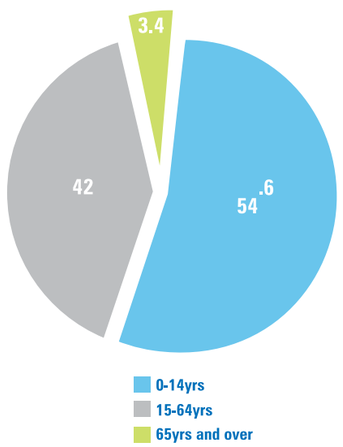
117 per 1,000 live births, and a maternal mortality rate of 578 per 100,000 live births. As of 2006, Liberia had the highest population growth rate in the world (4.50% per annum). The 2008 census indicated a population growth rate of 2.1% and 5.8 total fertility rates. The 2008 census results show that the average expectation of life at birth for Liberia was 52.7 years, i.e., 51.6 years for males and 53.9 years for females (see Table 1.1 below). The age dependency ratio for Liberia is very high with children of 0–14 years of age accounting for 42% of the population, while the population in retirement age comprised 3.4% (see Figure 1.3 below).

The population of Liberia consists of sixteen indigenous ethnic groups and various foreign minorities, including Lebanese, Indians, and other West African nationals. Indigenous peoples comprise about 95% of the population, of which the largest group are the Kpelle in central and western Liberia. Americo-Liberians, who are descendants of African-American settlers, make up 2.5% of the population, and Congo people, descendants of repatriated Congo and Afro-Caribbean slaves who arrived in 1825, make up an estimated 2.5% (CIA, 2011; www.theperspective.org/).

Thirty-one indigenous languages are spoken within Liberia, none of which is a first language to more than a small percentage of the population (www.ethnologue.com). English is the official language and serves as the *lingua franca* of the country (Moore, 2009). Liberians speak a variety of dialects collectively known as Liberian English (Moore, 2009).

By the year 2058 the expectation of life at birth in Liberia will increase to 64.4 years for both sexes, 63.4 years for males and 65.5 years for females. Similarly, the total fertility rate will decrease from 5.8 in 2008 to 3.1 by 2058, while the total population will increase to 10.3 million.

Table 1.3: Age distribution (%) of population of Liberia



1.2: PHYSICAL GEOGRAPHY OF LIBERIA

The Liberian landscape is characterized by mostly flat to rolling coastal plains containing mangroves and swamps, rising in the northeast rise to a rolling plateau and low mountains (Bateman et al., 2000). The relief system of Liberia is subdivided into the following four belts:

1 → The coastal belt extends upland to 32 to 40 km and is composed of gently undulating hills or low plains with an altitude not exceeding 15 m. This belt has three promontories: Cape Mount, Cape Mesurado, and Cape Palmas. The highest of these promontories is Cape Mount on the Sierra Leonean border with a height of over 350 m.

2 → The second belt is composed of hills, discontinuous ranges, and occasional escarpments that constitute the larger parts of Liberia's hinterland.

3 → The third belt is composed of plateaus that are about 200 to 300 m above sea level.

Table 1.2: Principal river basins of Liberia.

River Basin	Total Area (sq km)	Area in Liberia (sq km)
Cavalla	11,670	5,300
Cestos	4,850	3,900
St. John	6,650	5,700
St. Paul	8,460	4,950
Lofa	4,100	3,550
Mano	3,200	2,440

4 → The fourth belt is comprised of mountains that are located in the northern highlands and include the Nimba and Wologisi ranges along the Guinean border.

The highest point wholly within Liberia is Mount Wuteve at 1,440 m above sea level in the northwestern Liberia range of the West Africa Mountains and the Guinea Highlands (Bateman et al., 2000). However, Mount Nimba near Yekepa is higher at 1,752 m above sea level but is not wholly within Liberia as Nimba shares a border with Guinea and Côte d'Ivoire.

Liberia's watershed tends to move in a southwestern pattern towards the sea. As shown in Table 1.2 below, Liberia has six principal river basins, although smaller rivers and streams can be distinguished. All of these rivers empty into the South Atlantic Ocean. The country's main northwestern boundary is traversed by the Mano River, while its southeastern limits are bounded by the Cavalla River (Bateman et al., 2000). The largest of these rivers is the Cavalla found along the eastern side of the country. The river reaches east of the city of Tappita and forms the boundary between Liberia and Côte d'Ivoire, emptying into the South Atlantic Ocean about 25 km east of Cape Palms. The river is also navigable from its mouth for about 80 km inland to its first rapids.

1.3: CLIMATE PROFILE

The climate of Liberia, like any other country in West Africa, is determined by the position of the Intertropical Convergence Zone (ITCZ) or the Intertropical Discontinuity (ITD), as it is better known in West Africa. The ITD moves north and south during the year with areas north of its surface position experiencing dry seasons and areas south of its surface position experiencing wet seasons. The position of the ITD and the climate of Liberia are further influenced by the positions and strengths of the subtropical high-pressure belts located on average at about 45° north and south of the equator, and by the series of low-pressure areas and wave action between these high-pressure belts.

1.3.1: Precipitation

The equatorial climate is hot year-round with heavy rainfall from May to October except for a short interlude in mid-July to August (Bateman et al., 2000). The dry season extends from November to April, although there has been gradual change in both seasons over the last 30 years. However, there is hardly any month without rainfall. The heaviest rainfall is recorded in June while the lightest rainfall is recorded in December. The main type of precipitation experienced in Liberia is convection rainfall.

The coastal areas are wetter and except for highland areas where air is forced to rise, causing aerographic rains, reduced moisture in the atmosphere causes rainfall to decrease toward the interior. Relative humidity is about 90–100% during the rainy season and 60–90% during the dry season.

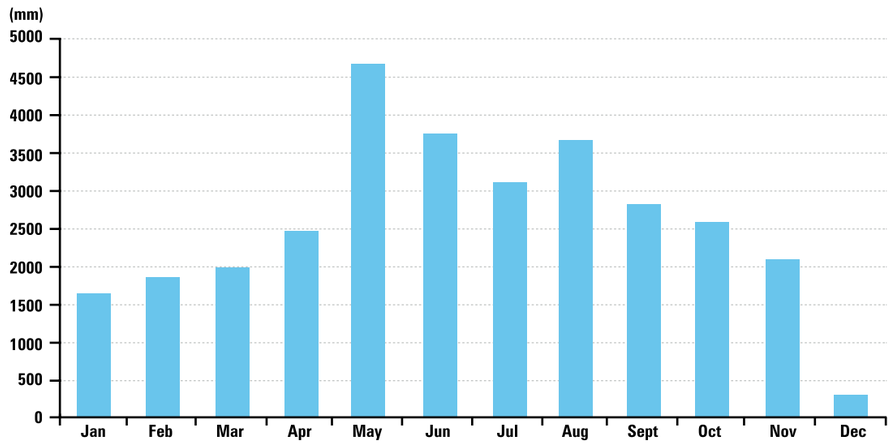
1.3.2: Temperature

The geographic location of Liberia means that the sun is overhead at noon throughout the year because of the country's close proximity to the equator. Insolation is very intensive in all parts of the country. As shown in Figure 1.5 below, temperature ranges from 28°C in November to 32°C in June.

1.3.3: Sunshine

As seen in Figure 1.6 below, the average length of bright sunshine in Liberia is about 7.7 hours/day with

Figure 1.4: Mean Monthly Rainfall (mm) of Liberia from 1953 - 1982



a maximum length of about 9 hours in January and February in the dry season and a minimum length of about 7 hours in August, September, and October, the peak of the rainy season.

1.4: ECONOMY OF LIBERIA

Liberia is one of the world's poorest countries, with a formal employment rate of only 15% (Bureau of African Affairs, 2011). GDP per capita peaked in 1980 at US$496. In 2010 the country's nominal GDP was US$974 million, while nominal GDP per capita stood at US$226, the third-lowest in the world (IMF, 2010). Historically, the Liberian economy has depended heavily on foreign aid, foreign direct investment, and exports of natural resources such as iron ore, rubber, and timber (Bateman et al., 2000).

Following a peak in growth in 1979, the Liberian economy began a steady decline due to economic mismanagement following the 1980 coup (GOL, 2011). This decline was accelerated by the outbreak of civil war in 1989. GDP was reduced by an estimated 90% between 1989 and 1995, one of the fastest declines in history (GOL, 2011). With the end of the war in 2003, GDP growth began to accelerate, reaching 9.4% in 2007 (IMF, 2011). The global financial crisis slowed GDP growth to 4.6% in 2009 (IMF, 2011). Strengthening agricultural and forestry sectors led by rubber and timber exports increased growth to 5.1% in 2010 and an expected 7.3% in 2011, making the economy one of the 20 fastest-growing in the world (IMF, 2010; Africa Governance Initiative, 2011). Current impediments to growth include a small domestic market, lack of adequate infrastructure, high transportation costs, poor trade links with neighboring countries, and the high dollarization of the economy (IMF, 2010). Liberia used the US dollar as its currency from 1943 until 1982 and continues to use the US dollar alongside the Liberian dollar (Africa Governance Initiative, 2011). Following a decrease in inflation beginning in 2003, inflation spiked in 2008 as a result of the worldwide food and energy crises (Ministry of Finance, 2011), reaching 17.5% before declining to 7.4% in 2009 (IMF, 2011). Liberia's external debt was estimated in 2006 at approximately $4.5 billion, 800% of GDP (GOL, 2011). As a result of bilateral, multilateral, and commercial debt relief from 2007–2010, the country's external debt fell to $222.9 million by 2011 MOF, 2011).

While official commodity exports declined during the 1990s as many investors fled the civil war, Liberia's wartime economy featured the exploitation of the region's diamond wealth (*BBC News*, 2000). The country was a major trader in Sierra Leonian blood diamonds, exporting over US$300 million in diamonds in 1999 (*CBC News*, 2006). This led to a UN ban on Liberian diamond exports in 2001. The ban was lifted in 2007 following Liberia's accession to the Kimberley Process Certification Scheme (*USA Today*, 2007). In 2003 additional UN sanctions were placed on Liberian timber exports, which had risen from US$5 million in 1997 to over US$100 million in 2002 and were believed to be funding rebels in Sierra Leone (Greenpeace, 2003; Strieker, 2002). The sanctions were lifted in 2006 (Xu, 2009). Due in large part to foreign aid and investment inflow following the end of the war, Liberia maintains a large account deficit, which peaked at nearly 60% in 2008 (IMF, 2010). Liberia gained observer status with the World Trade Organization (WTO) in 2010 and is in the process of acquiring full member status (Star Radio Liberia, 2010).

Liberia has the highest ratio of foreign direct-investment to GDP in the world with US$16 billion in investment since 2006 (Africa Governance Initiative, 2011). Following the inauguration of the Sirleaf administration in 2006, the country signed several multi-billion dollar concession agreements in the iron ore and palm oil industries with numerous multinational corporations, including BHP Billiton, ArcelorMittal, and Sime Darby (AllAfrica.com, 2010). The Firestone Tire and Rubber Company, now Firestone Natural Rubber Company, has operated the

Figure 1.5: Mean Monthly Temperatures (ºC) of Liberia from 1953 to 1982

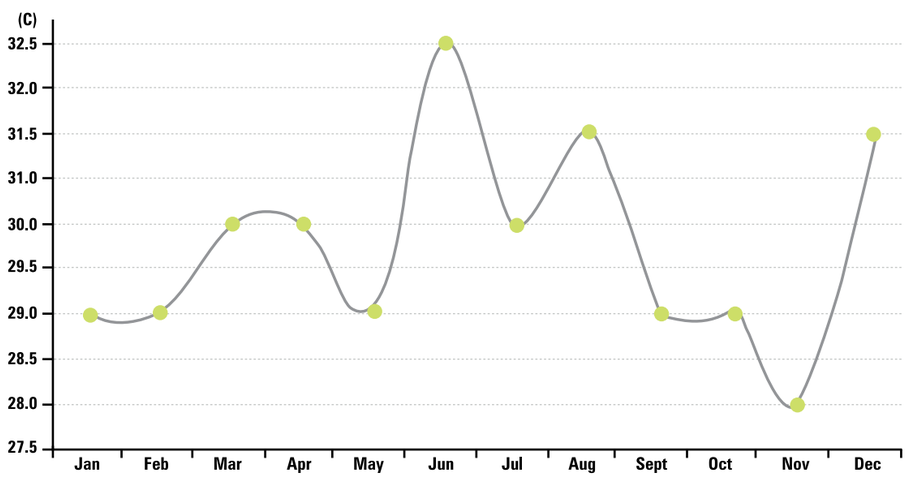


Figure 1.6: Mean Monthly Sunshine (Hrs) in Liberia

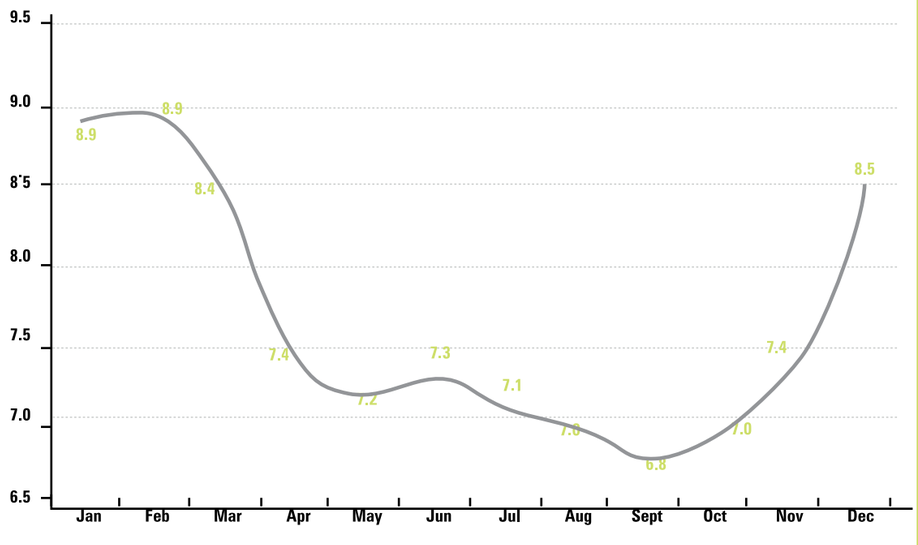


Table 1.3: Estimated economic indicators of Liberia (2011 US$)

	2009	2010	2011	2011 World Ranking
GDP – PPP (US$ billion)	1,632	1,734	1,836	190
GDP – Exchange rate (US$ billion)			1.2	
GDP – Real Growth Rate (%)	4.6	5.6	6.9	25
GDP/Capita – PPP (US$)	400	400	400	223
GDP – Composition by sector	Agriculture (76.9%), industry (5.4%), services (17.7%) (2002 est.)			
Labor force	1.372 million (2007), world ranking 132			
Labor force – by occupation	Agriculture (70%), industry (8%) and services (22%) (2000 est.)			
Unemployment rate (%)	85%, world ranking 197 (2003 est.)			
Population below poverty line (%)	80% (2000 est.)			
Household income (%)	2.4% for lowest 10%, 30.1% for highest 10% (2007 est.)			
Distribution of family income	Gini index 38.2 (2007 est.), world ranking 74			
Budget (US$ million)	Revenues: 420.5, expenditures: 431.3			
Taxes and other revenues	35% of GDP (2011 est.), world ranking 66			
Budget surplus (+) or deficit (-)	-0.9% of GDP (2011 est.), world ranking 53			
Inflation rate (consumer price)	7.3% (2010 est.), 10% (2011 est.), world ranking 188			
Commercial bank prime lending rate	14.3% (Dec. 31, 2010 est.), 15.7% (31 Dec. 2011 est.)			
Agriculture – products	Rubber, coffee, cocoa, rice, cassava (tapioca), palm oil, sugarcane, bananas, sheep, goats, and timber			
Industries	Rubber processing, palm oil processing, timber, and diamonds			
Electricity	Production = 335 million kWh (2008), world ranking 165 Consumption = 311.6 million kWh (2008), world ranking 167			
Oil	Production 0 bbl/day (2009), world ranking 189 Consumption 4,500 bbl/day (2010), world ranking 172 Exports = 23.37 bbl/day (2009), world ranking 131 Imports = 4,552 bbl/day (2009), world ranking 131			
Current account balance	-$511.2 million (2011 est.), world ranking 111 -$692.5 million (2010 est.)			
Exports	$362.3 million (2011 est.), world ranking 177 $207 million (2010 est.) Commodities: rubber, timber, iron, diamonds, cocoa, and coffee Partners: South Africa 26.9%, US 18.1%, Spain 7.8%, Denmark 5.4%, Venezuela 4.8%, Malaysia 4.3% (2010)			
Imports	$763 million (2011 est.), world ranking 183 $726.7 million (2010 est.) Commodities: fuels, chemicals, machinery, transportation equipment, manufactured goods, and foodstuffs Partners: South Korea 37.2%, China 26.3%, Singapore 17.3%, Japan 11.5% (2010), South Korea 37.2%, China 26.3%, Singapore 17.3%, Japan 11.5% (2010)			
Reserves of foreign exchange and gold	$579.5 million (Dec. 31, 2011 est.), world ranking 149 $399.8 million (Dec. 31, 2011 est.)			
Debt – external	$1.66 billion (Dec. 31, 2009 est.), world ranking 145 $3.2 billion (2005 est.)			
Exchange rates – Liberian$ per US$	74.2 (2011 est.) 71.78 (2010 est.)			

world's largest rubber plantation in Liberia since 1926 (www.firestonenaturalrubber.com/Company). Liberia has also begun exploration for offshore oil: unproven oil reserves may be in excess of one billion barrels (Reuters Africa, 2009). The government divided its offshore waters into 17 blocks and began auctioning off exploration licenses for the blocks in 2004, with further auctions in 2007 and 2009 (Business Wire, 2004; Pearson, 2007; Deloitte Petroleum Services, 2009). An additional 13 ultra-deep offshore blocks were demarcated in 2011 and planned for auction (Toweh, 2011). Among the companies that have won licenses are Repsol, Chevron, Anadarko, and Woodside Petroleum (Konneh, 2010).

Due to its status as a flag of convenience, the country has the second-largest maritime registry in the world (behind Panama) with 3,500 vessels registered under its flag, accounting for 11% of ships worldwide (Schoen, 2003).

The Liberian economy grew by 6.3% in 2010. The main sectors of the economy are mining, agriculture, and forestry, while the main natural resources are iron ore, rubber, timber, diamonds, and gold. Richly endowed with water, mineral resources, forests, and a climate favorable to agriculture, Liberia had been a producer and exporter of basic products, primarily raw timber and rubber, and is reviving those sectors. Local manufacturing, mainly foreign-owned, had been small in scope. President Ellen Johnson Sirleaf, a Harvard-trained banker and administrator, has taken steps to reduce corruption, build support from international donors, and encourage private investment. Embargos on timber and diamond exports have been lifted, opening new sources of revenue for the government, and Liberia shipped its first major timber exports to Europe in 2010. The country reached its Heavily Indebted Poor Countries (HIPC) initiative completion point in 2010, and nearly US$5 billion of international debt was permanently eliminated. This new status will enable Liberia to establish a sovereign credit rating and issue bonds. Liberia's Paris Club creditors agreed to cancel Liberia's debt as well. The International Monetary Fund (IMF) has completed the sixth review of Liberia's extended credit facility, bringing total disbursements to over US$379 million. The African Development Bank (ADB) approved a grant of US$48 million in 2011 to finance economic governance and support for competitiveness. Rebuilding infrastructure and raising incomes will depend on generous financial and technical assistance from donor countries and foreign investment in key sectors, such as infrastructure and power generation.

Based on the 2012 Social Institutions and Gender Index (SIGI), the Development Centre of

Table 1.4: Valuable statistics of the energy sector of Liberia

Indicator	Value	Source
Energy sector share of national GDP (%)	0.8	CBL, 2008
Annual petroleum product consumption (m^3)	247,111	LPRC, 2008
Current power generation from the national grid	9.6	MW LEC, 2008
Urban population with access to electricity (%)	10	NEP, 2008
Current electricity tariff	0.43 US$/kWh	LEC, 2008
Rural areas electrified by national grid (%)	0	LEC, 2008
Rural population with private access to electricity (%)	<2	NEP, 2008
Rural population with access to national grid (%)	0	LEC, 2008
Annual charcoal consumption	~36500	NACUL, 2005
Annual firewood consumption (m^3)	0.8 Million	CSET, 2004

the Organization for Economic Co-operation and Development (OECD) ranks Liberia 62 out of 86 non-OECD countries assessed (OECD, 2012). The maternal mortality rate from the 2008 census was 890 per 100,000 live births. The Human Development Index of Liberia was 0.300 in 2010. The latest overall ranking for the country using the Ibrahim African Governance Index (IIAG) was 36 in 2011. Also, Liberia's overall ranking in the African Governance Report (AGR) was 45 in 2011, while Liberia's ranking was 3.2 on Transparency International's 2011 Corruption Perception Index, placing Liberia at 91 out of 183 countries.

1.5: MAJOR SECTORAL POLICIES AND PROGRAMS

1.5.1: Energy

The objective of the National Energy Policy (NEP) of Liberia is "to ensure availability of modern energy services for all Liberians, in both the urban and rural areas." (NEP, 2009 Access to modern energy services is recognized as one of the essential requirements for sustaining people's livelihoods and propelling communities living at subsistence levels to higher levels of prosperity (GEA, 2008).

With appropriate technology, Liberia's post-war social and economic development can be largely achieved with a sustainable energy supply from extensive use of increasingly efficient and decentralized renewable sources such as hydro, solar, wind, geothermal, biomass and dung. The provision of adequate, efficient, and affordable energy services is essential for reducing poverty, raising the standard of living, and enhancing sustainable development in post-war Liberia.

Table 1.4 below shows valuable statistics of the energy sector of Liberia. Liberia imports all its petroleum products, which make up not less than 95% of the primary energy supply of the country. The yearly volumetric import of petroleum products is approximately 175,000 metric tons (NEP, 2009). This consists predominantly of gasoline, diesel fuel, and to a lesser extent, jet fuel and kerosene. In 2004 it was estimated that over 95% of the population relied on firewood, charcoal, and palm oil for their energy needs (NEP, 2009).

Figure 1.7 below shows the trend in consumption of petroleum products from 1991 to 2008 according to data collected and processed by the energy sector GHG emissions inventory team and the Liberia Petroleum Refining Corporation (LPRC) annual reports. While the supply patterns show a decline between 2000 and 2003, the graph illustrates a take-off and very rapid growth rate in the consumption of petroleum products between 2003 and 2008, with an almost linear curve

Table 1.4: Valuable statistics of the energy sector of Liberia

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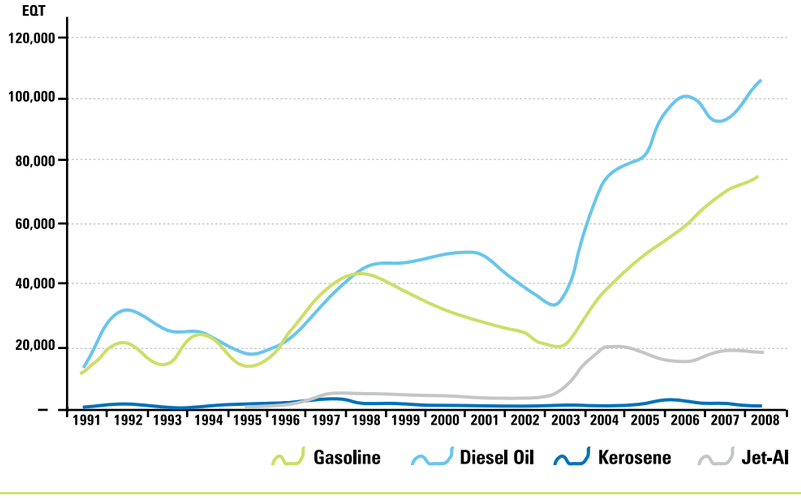
Current power generation from the national grid	9.6	MW LEC, 2008
Urban population with access to electricity (%)	10	NEP, 2008
Current electricity tariff	0.43 US$/kWh	LEC, 2008
Rural areas electrified by national grid (%)	0	LEC, 2008
Rural population with private access to electricity (%)	<2	NEP, 2008
Rural population with access to national grid (%)	0	LEC, 2008
Annual charcoal consumption	~36500	NACUL, 2005
Annual firewood consumption (m^3)	0.8 Million	CSET, 2004

Figure 1.7: Current and Projected Petroleum Products Supply 1991 - 2008 By Fuel Type in Liberia (TOE)



of 14.5% during the last four years (2005–2008). In general, changes in consumption patterns reflect a low quality of data but also a probably erratic supply constraint.

Gasoline and diesel oil together represent almost 90% of the total petroleum products consumed since the 1980s. Table 1.5 below shows the share of petroleum products consumed by transport, electricity generation, and other subsectors of the energy sector. Data from the 2000–2008 periods describe a similar situation.

The disaggregation in Table 1.6 below shows the proportion of various products, particularly those used in the transport sector and for public and private electricity generation (gasoline, diesel oil) and household lighting energy (kerosene). The yearly average consumption during the period 2000–2008 has been 127,665 TOE.

Table 1.5: Estimating energy subsector share of consumption of petroleum products (1986 and 1999).

Subsectors	1999 (TOE)	1986 (%)	1999 (%)
Transport	71,204	36	61.37
Mining	2,500	1.5	1.94
Industrial	833	0.5	0.65
Residential	833	1	0.65
Commercial	3,000	1	2.33
Government	2,333	2	1.81
Electricity generation	37,568	56	29.18
Agriculture and forestry	2,667	2	2.07
TOTAL	**120,938**	**100**	**100**

Table 1.6: Consumption of petroleum products by energy subsectors (1999 and 2008).

Subsectors	1999 (TOE)	2008 (TOE)
Transport	71,204	123,572
Mining	2,500	3,906
Industrial [1]	833	1,309
Residential	833	1,309
Commercial	3,000	4,692
Government	2,333	3,645
Electricity generation	37,568	58,755
Agriculture and forestry	2,667	4,168
TOTAL	120,938	201,356

Using the 2008 figures for petroleum product consumption among subsectors in Table 1.6 above, we can see that from a total of 201,356 TOE consumed, transport absorbed 123,572 TOE while electricity generation consumed 58,755 TOE. The remainder (<10%) was shared among the agriculture and forestry, mining, industrial, residential, government, and commercial subsectors. This assessment is also an indication that:

- The industrial and commercial sectors are still very weak.
- Agriculture and forestry is restarting very slowly.
- Households (residential sector) are still using traditional, more affordable fuels rather than petroleum products for most end-uses like lighting and cooking .

As the quantities of petroleum products consumed overall are consequently relatively low, this may be an opportunity to introduce other non-traditional, non-fossil fuels by implementing programs, projects, and policies to overcome barriers in adopting new end-use technologies. The very slow move in the share of the consumption of petroleum products can be used to estimate quantities per end-use sectors.

This picture can considerably change if sectors like mining and industry start significant economic activity, thus distorting the basis on which calculations are made. This is a clear warning about all data processed in GHG inventories and mitigation studies.

1.5.1.1: Electricity subsector

An act of the national legislature created the Liberia Electricity Corporation (LEC) on 12 July 1973 as a power parastatal with a mandate to plan, generate, transmit, distribute, and sell electricity at reasonable rates in the country. In October 1976 the LEC began operation.

Of the total petroleum products available in Liberia, electricity generation in Liberia consumed 56% in 1986 (pre-war) and 29.18% in 1999. Prior to the war, Liberia's total installed generation capacity was 412.7 MW, of which the LEC owned 195 MW (182 MW in Monrovia and 13 MW in rural areas). The Mount Coffee Hydroelectric Power Plant accounted for about 64MW of electric power out of a total installed capacity of 182 MW generated by the LEC Monrovia grid. The hydroelectric power plant in Harbel, Margibi County, operated by the Firestone Natural Rubber Company, produces 4MW. The total installed generation capacity of LEC in 2012 is 22.6MW. The rest is produced by private sector.

The electricity-generating capacity of the LEC in 2009 was based on 9.6-MW diesel generators, 80 km of transmission and distribution network, with about 1,000 street lights and over 2,500 customers in Monrovia. The GOL signed a 25-year Power Purchase Agreement (PPA) with Buchanan Renewable Energies (BRE), which was expected to construct a 35 MW biomass power plant to supply electricity to Monrovia and its surrounding communities. The power plant would be fueled with wood chips from Liberian rubber trees that are beyond their useful life and that must be removed to make way for new, productive rubber trees. The electricity provided from renewable sources would be sold at a much lower price than current electricity prices, and would be transmitted by the LEC's grid.

[1] *Industrial" refers to non-mining industrial activities such as cement processing, saw milling, processing beverages, etc.*

Figure 1.8: Samples of bad and good roads in Liberia.

Currently (2012), there is about 30 km of distribution network in Liberia, compared with 400 km of transmission lines and 860 km of distribution network before the 1989 war. However, the average power demand for 743 LEC customers in Monrovia during June 2001 was rated at 1.6 MW compared to 199.3 MW for a little over 3,000 Monrovia customers prior to the conflict.

Liberia has great potential for solar energy because it falls in the equatorial belt (which lies between latitudes 15°S and 15°N) and receives the second highest annual solar radiation on earth. Despite this enormous solar energy potential, not much has been done to generate electricity from solar. About 85% of the current annual energy consumption in the coastal regions is charcoal and 5% is wood fuel, while the hinterland uses 85% wood fuel and 5% charcoal. A relatively small quantity of LPG is being used for cooking by a very limited number of households and commercial establishments.

Figure 1.9: Deserted train tracks of the former Bong Mines Company.

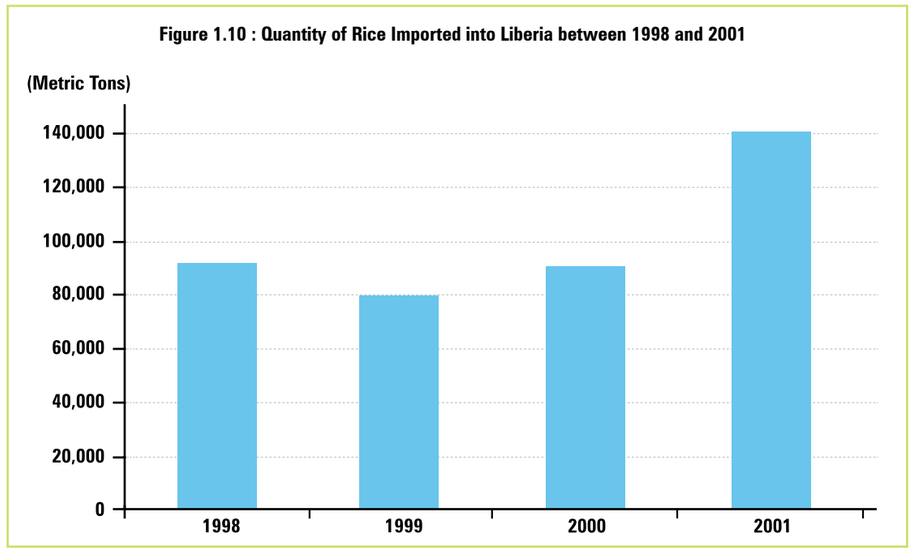
1.5.2: Transport Sector

The conflict in Liberia has reduced the capacity of the transportation sector. The road network is in a devastated condition with very limited road construction, which was largely funded by logging companies during the past 15-year civil war. Only 6.2% of the total network of 10,600 km is paved. Most roads are impassable during the rainy season from April to October (see Figure 1.8 below).

Vehicle statistics for 2001 to 2004 from the Bureau of Land Transport of the Ministry of Transport (MOT) indicate that the total number of vehicles (sedans, Jeeps, trailers, trucks, and buses) plying the streets and roads of Liberia in 2001 were 8,225. The number of vehicles declined to 5,665 in 2002 and 5,660 in 2003 due to the civil war. In 2005 the number of vehicles increased dramatically to 10,150. Most of these vehicles use low-grade diesel and mixed petroleum, and have high potential to emit large quantities of GHG.

Liberia has only one international airport, the Roberts International Airport (RIA), located 45 km south of the nation's capital of Monrovia. There are a few gravel-surfaced runways and paved runways in the country. One of the frequently-used paved runways is the James Spriggs-Payne Airport, which is situated in Monrovia.

The 490 km of rail lines in Liberia were paralyzed by the civil war. Currently, only the Bong Mines rails are functional after being rehabilitated for private and informal rail transport services from Monrovia to the old Bong Mining premises in Lower Bong County. The railway network was not developed to transport passengers within and outside the country but to



transport iron ore from the Bong and LAMCO mines to the ports of Monrovia and Buchanan. This rail network has not been maintained since iron ore mining companies ceased operation due to civil unrest, thus exposing these rails to looting and destruction.

In the 1980s, four seaports (Buchanan, Greenville, Harper, and Freeport of Monrovia) handled approximately 200,000 tons of general cargo and around 400,000 tons of imported petroleum products per year. In addition, all of the seaports were used for timber export while Buchanan and Freeport of Monrovia were used for the export of iron ore, cocoa, coffee, and rubber. The three ports of Monrovia, Greenville, and Harper are generally engaged in the transshipment of rubber and logs (timber). Rubber is also exported from the ports of Harper and Monrovia. In the Freeport of Monrovia harbor, there are sunken vessels and boats that cause extensive pollution around the fuel storage installations.

Liberia currently has the world's second largest fleet in shipping tonnage. This is mainly a result of Liberia's status as an "open registry" or "flag of convenience." In 2001 a total of 1,566 ships with a combined gross tonnage of about 52 million were registered in Liberia, and the majority were foreign-owned. Annual revenues from shipping were reported to be more than US$20 million, which is lower than fees charged by other registries.

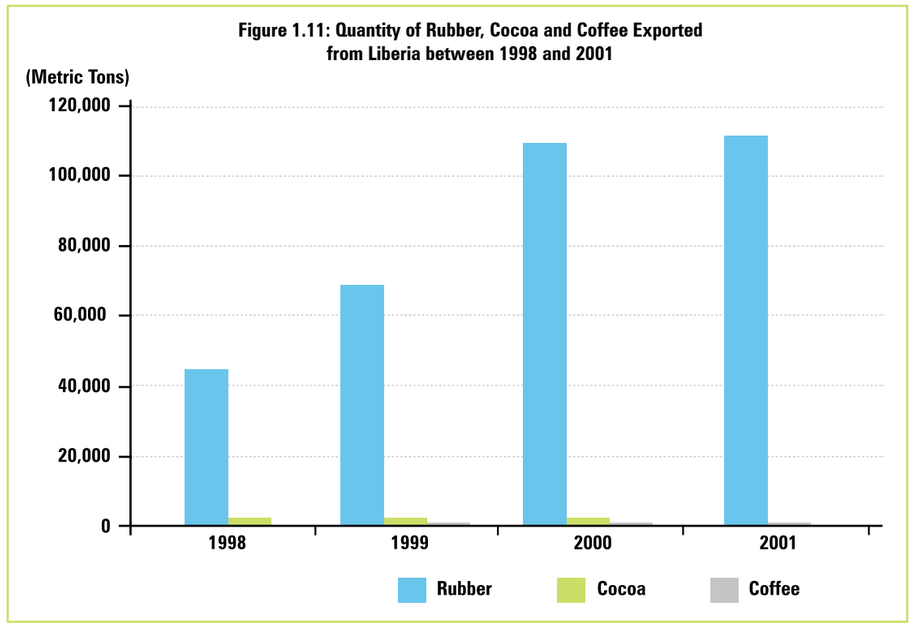
The six major rivers in the country are not navigable by boats or large canoes due to the many stems and debris found in these rivers. Rivers are not frequently used as a means of transportation in Liberia.

1.5.3: Agriculture

The agriculture system of Liberia is 80% subsistence involving shifting cultivation. Major food crops produced are rice, a primary staple food, with some of it imported (see Figure 1.10 below); cassava (a secondary staple), potatoes, palm for oil, coconut, kola nuts, fruits, etc. Liberia's Ministry of Gender and Development (MOGD) highlighted in 2009 that women provide about 80% of the country's agricultural labor force.

The weakness of the subsistence food production system intensified during the past 14 years of war. Rebel activities affected farming at all levels, leaving many fields uncultivated, and food production plummeted downwards. Production has not yet recovered to pre-war levels, compelling the country to import rice for domestic consumption needs. According to estimates (UNFFAO, 2003), less than 10% of the 4.6 million ha of arable land is cultivated. Also affected by the war was the production of major cash crops such as coconut, coffee, rubber, and timber. This situation has had a serious impact on the economy of Liberia.

The major agricultural exports of Liberia (cocoa, rubber, and coffee) were also impacted by the war, further damaging efforts to ensure food security in both urban and rural Liberia. When fully utilized the agricultural sector is one of those areas from which the nation stands to benefit immensely in terms of self-reliance. Liberia especially lags in production of its staple food – rice. In addition to the lack of basic tools and seeds for the production of food and non-food crops, the inactivity of the Liberia Produce Marketing



Corporation (LPMC), the sole buyer of wholesale agricultural products, has further weakened the food security system of Liberia.

The rice paddy production in 2001 was estimated at 219,040 metric tons. This estimate is 73% of its pre-war (1988) level of 298,760 metric tons. The current level of paddy production was achieved with 83% of agricultural households reporting rice growing during 2001. The average paddy production per rice farm and per rice household was estimated in 2001 at 1.52 metric tons and 1.75 metric tons respectively.

In 2001, land area cultivated for paddy production was estimated at 170,480 ha with an average yield of 1,285 kg/ha. This 2001 cultivated land estimate was about 28% below the 1988 pre-war level of 235,760 ha. Cassava production in 2001 was estimated at 373,390

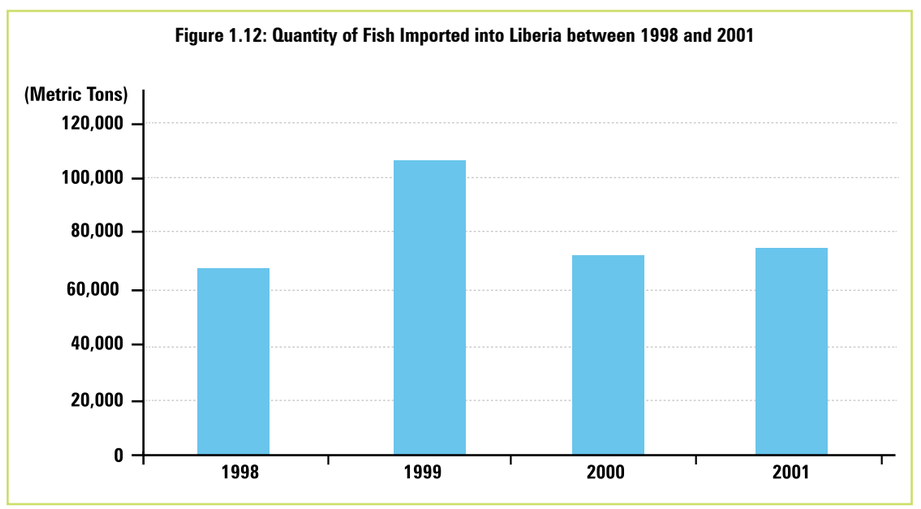
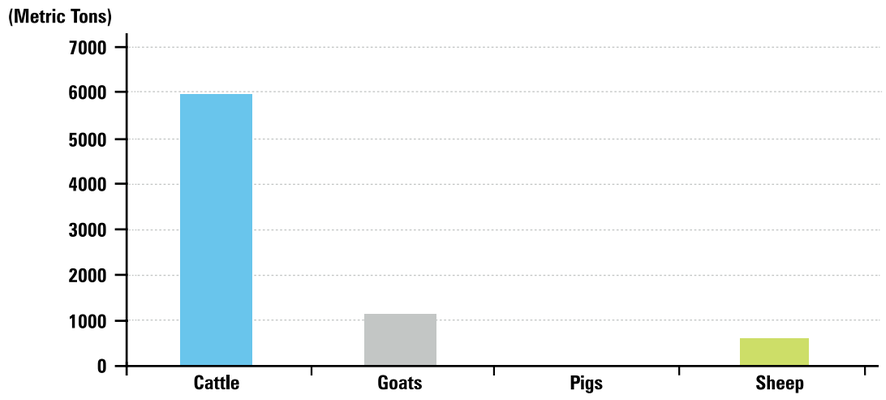


Figure 1.13: Quantity and Types of Livestock Imported into Liberia between 1998 to 2001



metric tons, which was about 91% of its 1998 level of 410,030 metric tons. The average production of fresh cassava per cassava farm and cassava household was estimated at 3.76 metric tons and 4.12 metric tons respectively. There were few company plantations and private farms that produced cash crops and livestock. The biggest plantation in the country is the Firestone Rubber Plantation, which was the world's leading producer of rubber in the 1960s.

Due to the high cost of rehabilitating cocoa and coffee farms affected by the war, 61% of the cocoa farms and 71% of the coffee farms have not been rehabilitated. This has hampered cocoa and coffee production. Between 1998 and 2001, the quantity of cocoa exported totaled 7,457.65 metric tons, while that of coffee was 2,110.80 metric tons. Both the 1998 and 2001 levels are far lower than the 1989 pre-war levels.

1.5.3.1: Fisheries and Livestock

The fisheries, which are a component of agriculture, are underdeveloped in Liberia. The continental shelf of Liberia has an area of 14,894 km2 and produces annually 7,616 metric tons of fish and 126 metric tons of mollusks and crustaceans. Livestock production is very limited in Liberia due to the heavy cost associated with such ventures. There are, however, private livestock farms in Liberia where domestic animals such as cattle, goats, pigs, chickens, ducks, and other livestock are raised.

Due to the underdevelopment of the fisheries and livestock sectors, livestock and fish are imported by the country. The total quantity of fish imported (Figure 1.12 below) between the period 1998 to 2001 was 6,776 (1998), 10,799 (1999), 7,243 (2000) and 7,498 (2001) metric tons respectively. The total quantity of livestock imported (Figure 1.13 below) for slaughter during the same period was 6,000 metric tons of cattle, 1,136 metric tons of goats, 36 metric tons of pigs, and 619 metric tons of sheep.

1.5.4: Information, Culture, and Tourism

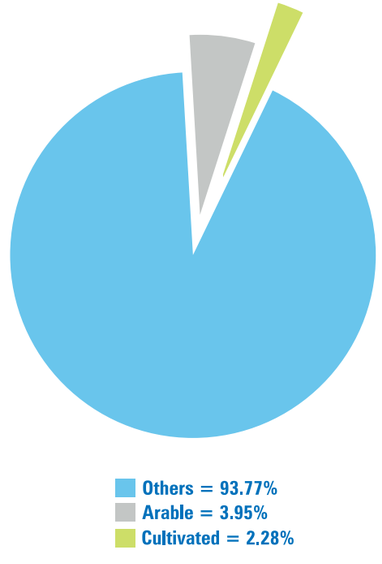
The Ministry of Information, Culture, and Tourism (MICAT) was established in 1965 by an act of the Legislature and granted the authority to direct and supervise all aspects of internal and external information programs about Liberia. The successful implementation of MICAT's mandate has increased the number of newspapers from less than five in pre-war Liberia to fifteen in 2005. There are also community radios in each of the fifteen counties which help to relay programs from the Monrovia-based radio stations, especially those stations that air only on frequency modulation (FM). Television stations have also increased from two in 2003 to four in 2005. The existence of these mass-media institutions creates opportunities and a wide range of enabling environments for development-oriented Information, Education and Communication (IEC)-advocacy in rural and urban localities.

MICAT also monitors, guides, and serves as a catalyst in promoting cultural activities in Liberia. It is empowered to control, regulate, and coordinate the annual registration of information concerning video centers, clubs, cinemas, culture troupes, arts and crafts, antiquities, and also cultural and tourism institutions such as hotels and other activities.

The major institutions which help to train, guide, develop, and protect the Liberian cultural heritage are the National Museum and the national cultural centers (Kendeja in Montserrado and Basao Cultural Village in Bomi). Located in Monrovia, the National Museum of Liberia was the archive of the country's cultural artifacts from all parts of Liberia. However, the 5,000 artifacts in the museum collection in 1989 were reduced to about 100 by the end 2005. Efforts by cultural authorities to recollect looted artifacts have not been successful to date; most of the works were sold or damaged. Today local crafts and artisanal objects are stored and exhibited at the museum. The National Cultural Center (NCC) at Kendeja was established in 1964 to promote Liberia's cultural heritage. In collaboration with the Basao Cultural Village, the NCC has trained cultural artists, craftsmen, dancers, and singers. The centers also organize performing programs for Liberian guests and major celebrations.

The MICAT designs policies aimed at promoting the tourism sector of the Liberian economy. It also coordinates, supervises, and controls tourism programs in the 50 government-recognized tourism institutions. These include hotels, guest houses, beaches, motels, restaurants, and islands (mostly located in or around Monrovia). The government-owned tourism institutions, particularly Hotels Africa and Ducor and Providence Island, have yet to be resuscitated to their pre-war status. However, two of the damaged structures on Providence Island have been renovated. Both the Amphibian and performing theatres are now open to tourists. In fact, about 25 tourists visited the island for sight-seeing in 2005.

Figure 1.14: Percentage Distribution of Land Use in Liberia in 2001



1.5.5: Industry

Industries in Liberia are privately owned with the exception of a few government manufacturing companies. Since the independence of Liberia in 1847, foreign investors especially Americans and Asians have monopolized businesses and industries and dominate the industrial sector of the economy. Industrial production in the country is on a low scale and normally of poor quality and is therefore unable to compete on the international market.

There are a few factories in Liberia, such as Monrovia Breweries Inc, the United States Trading Company–Coca Cola (USTC) factory, CEMENCO, NICOM, etc., that produce commodities for the Liberian market. These factories started production as far back as the early 1970s. The manufacturing industries in Liberia do not have the capacity to produce motor vehicles, simple machines, or high technology machines such as computers, electronic devices, etc. Goods produced in Liberian industries are food stuffs, alcoholic beverages, vegetable drinks, furniture, household utensils, nails, zinc, etc.

1.5.6: Land Use and Forestry

Liberia has one of the world's oldest forests, filled with endangered animal and tree species. The natural forest of Liberia covers 4.8 million ha, with disturbed productive (unprotected productive forest) forest constituting 45% of the total ha available.

An analysis of land use in 2001 (see Figure 1.14 below) shows that 3.95% of the land in Liberia was arable while another 2.28% was used for permanent crops.

The reforestation efforts initiated prior to the 14-year civil conflict have produced an artificial forest that occupies 10,158 ha in Liberia. The largest of these man-made forests is the Bomi Hills in Bomi County with 3,521 ha. This is followed by the Trial Industrial Plantation and the Foya Afforestation with 1,416 ha each. The purpose of the artificial forest is to complement the natural forest that is being depleted by the rampant illegal logging and farming activities in the country. The level of deforestation emanating from logging intensified during the period 1997–2002. For example, in 1998 the 26 logging companies operating in Liberia produced 157,134 m3 of logs.

An analysis of port operation and market in 1998 shows that the Freeport of Monrovia shipped 39.3% (31,707 m3) of the log consignment, while the Port of Greenville exported 34.7 % (27,960 m3). The harvesting and exportation of logs by month shows a sharp decline during the peak of the rainy season (July–December), when most of the roads are impassible in the hinterland where most of the timber harvesting

takes place. The logging industry generates enormous revenue in Liberia. For example, in 1998 the total revenue received was about US$3 million. The high level of revenue from logging, particularly in the past 14 years, increases the probability of depletion of the forest in Liberia.

Charcoal made of wood is used as fuel for cooking and heating of tea and bath water in households, restaurants, and other facilities. Close to 95% of the 1.5 million people in Monrovia use charcoal for cooking and heating, particularly following public electricity outages from 1990 to the present. The widespread use of charcoal is thus a major accelerator of the deforestation that Liberia is experiencing. The illicit destruction of forest for charcoal production has even extended into rubber plantations, where charcoal miners illegally destroy rubber tress to make charcoal.

As a consequence of high demand, the price of charcoal increased 6,000% between 1989 and 2005, from LD$2.50 to LD$150. The huge price increase prompted the rampant destruction of the forest around Monrovia and nearby counties.

Another form of forest destruction for energy generation is the use of firewood for cooking and heating. Outside of Monrovia, some 70–80% of the population in urban centers and large rural localities use firewood. In the rest of Liberia, i.e., the rural areas, towns, and villages, firewood for cooking is universal (100%).

1.5.7: Biodiversity (Flora and Fauna)

Current estimates of flora and fauna show that there are over 2,000 species of flowering plants in Liberia, of which 240 are valuable timber trees. The fauna also consists of 125 species of reptiles and other amphibians, as well as more than 1000 insect species. There are multiple species of birds and mammals such as hawks, eagles, rats, monkeys, leopards, elephants, etc.

The southeastern region of Liberia has the largest forest park: the Krahn-Bassa National Forest, which covers an area of 513,962 ha or 37.1% of the area of all the national parks combined. The overall size of the ten national forest parks in Liberia in the southeast is 66,969 ha. Of these ten parks, five are located in Lofa County, two in Grand Gedeh County and three in Nimba County.

The largest of the national forest and natural reserves in Liberia is the Lofa/Mano Forest with 37.3% (208,120 ha) of the forestland, followed by Cestos/ Sehnwen, 25.9% (144,800 ha), and the Sapo Forest, 23.4% (130,747 ha). The Lofa/ Mano Forest is located in Lofa County, while the Cestos/ Sehnwen and the Sapo Parks are located in Sinoe and Rivercess counties.

1.5.8: Waste Management

Prior to the 1989 civil crisis, the Liberia Water and Sewage Corporation (LWSC) and the Monrovia City Corporation (MCC) were responsible for and capable of managing the disposal of household and material waste within major settlements in Liberia.

The period 1989–2005 has been marked by a poor waste-management system in Liberia. There was no institutional mechanism to ensure the proper disposal of rubbish as well as human feces in both urban and rural localities. The destruction of the water plant and electricity facilities has increased the level of improper waste disposal experienced in Liberia, particularly in Monrovia and other urban centers.

The most common method of disposing of waste is by throwing it on private and public heaps and in freshwater bodies, which affects the environment as well as human and animal health. Some of the rubbish (metallic substances, chemical fluids, plastic bags, and other indissoluble substances) are difficult to dissolve or rot, thereby posing serious environmental and human/animal health problems.

In addition to household rubbish disposal, industrial waste management is a problem in Liberia. This is because of the lack of institutional mechanisms to strengthen regulation and monitor the discharge of industrial waste products into the ocean and freshwater bodies and on the land, common practices which require rigorous monitoring. However, efforts are being made to address the improper disposal of waste.

Figure 1.15: Images of disposed waste in Monrovia

CHAPTER → 2

NATIONAL **GREENHOUSE** GAS INVENTORY

2.1: INTRODUCTION

Liberia ratified the United Nations Framework Convention on Climate Change (UNFCCC) in November 2002 and implemented an 18-month National Adaptation Programme of Action (NAPA) project in 2004. The national green house gas (GHG) inventory report of Liberia has been prepared as part of Liberia's Initial National Communication (INC), fulfilling its mandatory obligation as a non-Annex I party to the UNFCCC in accordance with Article 4, paragraph 1(a), and Article 12, paragraph 1(a) of the Convention.

In this inventory, national and sectoral emissions of GHG are estimated for the year 2000. The year 2000 has been selected as the base year because it is the year with the most complete activity data (AD) for Liberia. Land-use change and forestry, agriculture, and waste sectors had activity for 2000. However, AD for the energy sector was extrapolated from 1999. The industrial processes sector has not been estimated because it is not a key category.

2.1.1: Institutional Arrangement

The Environmental Protection Agency (EPA) of Liberia is the designated inventory agency responsible for the coordination of the preparation of national GHG inventories and compilation of the INC under the UNFCCC. It also serves as the National Focal Point (NFP).

Preparation of the inventory largely revolved around the lead agency and contracted national experts. Inventory data were generally collected through informal arrangements between national experts and staff of relevant ministries, departments, and agencies. There was limited motivation for organizations to share their data with the inventory agency, but through their participation in the national inventory capacity-building activities in 2008, the organizations were able to provide some of the required data. However, there are no clear roles or functions for these various agencies regarding the provision of inventory data needed for the preparation of the national report. Where some form of data such as energy statistics existed in the relevant institutions, the data were compiled for other purposes and were not very suitable for disaggregation. The situation in Liberia, in addition, was aggravated by fourteen years of civil strife, which led to the loss of a lot of statistical data.

The ministries, departments, and private sector corporations that collaborated in providing relevant data for the energy sector were the Department of Energy of the Ministry of Lands, Mines and Energy (MLME), the Statistics Department of the Ministry of Planning and Economic Affairs (MPEA), and the Commercial and Planning Departments of the Liberia Electricity Corporation (LEC), the Liberia Petroleum Refining Company (LPRC), the Rural and Renewable Energy Agency (RREA), and small-to-medium-size private-sector power-producing companies currently operating in the country.

The Marketing Department of the LPRC provided data on petroleum-product imports, sales, and distribution. The LEC provided data on power generation. Other institutions that contributed AD include the Bureau of State Enterprises (BSE), the Ministry of Commerce, Industry and Transportation (MCIT), the Ministry of Transport (MOT), the Liberia Domestic Transport Agency (LDTA), the Freeport of Monrovia, the Liberia Maritime Authority, the Ministry of Agriculture (MOA), the Forestry Development Authority (FDA), the Department of Waste, Environmental Health and Sanitation of the Ministry of Health & Social Welfare, the General Services Agency (GSA), the Ministry of Commerce and Industry (MOCI), the Monrovia City Corporation (MCC), the Liberia Institute of Statistical and Geo-Information Services (LISGIS), and the Liberia Water and Sewer Corporation (LWSC). The Private-Sector Corporation included the Rubber Planters Association of Liberia (RPAL).

2.1.2: Completeness

The inventory submitted covers the selected base year of 2000 and all sectors and gases in accordance with the UNFCCC reporting guidelines but excludes actual emissions of HFCs, PFCs and SF6. The Revised 1996 Intergovernmental Panel on Climate Change (IPCC) worksheets and the UNFCCC inventory software were used for the preparation and reporting of the outcome of inventory as included in Annex 1. The tables are completely filled in with notation keys—NO (Not Occurring), NE (Not Estimated), NA (Not Available)—as appropriate to increase transparency of the reporting. Although to date no detailed information is available on the assessment of excluded categories, as part of the inventory improvement plan effort will be made to estimate significant country-categories reported as NE.

2.1.3: Transparency

The inventory worksheets provide—to the extent possible—information needed in the documentation box to assess the default methods and default emission factors (EFs) used in the inventory estimations. The detailed description of IPCC methods was adopted from the *Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories* (hereinafter referred to as the Revised 1996 IPCC Guidelines) and the *IPCC Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories*, 2000 (hereinafter referred to as the IPCC Good Practice Guidance or IPCC GPG). These guidelines will be used as the basis for the development of the sectoral workbooks in the preparation of the next National Communication (NATCOM).

2.1.4: Recalculations and Time-Series Consistency

The activity data for 2000 will be verified in a Quality Assurance/Quality Control (QA/QC) plan that might be adopted in the preparation of the next national inventory. Any recalculations necessary will be performed to ensure real improvements in the Liberia inventory. Many improvements are expected from new survey data for 2000–2010 and from the use of applicable higher-tier methods to address the time-series and trends analysis that could not be carried out under this process due to data gaps in the 1990–1999 period.

The development of sectoral workbooks, when implemented as recommended, will provide documentation in the NATCOM national inventory report that reflects the essential elements of estimations and reporting recalculations in accordance with the IPCC GPG. These elements include: a description of the changed or refined methods, the justification for the methodological change or refinement in terms of an improvement in accuracy, transparency or completeness; the approach used to calculate the previously submitted estimates, and a comparison of the results obtained using the new approaches.

2.1.5: Uncertainty Analysis of Emissions Estimates

The uncertainty in the AD collected is described as very high by all the sectoral experts because of the nature of data handling during and after the civil conflict period (1989–2003). Improvement in the quality of AD and emission-factor choices and/or estimates using expert judgment, default values, and quantitative methods will help determine uncertainties for identified key categories in the next inventory preparation.

2.1.6: Verification and Quality Assurance/ Quality Control Approaches

For the next NATCOM, a QA/QC plan will be developed as recommended as part of the national inventory workbooks for the entire sector in accordance with the IPCC GPG. This will make use of general QC procedures (tier 1) as well as category-specific procedures (tier 2) for key categories and for those individual categories in which significant methodological and/or data revisions are identified. The plan will include procedures for external reviews, procedures for monitoring and assessing the quality of AD, a system for documenting and archiving national inventory data, and guides to implementing the QA/QC plan. In addition, clear roles will be established for data providers in government, private sector and national experts, and consultants in the development and implementation of the QA/QC tier-1 plan. An external peer review process will also be established to form national working groups for all sectors.

2.1.7: Archiving

The limited AD collected by national experts through surveys is currently archived in a rudimentary data base at the Liberia EPA consistent with the UNFCCC guidelines. The description of procedures and arrangements undertaken to collect and archive data for the preparation of national GHG inventories, as well as efforts to make this a continuous process, including information on the role of the institutions involved in the inventory management team, will be addressed during the preparation of the second NATCOM.

2.1.8: Methodological Choices and Activity Data Sources

The methodological choices made as result of Liberia's unique post-conflict national circumstances were largely guided by the use of decision trees in the IPCC GPG, which provides IPCC default methods, emission factors, and, where applicable, default AD that best represent the national circumstances of parties.

2.1.8.1: Activity Data

The unique national circumstance of Liberia is the loss of data due to the country's instability in the 1990s. The existing, limited country-activity data for various sectors covered different inventory years. For instance, pre-conflict country data existed for the agriculture sector (1975–1984) and energy sector (1981–1986). There was no pre-conflict or post-conflict country data for land-use change and forestry, agriculture, and waste sectors. The pre-conflict and post-conflict AD for agriculture (1975–1984, 2000) and land-use change and forestry (1994–2004) have been obtained exclusively from United Nations (UN) Food and Agricultural Organization (FAO) statistics.

The waste-sector data was derived from a national municipal solid-waste inventory survey undertaken in 2004 by the MCC and UNICEF for the period 1995–2006. The survey covered four municipalities in Monrovia with about 90% coverage in 2004. The data included limited characterization and waste composition.

Because of the problem of different periods for the various sectors, the base year selected for the INC is the year 2000. The AD for the energy sector for 2000 was extrapolated from 1999. The AD for agriculture for 2000 was obtained from FAO statistics. The industrial processes sectors have not been estimated because the potential key categories that contribute to non-energy emissions were not occurring in the selected inventory year 2000.

2.1.8.2: Emission Factors

The methodology principally applied recommended IPCC default emission-factors based on Liberia's national circumstances for all sectors as documented in the Revised 1996 IPCC Guidelines and/or the IPCC GPG. Country-activity data and/or emission factors have been used where they existed or could be derived from available information. For instance, the data for degradable organic carbon and municipal waste generation were obtained from country studies on waste generation by UNICEF and MCC.

2.1.8.3: Methodologies

The adopted IPCC default methodologies recognize various provisions of the UNFCCC guidelines for national GHG inventories for non-Annex I parties. The methods for estimating and reporting the national GHG inventories are thus based on the Revised 1996 IPCC Guidelines. Methodological choices were made using the decision trees of the IPCC GPG and recommended methods (tiers). Priority was given to those methods believed to produce the most accurate estimates based on the national circumstances of Liberia and the availability of data.

2.1.9: Key Categories

Tier 1 key category analysis for level assessment was performed for 2000 in accordance with the IPCC GPG as part of the initial inventory report submission, which excluded emissions from the Land Use, Land-Use Change and Forestry (LULUCF) sector. The key-category analysis of the twelve emissions sources, which were estimated, identified seven key categories (KCs) in the energy sector and two in the agriculture sector shown in Table 2.5. Emissions from industrial processes were reported as NO (Not Occurring) under the current economic sectors.

2.1.10: Inventory Management System

For the development of the national inventory on a sustainable basis, it was necessary to build a critical mass of experts. Capacity- and competence-building and training workshops were organized by the UN Environment Programme (UNEP) for the sectoral teams before undertaking the inventory preparation. The training program was organized for the Liberian EPA and the collaborating institutions responsible for the collection and/or use of country data. The training comprised an overview of national GHG inventories (institutional arrangement, key categories, methods, AD, emission factors, uncertainty assessment, archiving, and reporting) and of estimation methodologies based on Revised 1996 IPCC Guidelines and the IPCC GPG.

Table 2.1: GHG emissions by sector (without LULUCF), 2000.

GHG Source and Sink categories	TotalGg CO_2 eq.	Sector Share (%) (without LULUCF)
Energy	5,414	67.5
Industrial processes	NO	NO
Solvent and other product use	NE	NE
Agriculture	2,562	31.9
LULUCF	-96,811	
Waste	46	0.6
Other (please specify)	NO	NO
Total (without LULUCF)	8,022	100
Total (with LULUCF)	**-88,789**	

Note: LULUCF– Land Use Change and Forestry

The results of the key-category analysis are summarized in Annex 2. Along with other factors that will be identified through the quality assurance/quality control (QA/QC) plan during the next inventory preparation, these results will be used as driving factors in prioritizing areas where resources should be increased for improvement in the next submission.

The national institutional arrangement for inventory management should be considerably improved in the next inventory preparation process. In addition to the Liberia EPA continuing its role as the national designated inventory agency and the NFP, the following key improvements are recommended, among others, to ensure the accessibility to data and information in Mineral Development Agreements (MDAs) and continuity of national inventory preparation:

→ The institutionalization of sectoral inventories in relevant departments of tertiary educational institutions and collaborating MDAs to ensure the development of national institutional memory and continuity of inventory preparation and improvement.

→ The formation of national sectoral working groups by the lead departments and the relevant MDAs to motivate collaborating institutions to share their data and information.

→ The constitution of a national inventory committee by representatives of the national working groups for peer review of the inventories.

→ The inclusion of relevant technicians from the various line ministries, agencies, the private sector, and tertiary institutions in these national working groups.

→ Development of the capability of such working groups to prepare national sectoral inventory work-books appropriate to the national circumstances of Liberia based on decision trees in the IPCC GPG.

→ Formal contracts initiated at a high level of management between the inventory teams and the various MDAs to ensure that requests for AD and other relevant information are recognized, supervised, and delivered.

2.2: INVENTORY ASSESSMENT RESULTS

2.2.1: Aggregate Emissions by Sources and Removal by Sinks

The total national GHG emissions for the year 2000 amounted to 8022 Gg CO_2 eq. The energy sector accounted for 67.5% of the total GHG emissions, followed by agriculture (31.9%), and waste (0.6%). Solvent and other product use was not estimated. The relatively high energy-sector emissions are consistent with Liberia's unique post-conflict national circumstances in 2000. These circumstances are characterized by intensive use of stand-by generators, which have very low thermal efficiencies leading to high consumption of petroleum products per power-generation unit.

Table 2.2: GHG emissions by gas (without LULUCF), 2000.

GHG Source and Sink Categories by Gas	Gg CO_2 eq.	Share by Gas (%) (without LULUCF)
CO_2	3,571	44.5
CH_4	4,141	51.6
N_2O	310	3.9
TOTAL	**8,022**	**100**

Table 2.3: Summary report of emissions estimations for the energy sector.

GHG Source and Sink Categories	CO_2 Gg CO_2 eq.	CH_4 Gg CO_2 eq.	N_2O Gg CO_2 eq.	Year 2000 Gg CO_2 eq.	Contribution to National Total (%)	Contribution to Sector (%)
Total National Emissions	3,571	4,141	310	8,022		
(1) Energy	3,571 (66%)	1,533 (28.3%)	310 (5.7%)	5,414 (100%)	67.5	
A. Fuel combustion (by sector)						
1. Energy industries	1,117	0	0	1,117	13.9	20.6
2. Manufacturing industries and construction	105	0	0	105	1.3	1.9
3. Transport (road vehicles)	2,152	21	0	2,173	27.1	40.1
4. Other sectors	197	1,512	310	2,019	25.2	37.3
5. Other: please specify						
B. Fugitive emissions from fuels						
1. Solid fuels		NO	NO	NO		
2. Oil and natural gas		NO	NO	NO		
C. Other sectors (biomass, gas and other fuels)						

2.2.2: Aggregate Emissions by Gas

Presented in Annex 1 is the summary table of national GHG inventory of anthropogenic emissions by sources and removals by sinks of all GHG not controlled by the Montreal Protocol and GHG precursors. Table 2.1 below summarizes the GHG emissions by sector without LULUCF for the base year 2000.

Table 2.2 summarizes the GHG emissions by gas without LULUCF for BY2000.

The most important GHG in Liberia was methane (CH_4), which contributed 51.6% of the total national GHG emissions, expressed in CO_2 eq., followed by carbon dioxide (CO_2) with 44.5% and nitrous oxide (N_2O) with 3.9%. Hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulfur hexafluoride (SF6)

Table 2.4: Comparison of energy-sector emissions in 1986 (pre-conflict) and 2000.

Greenhouse Gas Source and Sink Categories	1986 Gg CO_2 eq.	2000 Gg CO_2 eq.	1986 Contribution to Category Emissions (%)	2000 Contribution to Category Emissions(%)	1986–2000 Change (%)
1. Energy	23,154	5,414	76.6		
A. Fuel combustion (by sector)					
1. Energy industries	6,781	1,117	29	20.6	84
2. Manufacturing industries and construction	170	105	1	1.9	38
3. Transport	4,536	2,173	20	40.1	52
4. Other sectors	11,336	2,019	49	37.3	82

were not estimated. The high methane emissions reflect the predominantly agricultural nature of the Liberian economy.

2.2.3: Energy Sector

The results of emissions estimations for the energy sector are summarized in Table 2.3.

In 2000, emissions from the energy sector accounted for 67.5% of the total emissions. CO_2 accounted for 66% of sectoral emissions, while CH_4 and N_2O contributed 28.3% and 5.7%, respectively. Transport (road vehicles) was the largest emitting category in 2000, contributing 40.1% to total sectoral emissions. The majority of the vehicles in Liberia are dilapidated and poorly maintained, inefficiently consume low-grade fuel, and are forced to use bad roads. About 90% of imported vehicles are used-vehicles with fuel-combustion effectiveness of about 75%. On the average, 60% of imported used-vehicles in Liberia are ten years old. These vehicles are a major source of CO_2, CO, and other GHG emissions into the atmosphere. The emission of these gases/smoke into the open air influences unfavorable climate change.

The very high road-sector emissions also reflect the large fleet of vehicles being used by UN peacekeeping forces.

The category "Other Sectors" contributed 20.9%, principally driven by high usage of very low thermally-efficient generators for the residential and commercial subsectors. The energy industries subsector produced 20.6% of the emissions from the energy sector. The relatively low emissions (1.9 %) from manufacturing industries and construction reflects the low production and contribution of this subsector to the national economy.

The key category analysis identified the three significant categories- fuel combustion, fugitive emissions from fuel and other sectors in the energy sector.

The sector emissions in the pre-conflict year 1986 and 2000 are compared in Table 2.4. The relative estimates indicate that energy-sector emissions have decreased more than four-fold from 23,154 Gg CO_2 eq. in 1986 to 5,414 Gg CO_2 eq. in 2000, representing a reduction of almost 77%.

The rate of growth in energy-sector emissions in the past decade is a measure of the economic growth of Liberia. Emissions growth in the 2010s can, however, be slowed considerably if Liberian hydropower generation is brought back on stream as part of the country's climate change mitigation response in support of sustainable economic development.

While power generation has declined by over six-fold since 1986, road-transport emissions have doubled from 20 to 40% during this period.

For the period 1991–1999, fairly reliable data on petroleum importation and distribution are available from the LPRC Marketing Department. The 1999 data were used to extrapolate the data for base year 2000.

The category "Other Sectors," which includes biomass, gas and other fuels, is identified as a key category. The use of biomass as energy increased in post-conflict Liberia as a result of low energy-generation. The increased residential combustion of biomass in general has the largest impact on CH_4 emissions, accounting for the high contribution of this category to energy emissions.

2.2.4: Agriculture Sector

Country-specific AD was scanty or not available for most of the GHG emission categories in the period of 1995-2004. AD on rice production were therefore obtained from the FAO statistical database on the FAO

[1] *In this report, the term "total emissions" refers to the aggregated national GHG emissions expressed in terms of CO_2 eq. excluding LULUCF, unless otherwise specified.*

Table 2.5: GHG Emissions by Category in Agriculture Sector

Greenhouse Gas Source and Sink Categories	CO_2 Removals (Gg)	CH_4 (Gg)	N_2O (Gg)	2000 Gg CO_2-e	% category contribution to National Totals Gg CO_2-e	% contributions to sector Gg CO_2-e
Agriculture		122	0	2,562	31.9	
A. Enteric fermentation		117		2,457	30.6	95.9
B. Manure management		4	0	84	1.0	3.3
C. Rice cultivation		0		NE	NE	0.0
D. Agricultural soils			0	NO	NO	0.0
E. Prescribed burning of savannahs		0	0	NE	NE	0.0
F. Field burning of agricultural residues		1	0	21	0.3	0.8
G. Other (please specify)		0	0	0	0.0	0.0

website at http://foodsta.fao.org. National data for prescribed burning of savannahs were also obtained from a 2004 World Bank report, *Current State of the Forest Cover in Liberia*. AD existed in 1974–1985, however. The data were obtained from national agricultural surveys which were regularly conducted every year before the onset of the conflict in 1989.

By strengthening existing agricultural institutions, better AD can be made available in the next national communication.

IPCC default emission factors and methods have been used for the emissions estimation based on the decision trees.

Total emissions from the agriculture sector in 2000 amounted to 2,562 Gg CO_2 eq. and contributed 31.9% of the total national GHG emissions (see Table 2.5). The tier 1 key categories analysis identified CH_4 emissions from enteric fermentation and manure management as key categories.

2.2.5: Land Use and Land-Use Change and Forestry (LULUCF)

The AD on annual extracted volume of roundwood and annual extracted volume of fuel wood (1986–1995) were obtained from statistics on the website of the UN Economics Commission for Europe (UNECE) Forestry and Timber Section. The certainty level of the data could not be determined. The AD on the land area of forest/biomass stocks for 2000 were compiled from several sources including the above-mentioned 2004 World Bank report on the forest cover of Liberia, FDA annual reports, and the 1993 FAO report, *Forest Resources Assessment for Tropical Countries*. The certainty level of these data sources is considerable as they are some of the most authentic sources of data on forest area /biomass stocks. Default values of emission factors were used due to difficulties encountered in deriving national data.

Table 2.6 summarizes the GHG emissions by category from LULUCF. In 2000, the carbon uptake in the LULUCF category was estimated at -69,991 Gg CO_2 eq.

2.2.6: Waste Sector

It is reported that prior to the wars, about 85% of Monrovia's waste was collected for disposal at solid-waste disposal sites. Other counties such as Buchanan, Gbarnga, Greenville, Harper, Kakata and Robertsport also had relatively-developed waste collection and disposal systems. However, the waste collection services have ceased functioning in most areas in the post-conflict period. The operating capacity of the MCC has declined significantly, leading to the accumulation and open burning of large amounts of waste in Monrovia.

The country and urban population data were obtained from LISGIS. The data included the 1984 census and population projections for 2002–2006 based on a 1997 UN Common Country Assessment (CCA) survey. Table 2.7 below presents the inventory data summary.

The LWSC provided information and limited data on the wastewater treatment facility in Monrovia.

Table 2.6: GHG emissions by categories from LULUCF.

Greenhouse Gas Source and Sink Categories	CO_2 Emissions (Gg)	CO_2 Removals (Gg)	CH_4 (Gg)	N_2O (Gg)
Land-use change and forestry	17,631	-114,442	NE	NE
A. Changes in forest and other woody biomass stocks	17,631		NE	NE
B. Forest and grassland conversion	-114,442		NE	NE
C. Abandonment of managed lands	NE	NE	NE	NE
D. CO_2 emissions and removals from soil	NE	NE	NE	NE
E. Other (please specify)		0	0	0
Net emissions		**-69,991**		

There is a net CO_2 uptake of 69,991 Gg making the forest sector Liberia a sink.

Table 2.7: GHG emissions by category from the waste sector.

Greenhouse Gas Source and Sink Categories	CO_2 (Gg)	CH_4 (Gg)	N_2O (Gg)	2000 CH_4 Gg CO_2-e	Contribution to National Total (%)	Category Contributions to Sector (%)
Waste		2.18	NE	45.82	0.6	
A. Solid waste disposal on land		2.00		42.00	0.5	91.7
B. Wastewater handling		0.18	NE	3.82	0.0	8.3
C. Waste incineration				NE	0.0	0.0
D. Other (please specify)		NO	NO			

The treatment plant, along with septic tanks, are sources of CH_4 emissions in Monrovia. Installed in the pre-war era, the treatment plant is an anaerobic system designed to utilize methane emissions, but this has never occurred. Instead, methane is vented directly into the atmosphere. Another potential source of emissions in Monrovia is the domestic wastewater discharged into the lagoon catchment in Fiama.

Waste generation, composition, collection, and disposal data for 2000 was obtained from a national municipal solid waste inventory survey undertaken in 2004 by the MCC and UNICEF covering four municipalities in Monrovia with about 90% coverage. The data, however, had limited waste characterization and composition. Waste disposal AD for the previous years were also not available. And the changing nature of the waste composition over the period was not documented.

The methodological choices have been based on the IPCC GPG where applicable, otherwise on the Revised 1996 IPCC Guidelines. Where the GPG is applicable, the estimation method has been selected based on Liberia's national circumstance for that source category consistent with the methodological options provided in the decision trees.

IPCC default estimation methodologies and emission factors were applied except for country-specific degradable organic carbon derived from the UNICEF-MCC study data. As far as practicable, quantitative estimates of uncertainties have been obtained from GPG. Otherwise expert judgment has been used.

In 2000, the waste sector accounted for about 0.60% of Liberia's national total CO_2 eq. emissions. A significant subcategory is CH_4 emissions from solid waste disposal sites (SWDS) on land, which contributed 91.7%. Domestic and commercial wastewater handling (DCWWH) accounted for 8.3%. The emissions from the sector are presented in Table 2.7.

Waste sector emissions have declined substantially—by 63.8%—from 1986 in the pre-conflict period. This is due to the decline in the proportion of solid-waste collection and disposal in managed SWDS from about 85% to about 20–30 % by 2000. A greater proportion of solid waste is now burned or buried in communities or dumped in wetlands for land reclamation.

2.3: COMPARISON OF THE REFERENCE AND SECTORAL APPROACHES

For the year 2000, CO_2 emissions from fuel combustion have been calculated using the reference and sectoral approaches. The concentration of energy-sector activities in Monrovia helped in the collection of source-category specific data for power production, and manufacturing activities. This made it possible to disaggregate energy-sector emissions and use a sectoral approach to estimate energy-sector emissions despite the absence of a national energy balance.

The difference between the results of the reference approach (3,625 Gg CO_2 eq) and the sectoral approach (35,571 Gg CO_2 eq) is about 10%.

2.4: NATIONAL INVENTORY IMPROVEMENT PLAN

The key components of the National Inventory Improvement Plan (NIIP) are that Liberia will:

- Restructure, involve, and strengthen relevant national institutions in order to deliver the needed AD and develop national inventory workbooks in the next inventory preparation for 2001–2010.

- Develop and implement a national policy paper on the national inventory, with particular attention to formalizing an institutional arrangement. Key to this will be the establishment of sector working-groups and the participation in sector working-groups of high-level authorities in the relevant ministries, departments, agencies, tertiary institutions, and the private sector. This will ensure an ongoing commitment to fund the relevant agencies for all aspects of data development and quality.

- Undertake capacity development in the use of activity datasets and quality and uncertainty assessment for the second NATCOM (e.g., schedule workshops to discuss methods, data collection, data sets, and quality).

- Develop agreements with industry associations and formalize roles and agreements between the national inventory coordinating agency, the Liberia EPA, and other government institutions to ensure timely delivery of accurate information.

- Develop the framework for Liberia's energy data and balances, improve on category aggregation and allocation of energy-use of fuels, and provide good documentation and archiving of inventory data.

- Use the members of the working groups for peer review and verification and in general provide explanatory information on methods and emission-factor selection in the national inventory report for the second NATCOM.

- Dialogue with multilateral institutions involved in studies and data collection to integrate inventory datasets that will complement the delivery of AD and emission factors.

Liberia's commitment to the national inventory process is to ensure coordination and rationalization of Liberia's AD, methods, documentation, and archiving of the national inventory in order to provide a centralized national database for policy decisions on climate change and sustainable national development.

2.5: CONCLUSION

Liberia's national GHG inventory for 2000 has been prepared as part of its INC. The year 2000 was selected as the base year in recognition of the national circumstance in the post-conflict period. The activities concentrated in Monrovia and environs facilitated the collection of source-specific AD for estimation of category-specific energy emissions. International data sources (e.g., the FAO database) and in-country data collection under various collaborative studies by the UNDP, UNICEF, and the World Bank also provided some AD for the agriculture, forestry, and waste sectors for 2000.

In order to improve on this system, a NIIP has been developed for implementation under the next NATCOM. The plan will ensure clear roles and responsibilities for different institutions in integrating inventory data formats into national data-collection activities. Liberia will also take advantage of multilateral and bilateral data-collection studies in order to integrate inventory data formats, improve data quality, and maximize the use of resources for data collection and delivery during preparation of the next national inventory report.

Liberia used the national inventory software to conduct the inventory for base year 2000. The documentation boxes were used to provide the basis for methodological choices. The inventory, to the extent possible, applied the UNFCCC reporting guidelines, the Revised 1996 IPCC Guidelines, and the IPCC GPG.

Liberia identified areas that need improvement. These include increasing the involvement of sectoral institutions in inventory preparation, formalization of institutional arrangements, development of methodologies consistent with the national circumstances and in accordance with the IPCC GPG, better QA/QC activities and archiving of national inventory data to ensure institutional memory, and the development and delivery of Liberia's energy balances.

CHAPTER → 3

GREENHOUSE GAS MITIGATION ASSESSMENT

3.1: INTRODUCTION

Liberia has not previously conducted an assessment of GHG mitigation measures due to inadequate human resources, technological constraints, and the lack of data-gathering capability. Within the framework of the preparation of Liberia's INC, and with the support of consultants, Liberia has undertaken a mitigation analysis and examination of options for reducing the sources of GHG emissions and/or enhance their sinks.

The objective of this assessment is to conduct a national-level analysis of the technologies and practices that can either reduce the sources of GHG emissions (abatement) and/or enhance their sinks (uptake) while supporting sustainable development. The specific objectives are:

- Identify GHG mitigation technologies currently existing internationally.
- Assess the applicability of those GHG mitigation technologies to Liberia.
- Identify barriers to the implementation of those GHG mitigation technologies in Liberia.
- Develop strategic recommendations for increasing the implementation of GHG mitigation technologies in Liberia.

The assessment is constrained by inadequate, unreliable, and out-of-date information on activity, which has made it difficult to conduct a quantitative assessment of mitigation options. The GHG inventory, which was supposed to be the basis for the assessment, suffered from a lack of AD and was incomplete, particularly for the forestry, agriculture, and waste sectors.

The assessment covers identification and analysis of all measures and activities under implementation and planned at the national level that can contribute to the reduction, removal, or sink of GHG emissions. It includes the energy, LULUCF, agriculture, and waste sectors.

3.2: ENERGY SECTOR

3.2.1: Current and Future Energy Policies for the Energy Sector

In January 2006, the Economic Community of West African States (ECOWAS) approved a white paper on a regional policy for increasing access to energy services for rural and peri-urban populations in line with achieving the Millennium Development Goals (MDG) in the subregion. In line with these goals, Liberia aims to achieve the following:

- 40% of Liberian citizens living in rural and peri-urban areas and using traditional biomass for cooking shall have access to improved stoves and kerosene or efficient gas-cookers in order to cut indoor pollution.
- 30% of the urban and peri-urban population shall have access to reliable modern energy services enabling them to meet their basic needs (lighting, cooking, communication, and small production-related activities).
- 15% of the rural population shall have access to reliable modern energy services for meeting the same basic needs.
- 25% of the schools, clinics, and community centers in rural areas shall have access to modern energy services for lighting, refrigeration, information and communication, etc., and shall be equipped with productive energy capacity.

Further, in line with the international community, and based on the principle of extending energy access to all Liberians with the goal of maximizing efficiency and minimizing costs and adverse environmental impacts, the Government of Liberia (GOL) states the following additional targets:

- Reducing GHG emissions by 10% by 2015.
- Improving energy efficiency by 20% by 2015.
- Raising the share of renewable energy to 30% of electricity production and 10% of overall energy consumption by 2015.
- Increasing the level of biofuels in transport fuel to 5% by 2015.
- Implementing a long-term strategy of making Liberia a carbon-neutral country within a specified target period.

These data and trends are regarded as set of baseline trend for a "business as usual" background from which forecasts and mitigation scenarios could be derived. Assumptions were made on the basis of national and regional energy policies adopted by the GOL. These trends are not accurate to capture the energy picture reflecting the real economy. At this point, one can use default assumption like optimistic or pessimistic prospective to predict energy needed to fuel the economy.

Considering the above, one key assumption is the share of petroleum products among the energy sub-sectors. The GHG inventory available for the energy sector for 1986 and 1999 shows little change during this period. Comparison between volumes of gasoline and diesel oil supplied on one side and other fuels (kerosene and jet-A1) on the other side, tells us this picture did not change so much. Therefore, it can be used to determine how petroleum products are shared between subsectors in the 2000s based on Table 1.6 of Chapter 1.

National Energy Policy of Liberia (NEP) places particular emphasis on increasing the security of the energy supply and availability, implementing energy conservation practices, and enhancing the level of energy services. The NEP addresses strategic issues: access, quality, cost, and institutional framework. These issues reflect the need for energy products and services to be available, acceptable, affordable, and adequate.

The GOL policy objective is to ensure access to modern energy services for all Liberians. Cost is the main determinant of energy access and quality. The GOL policy objective is to ensure affordability through least-cost production and utilization of energy services.

The GOL expects to achieve its access goals for 2015 while reducing GHG emissions by 10%, improving energy efficiency by 20%, raising the share of renewable energy to 30% of electricity production and 10% of overall energy consumption, and increasing the level of biofuels in transport fuel to 5%.

Beyond 2015, the long-term strategy is to make Liberia a carbon-neutral country within a specified target period. The GOL will seek to leverage the country's biomass resources as a source of carbon credits for energy development. The GOL will promote the use of renewable energy such as solar and wind systems in power plants and all large commercial facilities such as supermarkets, hotels, restaurants, entertainment centers, hospitals, and large retail shops and stores.

As GHG is mainly produced by thermal power stations using petroleum products, the inventory team used data from the petroleum sector to approximate GHG emissions. In addition to the Liberia Electricity Corporation (LEC), a number of private-sector companies operate in the renewable energy and petroleum subsectors.

Prior estimates of electricity demand ranged from 11 to 25 MW/year, increasing at an average rate of 10.3% annually by 2010 and then decreasing slightly to a 3.4% growth annually until 2020 (State of the Environment (SOE), 2006). (International Finance Corporation (IFC) of the World Bank, projected electricity demand for Monrovia and its environs to be about 19 MW by 2010, 34 MW by 2015, and 41 MW by 2020. Some specialists project that the actual demand for Liberia, including the various concessions, is likely to be in excess of 350 MW by 2020 based on the following assumptions:

- Liberia's population, estimated at around 3.5 million from the provisional results of the 2008 census, has been growing at an average annual rate of 2.1%. Over 53% of the population is under 18 years of age. With a large pent-up demand for consumer goods and services as evidenced by previous levels of demand and rising incomes, demand for energy used in the production of these goods will increase as the population rises.
- Since pre-conflict electricity capacity exceeded 400 MW, it seems likely that at some point the economy will begin to take off and very quickly reach previous levels of capacity. Industries which are large consumers of energy are only now looking at Liberia for opportunities to re-invest. Cement processing, rubber processing, breweries, and other factories and industrial operations have a huge demand for power.
- Prior to the civil conflict, the iron ore industry consumed about 210 MW of electricity. Although none of these former mines is currently in operation, the GOL has prioritized their re-opening in the short-to-medium term, beginning with a recent concession agreement with Arcelor Mittal for one of the mines. The next two concessions for the Western Cluster iron

Table 3.1: Current and projected fuel consumption for electricity generation for the period 1999–2028

	1999	2008	2015	2020	2025	2028
Electricity generation	37,568	58,755	116,701	190,525	225,192	266,168

ore deposits and the old Bong Mines will be awarded soon. Furthermore, aggressive mineral exploration and resource-appraisal programs for additional iron ore deposits are underway. The prospects for new hard-rock mines for minerals such as gold, diamonds, uranium, and bauxite are very promising. The demand for energy for these operations in the medium and long term will be very significant, and without a strong government energy policy, the requisite power to fuel these mining operations will not be developed.

- The agriculture sector, although mostly artisanal at present, has a high demand for energy services. Agro-based concessions, such as rubber and other mechanized activities, produce electricity for their own consumption. Demand for energy in agriculture in the short, medium, and long term will be significant.

Notwithstanding the source, energy remains very important for Liberian women. They need it, and often are the customers who must pay for it [1]. The challenge remains to provide sufficient, reliable, and cost-effective energy to women in a manner that is equitable and environmentally and socially sustainable.

The breakdown in electricity supply over the years has led to the proliferation of private generators in the country. It is estimated that there are about 45,000 small and medium privately-operated power-generating units, concentrated mainly in Monrovia (SOE, 2006).

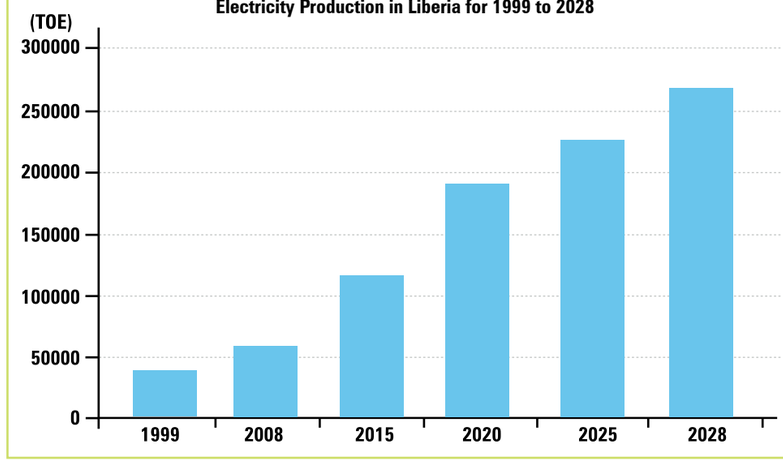
Table 3.2: Current and projected GHG emissions from public electricity generation for the period 1999–2028.

	Emission in Gg		
	CO_2	CO	N_2O
1999	1,199	3	3
1008	1,875	4.69	4.69
2015	3,725	9.32	9.32
2020	6,081	15.21	15.21
2025	7,187	17.98	17.98
2028	8,495	21.25	21.25

3.2.1.1: Current and Projected Fuel Consumption for Public Electricity Generation

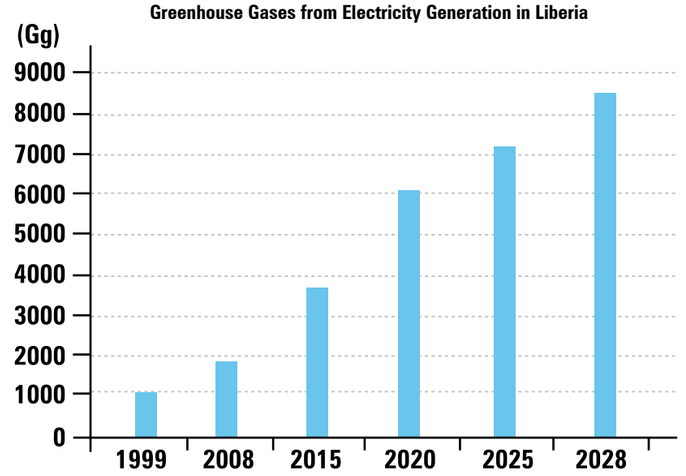
No reliable disaggregated data is available on public and private electricity production. For the purpose of this

Figure 3.1: Current and Projected Fuel Consumption for Electricity Production in Liberia for 1999 to 2028



[1] *Greenberg, M. 2009. A Gender Assessment for USAID in Liberia. USAID, Liberia.*

Figure 3.2: Current and Projected Emissions of Greenhouse Gases from Electricity Generation in Liberia



GHG mitigation assessment, only the combustion of gas oil and fuel oil has been considered as the most significant sources of GHG emissions. There has been an average 14% annual growth in diesel consumption since 2004. However, a 10.3% growth up to 2020 and a 3.4% growth between 2020 and 2028 are considered in this study. Table 3.1 and Figure 3.1 below give projections of fuel consumption from electricity generation for the period 1999 to 2028.

3.2.1.2: Current and Projected GHG Emissions from Public Electricity Generation

Table 3.2 and Figure 3.2 show current and projected GHG emissions from electricity production for the period 1999–2028.

3.2.2: Residential, Commercial, and Institutional (RCI) Subsector

3.2.2.1: Current and Projected Consumption of Petroleum Products in the RCI Subsector

In 2008 a total of 9,646 TOE of petroleum products was consumed in the RCI subsector. GHG emissions from the subsector result from direct and indirect use of various fuels to provide energy. Figure 3.3 below shows the main types of fuels used in Monrovia and its environs.

Table 3.3 and Figure 3.4 below show the projected consumption of petroleum products by the RCI subsectors under the following assumptions:

- Consumption in the residential subsector has accumulated with growth in the population about (3.3%), urbanization (5%), and with the substitution of kerosene and later LPG for traditional fuels. The assumption is a total of 10%.
- Consumption in the commercial and institutional subsectors will grow rapidly as a consequence of urbanization and informal activities in towns. A rate of 12% has been assumed.

Figure 3.3: Main domestic energy types used in Monrovia and agglomerations

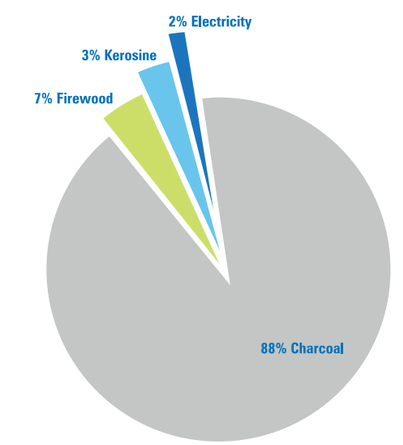


Table 3.3: Total and projected consumption of petroleum products (TOE) by the RCI subsectors.

	1999	2008	2015	2020	2025	2028
Residential	833	1,309	2,551	4,108	6,616	10,656
Commercial and institutional	5,333	8,337	18,430	32,481	57,242	100,860
TOTAL	**6,166**	**9,646**	**20,981**	**36,589**	**63,858**	**111,516**

3.2.2.2: Projected Emissions of GHG from the RCI Subsector

The estimation of emissions of GHG from fuel combustion in the RCI subsector (Table 3.4 and Figure 3.5 below) is calculated using inventories done for 1999. The major gas emitted is CO_2. Other GHG, such as CO, CH_4 and N_2O, have not been estimated because of the low amount of fuel consumed in this sector. It is assumed that the emissions of these gases is very low.

3.2.3: Transport Sector

3.2.3.1: Projected Consumption of Fuel Products by the Transport Sector

The transport sector is divided into three main subsectors:

- Road, transport, and railways for passenger and freight transport.
- Domestic sea transport for passengers and freight using schooners.
- Civil aviation.

Since all fuel used in the transport sector is imported, the government policies on energy consumption in the road, transport, and railways subsector aims to:

- Reduce the amount of imported fossil fuels used in Liberia.
- Develop fiscal policies encouraging motorists to import more fuel-efficient vehicles and to minimize travel.
- Promote the use of public transport.
- Encourage non-motorized transport.

Figure 3.4: Total and Projected Consumption of Petroleum Products (TOE) by the Residential, Commercial and Institutional sectors

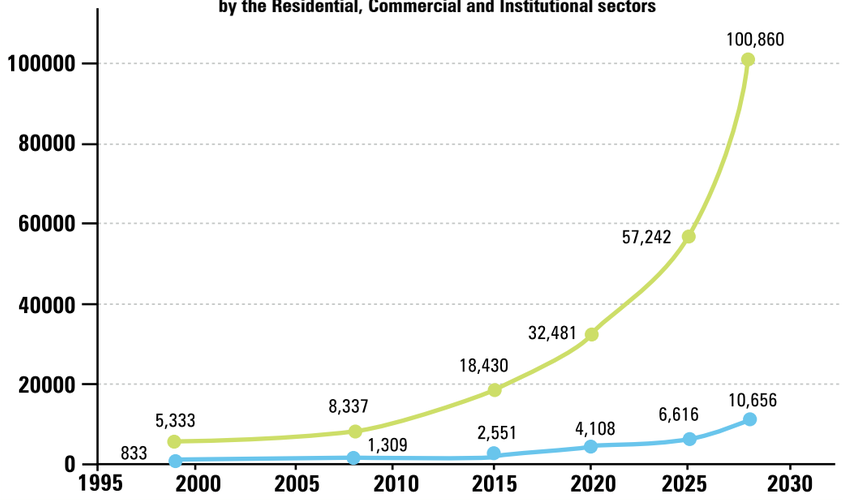


Table 3.4: Projected CO_2 emissions (Gg) from the RCI subsectors (2008–2028)

	1999	2008	2015	2020	2025	2028
Residential	26	41	80	128	207	333
Commercial and institutional	164	256	567	999	1,760	3,102
TOTAL	190	297	647	1,127	1,967	3,435

Figure 3.5: Prjected CO_2 emissions (Gg) from Residential Commercial and Insitutional Sectors (2008 - 2038)

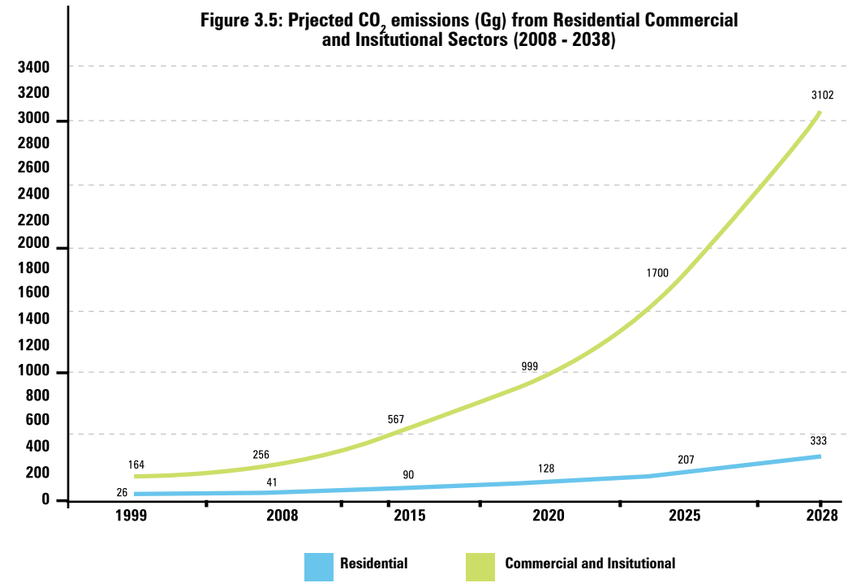
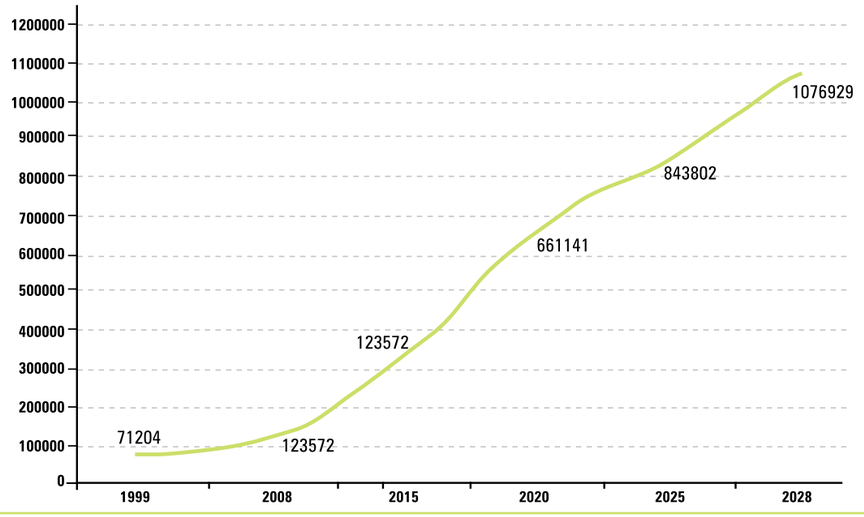


Figure 3.6: Projected Consumption (TOE) of Petroleum Products for the Transport sub-sector



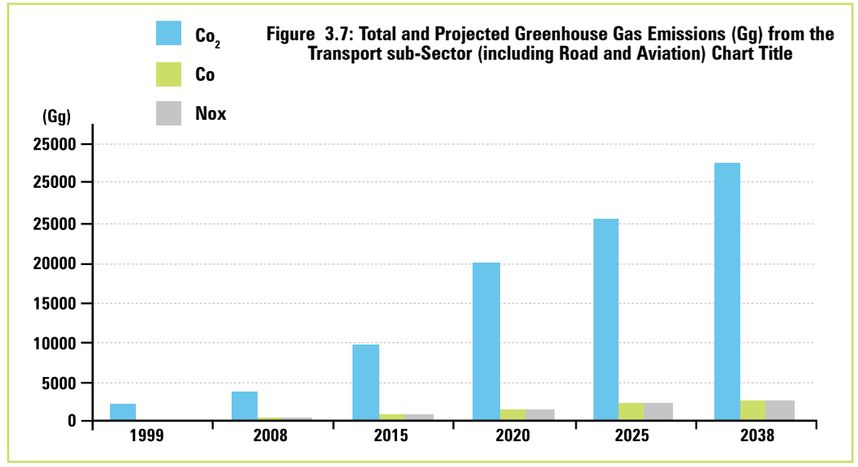


Figure 3.7: Total and Projected Greenhouse Gas Emissions (Gg) from the Transport sub-Sector (including Road and Aviation) Chart Title

- Institute annual or more frequent vehicle-testing for road worthiness.
- Reduce congestion.
- Develop land-use planning which promotes more efficient transport.

Gasoline and gasoil are the two main fuels used in the road transport subsector. The projection of the growth in consumption from 2008 to 2028 (Table 3.5 and Figure 3.6) was calculated based on the restoration of rail transport from 2008 to 2020 (15%) and a slower growth rate later (5%), taking into account a continuous urbanization and growing rural-urban fluxes.

3.2.3.2: Current and Projected Emission of GHG from the Transport Sector

Table 3.6 and Figure 3.7 show total and projected GHG emissions from the transport sector for the period 1999 to 2028. CO_2 will continue to be the major GHG emitted in the transport sector, reaching over 30,000 Gg by 2028. Other GHG emitted are CO and N_2O.

Table 3.5: Current and projected consumption (TOE) of petroleum products by the transport sector.

	1999	2008	2015	2020	2025	2028
Transport	71,204	123,572	328,704	661,141	843,802	1,076,929

Table 3.6: Total and projected GHG emissions (Gg) from the transport sector (including road and aviation).

	CO_2	CO	N_2O
1999	2,137	172	20
2008	3,709	298	298
2015	9,865	794	794
2020	19,842	1,597	1,597
2025	25,324	2,038	2,038
2038	32,321	2,601	2,601

Table 3.7: Trends and projections of consumption of petroleum productions (TOE) by the industrial sector, including mining, manufacturing, and construction.

	1999	2008	2015	2020	2025	2028
Industrial	3333	5213	7338	12932	22791	40165

Table 3.8: Current and projected GHG (Gg) from the industrial sector, including mining, manufacturing, and construction.

	1999	2008	2015	2020	2025	2038
CO_2	104	163	229	404	711	1253

3.2.4: Industrial Sector

3.2.4.1: Projected Consumption of Petroleum Products in the Industrial Sector

The industrial sector is being restored more slowly than the commercial and institutional subsectors. Therefore, a growth rate of 5% per annum is being assumed for a business-as-usual (BAU) scenario between 2008 and 2015. The growth rate is expected to accelerate after 2015, and thus a 12% growth rate is assumed as the country attempts to restore the full industrial capacity that existed before the war. As for other sectors, aggregate data are used but actual figures (quantities of fuels by type, power station efficiency, indirect electricity generation, etc.) are needed. Table 3.7 and Figure 3.8 show the trend in consumption of petroleum products by the industrial sector, with the resultant emissions of GHG shown in Table 3.8 and Figure 3.9.

3.2.4.2: Projected Emissions of GHG from the Industrial Sector

The emission of CO_2 from the industrial sector is expected to grow from 229 Gg in 2015 to 404 Gg in 2020, 711 Gg in 2025 and 1,253 Gg in 2038. The bulk of this emission will come from the direct use of fossil fuel, especially in the iron-processing industries, to produce heat.

The other GHG, such as CO, CH_4 and N_2O, have not been estimated because of the low amount of fuel consumed in this sector. Hence the emissions of these gases will be very low.

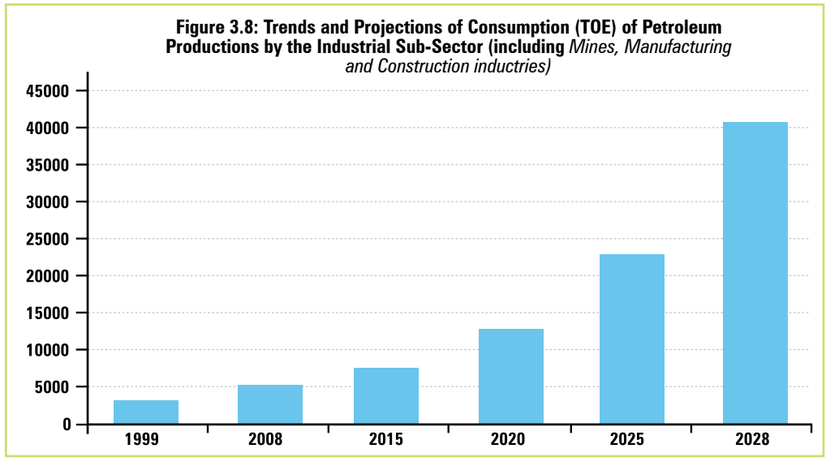
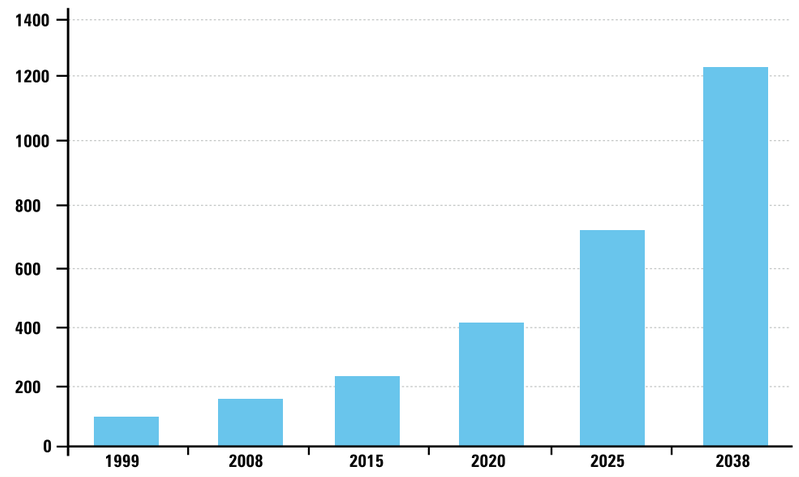


Figure 3.8: Trends and Projections of Consumption (TOE) of Petroleum Productions by the Industrial Sub-Sector (including *Mines, Manufacturing and Construction industries)*

Figure 3.9: Current and Projected Carbon Dioxide (CO_2) Emissions (Gg) from the Industrial sub-Sector (including mining, manufacturing and construction inductries)



3.2.5: Results of the Mitigation Assessment for the Energy Sector

As indicated at the beginning, the lack of reliable data has made it difficult to conduct a quantitative assessment of mitigation options. However, based on the data and information in the preceding section 3.1 and 3.2 that served as the baseline assumption, a qualitative assessment has been made and this constitutes a basis for possible future quantitative evaluation. Table 3.9 below gives mitigation options proposed for the energy sector.

3.3: FORESTRY SECTOR

3.3.1: Current Forest Policies and Strategies

The status and condition of forestland is largely determined by government policies. These policies govern, among other things, forest protection and conservation, wood extraction and harvesting, tax rebates for efficient charcoal kilns and wood stoves, etc. The government has decided to include the forestry sector in the Extractive Industries Transparency Initiative (EITI) and the Poverty Reduction Strategy (PRS), and the new forestry law reflects a consensus strategy for a more balanced and integrated development of the country's forest resources.

Putting the strategy into practice requires conservation measures (also as a means of carbon storage) and sustainable management of the forest and of secondary processing of forest products so that forestry can make a lasting contribution to economic growth. As well as respecting environmental considerations, the challenge is to encourage pro-poor growth based on:

- Sharing with communities the benefits of revenues from commercial concessions.

- Providing opportunities for meaningful participation of both women and men in value-chains.

- Sharing equity in productive forest resources.

Given the direction of policy and legislation towards recognition of community rights on forest lands, there is also an emerging need to avoid land-use conflict by developing opportunities for synergy between small-scale producers and commercial companies.

The GOL has developed an NEP and adopted two major environmental laws—the Environmental Protection and Management Law and the Environmental Protection Agency Act—as well as the new Forestry Law noted earlier. The EPA became fully functional in 2006.

Based on the report of the Forest Concession Review Committee, the Forest Reform Monitoring Committee (FRMC) has been established with the sole mandate of re-enforcing the GOL's commitment to implementing key forestry sector reforms, providing

Table 3.9: Mitigation options in the energy sector.

Sector	Mitigation Options	Targets
ELECTRICITY	1. Promote hydroelectricity as in the pre-war period. 2. Promote the use of renewable energy technologies and energy-efficient appliances. 3. Declare emission standards. 4. Reduce the losses in the electricity supply system.	1. Reducing greenhouse gas emissions by 10% by 2030. 2. Improving energy efficiency by 20% by 2030. 3. Raising the share of renewable energy to 30% of electricity production and 10% of overall energy consumption by 2030.
RESIDENTIAL, COMMERCIAL, AND INSTITUTIONAL	1. Use renewable energy technologies such as solar water heaters. 2. Use energy-efficient appliances such as compact fluorescence lamp. 3. Use LPG for domestic cooking. 4. Remove the subsidy for kerosene. 5. Set up an energy-efficient use and conservation extension service. 6. Incorporate energy-efficient measures and standards in building design. 7. Audit energy use in commercial and institutional buildings.	
TRANSPORT	1. Continue to improve the public transport system. 2. Equip the police force with the resources to enforce laws and regulations. 3. Put in place a traffic management plan. 4. Ensure integrated land-use and transport planning. 5. Establish a road improvement program. 6. Create a driver awareness campaign for efficient use of vehicles.	
INDUSTRIAL	1. Use renewable energy technologies in hotels and guest houses. 2. Use low-carbon fuel for industrial boilers. 3. Use more energy-efficient and clean technology. 4. Conduct regular audits of energy use and implementation of energy management plans. 5. Declare emission standards. 6. Initiate energy education and extension services.	

a venue to vet and monitor reform actions, and ensuring that policies and practices are consistent with internationally acceptable practices. The following ten core regulations have been promulgated:

1 → *Regulation No. 101-06: Public Participation in Promulgation of Regulations, Codes, and Manuals* addresses how regulations, codes, and manuals are amended and adopted and establishes procedures for broad public participation in their formulation.

2 → *Regulation No. 102-06: Forest Land-Use Planning* establishes sustainable land-use allocation through a participatory process that balances the economic development benefits for forest-dependent communities and protection of the environment for the benefit of the Liberian society.

3 → *Regulation No. 103-06: Pre-Qualification* establishes the step-by-step procedures and requirements for individuals and companies to follow to be pre-qualified to do forestry business in Liberia.

4 → *Regulation No. 104-06* defines the process to be followed by the Forestry Development Authority (FDA) in allocating and managing the forests, timber

sale contracts, and major forest-use permits based on the standards and procedures found in the Public Procurement and Concession Acts (PPCA) and National Forestry Reform Law (NFRL) of 2006, and in any other applicable law.

5 → *Regulation No. 105-06* deals with pre-felling requirements for Forest Management Contracts (FMCs) with respect to social agreements, environmental impact assessments, and forest management plans as provided for under the NFRL of 2006.

6 → *Regulation No. 106-06: Benefit Sharing* seeks to establish a fair and transparent way to allocate benefits to counties and affected communities.

7 → *Regulation No. 107-06: Regulation on Forest Charge* seeks to establish the charges that will be levied on the production of timber and non-timber forest products.

8 → *Regulation No.108-06: Establishing a Chain of Custody System* establishes a detailed operational procedure for supervision of log, timber, and wood product extraction.

9 → *Regulation No. 109-06: Penalties* details penalties applicable in case of violation of the NFRL and regulations, codes, and manuals to be issued by the FDA.

10 → *Regulation No.110-06: Rights of Private Landowners* establishes the rights of private landowners and the responsibilities of forest resource license holders.

The FDA is the national institution mandated to manage Liberian forest resources. The main responsibilities of the FDA are:

- To develop standardized regulations and codes of practices for sustainable forest management. These regulations and codes include guidelines for (i) planning the forest-concession management system, (ii) inventorying the forest-management cycle, (iii) conserving biodiversity, (iv) conducting socioeconomic surveys of communities surrounding forest concession areas, (v) managing timber theft, vi) establishing a code of practice for harvesting the Liberian forest, (vii) regulating construction and forest-engineering works, (viii) assessing environmental impact for forest concessions, and (ix) managing special areas.

- To review and improve domestic wood supply through surveys, data collection, and workshops, and to discuss local wood consumption, wood requirements, and wood supply procedures. These responsibilities include: (i) allocating a percentage of harvested timber from forest concessions for domestic use, (ii) allocating and granting annual coupes through bidding, and (iii) establishing community forestry and promoting tree-planting by local communities.

- To conduct assessments of forest resources and zoning including (i) formulating criteria for forest zoning and on-ground demarcation, (ii) forest classification, and (iii) identifying and classifying watershed areas and selecting pilot areas for management exercise.

- To strengthen further the monitoring and control of illegal activities in forest concessions.

- To improve technical capacity through training and the implementation of standardized technical guidelines and regulations, codes of practice, and recent technologies in forest management and production for the benefit of all stakeholders.

Table 3.10: Permanent forest proposed for Liberia.

Unprotected forests	2.60 million ha	6.50 million acres
Protected and proposed protected areas	1.01 million ha	2.50 million acres
Total	**3.61 million ha**	**9.00 million acres**

Table 3.11: Timber volume by stratum in Liberia.

Stratum	V/log/ha (m^3)	Total (10^6 m^3)	Grand Total (%)	Total A (106 ha)
Agriculture area with small forest presence	45	136.89	12.22	3.04
Mixed agriculture and forest area	83	109.38	9.76	1.32
Agriculture degraded forests	157	149.09	13.30	0.95
Open dense forests	206	208.88	18.64	1.01
Closed dense forests	213	516.33	46.08	2.42
Total	**704**	**1,120.57**	**100.00**	**8.74**

Table 3.12: Forest classes and areas of Liberia.

Class	Surface area (106 ha)	Share (%)
Urban area	0.05	0.5
Predominantly rural agricultural area	0.44	4.6
Agricultural area with small forest presence	3.04	31.7
Mixed agricultural and forest Area	1.32	13.7
Agriculture and degraded forest	0.95	9.9
Open dense Forest	1.01	10.6
Closed dense Forest	2.42	25.3
Open (free) water	0.01	0.1
Savannah or nude area	0.01	0.1
Littoral ecosystem complex	0.16	1.7
Agroindustrial plantation	0.18	1.9
TOTAL	**9.59**	**100**

3.3.2: Baseline Data and Information

The forest cover of Liberia is 4.5 million ha or about 45% of the total land area. The Liberia Forest Re-assessment (LFR) project detected a total forest cover of 4.65 million ha in the mid-1980s compared to 4.52 million ha in 2001. This amounts to an annual deforestation rate of 0.2% or a cumulative 2.6% forest loss. The loss resulted from logging, farming, hunting, settlement, mining, fuel production, plantation, and road building.

The forests in Liberia can be grouped into two categories: permanent forest and non-permanent forest. The proposed permanent forest consists of 3.61 million ha in unprotected areas and in protected areas or areas proposed for protection for conservation and community/communal forestry. There are 2.6 million ha of unprotected forest and 1.01 million ha of totally and partially protected forests contained in the permanent forest as indicated in Table 3.10 below. The non-permanent forests cover 2.1 million ha, primarily in patches on rural agroforestry belts of degraded land. The non-permanent forest can be harvested through the establishment of logging/extraction coupes and can basically serve the purpose of a community forest with non-permanent features. Table 3.11 indicates timber volume by stratum while Table 3.12 gives the forest classes and areas in Liberia.

3.3.3: Assessment of Forestry Sector Mitigation Measures for Liberia

This section presents the GHG mitigation measures identified in the forestry sector, with a brief description of their potential for implementation in Liberia (Table 3.13 below). The mitigation measures and technologies in the forestry sector are broadly categorized into forest protection or conservation, sink enhancement, and carbon substitution.

3.3.4: Barriers to the Implementation of Forestry Mitigation Measures and Technologies

The status and condition of forestland is largely determined by government policies in the forestry and related sectors. Biomass sector policies that provide for efficient, effective, and sustainable forest management and the maintenance of carbon stock and/or the enhancement of carbon sinks will encourage and enhance the mitigation measures identified in Table 3.13

Table 3.13: Possible mitigation options in the forestry sector.

Category/Technologies	Description
1. Forest protection and management	
Forest protection	Measures which increase the opportunities for harvesting and marketing of non-timber forest products such as nuts, honey, and fiber can aid forest protection. Introducing small-scale rural industries such as carpentry, brick-making, weaving, etc. may stem the rate of deforestation associated with subsistence farming.
Improvements in harvesting techniques, e.g., reduce logging impact	A good harvest selection system aims to keep all-aged stands through timber cuttings at shorter intervals and many light cuttings. Seedlings become established in small gaps. Under this system two or more intensive harvests are possible during one rotation. At periodic intervals exploitable trees are selectively felled over an area.
2. Sink enhancement	
Improvements in product conversion and utilization efficiency	Anti-log forests attempt to reverse the loss of forest cover by planting trees and lesser plants on deforested lands, regenerating the structure and functions of original forests. This is also commonly known as enhance regeneration or enrichment planting.
Reforestation	Planting trees on degraded land in forest area.
Afforestation	Conversion of non-forest area into forest area by planting trees
Timber plantation	Large-scale plantings on degraded land using short-rotation species, long rotation species, or exotic species with intensive management for wood production.
Agroforestry (social forestry)	Improving carbon sequestration and storage in both soil and biomass through planting trees intercropped with annual crops for the purpose of producing both agricultural and forest products. Long rotation systems that use trees for windbreaks, border planting, and over-storey shade can sequester carbon for many decades.
Urban forestation	Planting trees in parks and gardens, green belts, residential shade trees, and road side and demarcation trees in the rural areas. Urban tree planting offers advantages of reducing GHG through reduction in energy consumption from air conditioning.
3. Substitution	
Stoves for cooking	Replacing cooking stoves with low thermal efficiency (5-10%) with the higher-efficiency (40%) stoves.
Biogas	Biogas is a combustible gas produced by anaerobic fermentation of cellulosic materials such as animal dung, plant leaves, and waste from food processing and households.

above. However, policies in other sectors of the national economy such as agriculture and public works, though categorized as good policies for those sectors, may lead to depletion of forest carbon-stock and in some cases, serve as disincentives to increasing forest and rangeland cover. The mitigation measures presented in Table 3.13 above cannot be easily implemented due to the existence of barriers and the absence of incentives. The most common barriers to the implementation of biomass-sector mitigation measures can be divided into four categories: (i) policy/regulatory, (ii) institutional, (iii) technological, and (iv) socioeconomic. The following are major barriers identified in Liberia:

(I) Policy and Regulatory

a) Unclear policy framework, inappropriate policies, and limited law-enforcement of forest regulations; lack of incentives for good performance in forest management by concessionaires and inadequate financial incentives for forest conservation, reforestation, and maintenance of reforested area.

b) Land tenure system and land laws in Liberia impede implementation of mitigation measures.

c) Policies concerning harvesting and marketing of forest products, pricing, tariffs, and quotas for exports and imports may also hinder implementation of some of the mitigation options.

d) Lack of a wood-fuel conservation policy.

e) Inadequate program formulation and implementation strategy for improved cook stoves.

(II) Institutional

a) Unclear mandates, goals, and ideas about the exact role of each stakeholder (government, community, private individuals, and investors) in forest rehabilitation.

b) Insufficient coordination between relevant ministries and other stakeholders in forest utilization, weak institutional participation, complex bureaucracy system, and top-down approaches to program development.

c) Absence of enablers for participation by local communities, farmers, industries, and local governments.

d) Weak extension services and limited interactions between farmers and extension agents.

e) Weak system for disseminating new technology.

(III) Technological

a) Limited scientific data on silviculture, ecosystem management, and pastoral practices, including soil conservation.

b) Inadequate experience of technical personnel for provision of extension services such as selection of species appropriate for a certain locations and harvesting techniques for sustainable yields.

c) Non-recognition of native plant species and indigenous cultural practices in planning and managing forests.

d) Low recognition of women's role in forest management and conservation (including REDD).

e) Unsuitable selection of tree species to be planted based on market demand rather than the environmental condition of sites.

f) Mismatch between the technique of silviculture used and technical requirements.

g) Insufficient qualified local personnel to carry out projects and provide the extension services necessary for the successful involvement of local populations.

h) No demarcation of protected areas and protected forest boundaries, and overlap between protected areas, concession forest, and community lands.

i) Low consultation with women regarding local traditions and practices during the design of improved cook stoves.

(IV) Socioeconomic

a) Lack of funding and no incentive for long-term investments either by the private sector and/or by local communities.

b) Lack of infrastructure such as roads for transporting end-products to the market and uncertainty in prices.

c) Inadequate or lack of market information.

d) High borrowing rates on credit from banks and slow returns on investment by private investors and/or local communities.

e) Inadequate financing from the government for community forestry.

f) Inadequate or lack of markets for export of local fruit production from agroforestry mitigation projects.

g) Uncertainty and high fluctuations in prices of farm products.

h) Low cost of wood fuels (firewood and charcoal) offering little or no incentive for investment in efficient stoves.

i) Lack of funds for research and development in vegetable and cash crops.

Some of these barriers can be lifted through:

- Designing and implementing penalty and reward/ incentive systems.
- Enhancing the awareness of concessionaires and other stakeholders about the benefit of implementing GHG mitigation measures and technologies.
- Producing and disseminating information to policy makers regarding the total and average cost of implementing forestry mitigation measures.
- Providing financial support for research and development in agroforestry, afforestation, reforestation, and sustainable forest management that includes a gender perspective.
- Developing and testing efficient production, utilization, and management of wood fuels resources in pilot communities, ensuring the full participation of women.
- Encouraging research and production of low-cost improved cook stoves.
- Developing a national wood-fuel conservation policy and programs and strategies for improved cook stoves.
- Training community-level artisans to produce and fabricate these stoves.
- Supporting capacity building for sustainable forest management (agroforestry, bushfire controls, and sustainable logging practices).
- Providing technical support for selling carbon credits attributable to mitigation measures.

3.4: AGRICULTURE SECTOR

3.4.1: Current Agricultural Policies and Strategies

The Lift Liberia Poverty Reduction Strategy (LLPRS) recognizes the role of agriculture in achieving rapid, inclusive, and sustainable growth and development. The present government's commitment to the agriculture sector is evidenced by the resources it has allocated to several analytical studies and the use of their findings to prepare sector policies and investment strategies. Although Liberia possesses abundant land and water resources that can sustain crop-area expansion, these resources have to be harnessed in an appropriate policy, legal, and investment environment. Issues regarding property rights (e.g., access to land, security of tenure, and utilization) linger, land administration is weak, and a land-use policy is absent. Proper water-resource management and planning remain elusive. And shifting cultivation, illegal timber harvesting, and other practices which degrade land and water resources are rampant. Liberia needs to reframe its agricultural institutions, particularly the MOA and the Central Agricultural Research Institute (CARI), and improve education and health delivery systems to boost smallholder productivity and reduce poverty. The overriding goal for reviving Liberia's agricultural extension system should be building a pluralistic and participatory agricultural advisory and extension service. A national extension service strategy must be developed that promotes the participation of private actors in providing services throughout the country on a competitive, demand-driven basis. The education and health sectors also need to be engaged so that their rural services can be coordinated with agriculture.

Table 3.14: Sectoral origins of GDP in Liberia

Sector	2006	2007	2008
Agriculture and fisheries	192.3	210.4	213.8
Forestry	74.1	81.1	97.5
Mining and planning	0.7	0.8	0.8
Manufacturing	55.5	60.8	64.3
Services	110.5	120.9	130.7
Real GDP	433.1	474	507.1

The following cross-cutting areas are critical to the creation of an enabling agricultural development strategy that facilitates achievement of the targets of the Comprehensive Africa Agriculture Development Program (CAADP): public sector roles in providing agricultural services, financing agricultural development, maintaining openness in international trade relations, mainstreaming climate change, gender, youth, and vulnerable groups; pursuing a pro-poor, smallholder-based approach; remedying the dearth of evidence-based planning, and prioritizing investment.

National development strategies have recognized the creation of a socioeconomic and demographic database as a priority for improving statistical systems and establishing the empirical underpinnings of policies and programs. The MOA is committed to and has taken steps towards strengthening its policy development and monitoring and evaluation capacities with the support of development partners.

3.4.2: Baseline Data and Information

As shown in Table 3.14 below, the agriculture sector accounted for 42.2% of real GDP for 2008. Agriculture and forestry accounted for nearly 60 % of the total employment in 2007 and 2008 (Table 3).

Nearly 5.4% of Liberian land—amounting to approximately 600,000 ha—is said to be cultivated. Some 220,000 ha of this land is reported to be under permanent crop or plantation, while the rest is arable (FAO, 2005). Broadly, the arable areas are uplands and lowlands or swamps. Swamps can be classified as mangroves, riverine grassland, flood plains, and inland valleys. The degree of suitability of the swamps for agriculture is not known because they have not been characterized, but there is a general notion that the swamps are more useful for rice.

According to results of emissions assessments in Chapter 2, the agriculture sector emitted 2,562 Gg CO_2 eq. and contributed 31.9% of the total national GHG emissions. The bulk (99.2%) of the 2000 emissions came from animal husbandry (enteric fermentation [96%] and manure management [3%]). The National Capacity Self-Assessment (NCSA) project identified a number of activities in Liberia that contribute to climate change (UNDP, 2006). These include shifting cultivation with a fallow period of less than twelve years, uncontrolled logging, charcoal production, and improper waste disposal.

3.4.3: Assessment of Agriculture Sector Mitigation Measures

Despite the agriculture sector's low contribution to GHG in the atmosphere, there is a need to contribute to global efforts to mitigate emissions. In this study some mitigation options have been analyzed, and they have the potential to reduce emissions in the agriculture sector. These options include carbon sequestration by soils, capturing methane emissions from manure and agriculture waste, improving water management in irrigated rice fields, and increasing feed efficiency for livestock. Each of these mitigation measures requires implementers to change their existing practices and the transfer of technology.

3.4.4: Barriers to Implementation of Mitigation Measures and Technologies

Major barriers to adoption of technologies and implementation of the identified mitigation measures in the agriculture sector include the following:

- Lack of adequate capacity for research and for provision of extension services hampers the spread of technologies suitable to local conditions.
- Inadequate understanding of the baseline practices in different rice ecosystems and the socio-culture of the farmers hinders the introduction of new technologies.
- Small farm size, credit constraints, risk aversion, lack of access to information and human capital, inadequate rural infrastructure, and unreliable supply of complementary inputs also hinder adoption of new technologies.
- Extension workers need better knowledge about the technologies.
- At present most of the climate change mitigation activities are at the preliminary stage. Awareness of climate change issues and impacts is still limited in communities and sectors, and very little attention has been given to these issues, even though damage caused by extreme climate in the agriculture sector tends to increase from year to year.

3.4.5: Opportunities and Strategies to Adopt and Implement Technologies

The adoption of technologies in the agriculture sector may be accelerated by (i) the expansion of credit and saving schemes, (ii) shifting international research-funding towards water-use efficiency, irrigation management, and adaptation to salinity; and (iii) rationalization of input and output prices of agricultural commodities, taking development, equity, and sustainability issues into consideration. To accelerate the adoption of technologies, some of the following should be incorporated into the national plan:

- Development of human resources in the climate field, focusing not only on mitigation but also most importantly on impact and adaptation, and including programs for in-depth technical training on GHG mitigation analysis and climate change vulnerability and adaptation assessment.

Table 3.15: Current and projected waste generation (tons/day) in Monrovia (2010–2021).

Year	Population (millions)	Generation (tons/day)	Coverage (tons/day)	Collection (tons/day)	Collection (tons/day)
2010	1.059	724	45	326	118,917
2011	1.086	743	50	371	135,567
2012	1.114	762	55	419	153,009
2013	1.143	782	60	469	171,267
2014	1.173	802	65	522	190,372
2015	1.203	823	70	576	210,222
2016	1.233	843	75	643	230,814
2017	1.262	864	80	691	252,151
2018	1.292	884	85	751	274,231
2019	1.322	904	90	814	297,055
2020	1.352	925	95	878	320,622
2021	1.382	945	95	898	327,686

- Improvement of institutional capacity in the climate-change field related to agriculture, cross-sectoral initiatives, and other stakeholders.

- Development of and/or updating an incentive system for private or public investment in the agriculture sector and development of a market system that ensures the stability of agricultural product prices.

- Better cooperation and information exchange between governmental institutions, countries, and international organizations.

- Strengthening research programs on genetic development and agricultural practices,

- Strengthening networking with other relevant institutions at both the national and international level to facilitate the exchange of knowledge, experience, and technology.

- Funding research and development.

3.5: WASTE MANAGEMENT

3.5.1: Current Waste-Management Policies and Strategies

The Liberia EPA was created in 2002 by an act of the Legislature, which also simultaneously passed the Environmental Protection and Management Law and the Environment Protection and Management Policy of the Republic of Liberia. These three laws govern the management of the environment, including the waste-management sector.

The EPA is the primary institution in charge of developing and publishing national guidelines for solid-waste management in Liberia, environmental quality standards, related penalties and fines, and

Table 3.16: Solid waste composition in Monrovia.

Component	% by weight
Paper	10.0
Glass and ceramics	1.2
Metals	2.0
Plastics	13.0
Leather and rubber	0.2
Textiles	6.0
Wood, bones, and straw	4.6
Vegetable and putrescibles	43.0
Miscellaneous items	20.0
TOTAL	100
Density	250 Kg/m^3

Source: Waste Management Plan for Monrovia, UNICEF-DFID, August 2004

ensuring compliance for pollution control. The Ministry of Health and Social Welfare (MHSW) has the mandate, through its Division of Environmental and Occupational Health, to conduct sanitary inspections and evaluate compliance with the Public Health Law. The MLME and its Liberian Hydrological Service (LHS) are responsible for the evaluation of urban sanitation projects and provide guidance for the geotechnical investigation of engineered landfill sites. The Ministry of Public Works (MPW) is in principle responsible for the installation of the entire infrastructure required for waste-management delivery services, including waste collection and transfer stations, and the construction of engineered landfill sites. The municipalities have been charged, by the Public Health Law of 1975, with the responsibility for ensuring clean and sanitary environmental conditions in the territory under their jurisdictions. The municipal governments are thus responsible for local sanitation activities including the cleaning, collection, and disposal of generated solid waste.

An overview of the above-mentioned legal mandates demonstrates the overlap and imprecise division of responsibilities between the various public authorities. On the one hand, the EPA, the MHSW, and the municipalities all have a monitoring role, and on the other hand the MLME and the MPW have responsibility for preparing engineered landfill sites.
In general, four government ministries oversee the water supply and sanitation (WSS) sector. WSS service is provided by one public corporation and a number of city corporations. The rules governing these bodies have not changed. However, the Water and Sanitation Coordination Committee and the Inter-ministerial WatSan Committee are updating and developing standards, guidelines, policies, and laws for the WSS sector. Although good coordination of WSS sector objectives continues in the committees, a stronger secretariat is needed to effect the recommendations of both committees.

3.5.2: Baseline Data and Information

The following three sources of waste generation are recognized in Liberia:

1 → Solid-waste disposal on land.
2 → Industrial and domestic wastewater.
3 → Incineration of fossil-fuel-based products such as plastics.

Estimated current waste production for the municipality of Monrovia is about 724 metric tons and is projected to increase by 2.5% every year. Using this annual waste-generation rate, waste generation in Monrovia is projected as shown in Table 3.15 below.

The landfill project for solid waste was developed in Monrovia after identifying the most feasible solution amongst all alternatives. Assessment of feasibility included consideration of the potential social and environmental impacts of developing, operating, and closing the proposed sites. The composition of the waste is indicated in Table 3.16.

3.5.3: Assessment of Waste Management Sector Mitigation Measures in Liberia

The following mitigation options have been identified for implementation in Liberia:

1 → Recycling: Recycling technologies could be used to produce new materials for export such as handcrafts (e.g., handcraft made from aluminum waste, iron, etc).

2 → Composting: Composting technology is commonly used by farmers to make organic fertilizer. The common raw materials used for the composting are agricultural residues and animal waste.

3 → Incineration: Energy released during burning in a Combined Head and Power (CHP) plant can be used to generate electricity and heat. The power produced by CHP incinerators displaces fossil fuel consumption and therefore saves on GHG emissions.

4 → Methane recovery: Decomposing matter in landfill sites generates gas—a mixture of methane and carbon dioxide with other trace gases. Methane is a potent GHG, but it is possible to reduce that potency by capturing and burning some of the methane to convert it to CO_2 (called flaring). The heat from flaring can be used to generate electricity or supply local heating needs.

3.5.4: Barriers to Implementation of Mitigation

Implementation of the mitigation measures identified in section 3.5.3 would give not only environmental benefits but also economic benefits to Liberia. Producing energy from waste from incineration or landfill gas (methane recovery) would reduce CO_2 emissions through displacement of fossil-fuel use. This method of waste management would also improve air quality and public health. On the other hand, some of the options provide higher economic benefits than the current technologies.

Barriers to the implementation of the waste management technologies include:

(I) Policy and Regulatory

a) Low priority given to waste management in Liberia.

b) Inadequate or near lack of allocation of funding for waste management.

c) Poor or inappropriate policies regarding services for protection of public health and the environment.

d) Lack of an incentive system for investment in waste-management services.

e) Low enforcement of waste management regulations leading to no or improper treatment of wastes.

(II) Institutional

a) Lack of coordination between and lack of clear roles or functions for the relevant waste-management agencies: Ministry of Public Works (MPW), the MCC, the EPA.

b) Weak institutional capacity of local government agencies and city and town councils due to low priority accorded to waste management.

(III) Technological

a) Inadequate technical expertise for solid-waste management planning and operation and inadequately trained personnel.

b) Low priority for research and development activities in solid-waste management, and inappropriate selection of technology.

(IV) Socioeconomic

a) Weak national economy and insufficient funds for sustainable waste-management.

b) Absence of local industry to receive and process recycled materials such as paper.

c) Negative social perception of waste management and disrespect for workers in the sector.

3.5.5: Removing Barriers and Creating Opportunities

The following are opportunities for removing the barriers to waste-management mitigation:

a) Integrate climate change into solid-waste management policies, plans, and programs.

b) Promote, facilitate, and conduct educational campaigns on the environmental and societal benefits of waste reduction and recycling, composting options, and reduce the stigma attached to waste-management services.

c) Develop and promote policies and regulations that could facilitate small enterprises and private-public partnerships for waste management. These policies would include reducing or eliminating harassment of itinerant buyers, pickers, and waste dealers by police and assisting waste pickers in moving from manual to mechanical picking through retraining programs or subsidization of sorting/redemption centers.

d) Conduct studies and research on (i) waste streams (quantity and composition analyses), recovery/recycling systems, markets for recyclables, and problems in deciding facilitative/regulatory roles for the municipal authority; (ii) the needs of near-urban farmers for organic matter and support for safe-waste reuse in urban agriculture, and (iii) the potential of landfill sites as methane recovery project.

e) Disseminate information to parties potentially interested in a methane recovery project through a public awareness program.

f) Establish a system to control CH_4 generation and emissions from wastes through the design and development of an appropriate waste-management infrastructure.

3.6: NATIONAL GHG MITIGATION STRATEGY AND ACTION PLAN

Annex II of this NATCOM to the UNFCCC provides profiles of projects that were agreed at a workshop in Monrovia from March 5–9, 2012. The road map for the reduction of the contribution of Liberia to the GHG effect and global warming begins with the establishment of a sustainable institutional framework to deal with climate change. Strong institutional and human capacity-building is needed to conduct all related studies and set up policies for climate change mitigation at the country level.

The workshop recommended as a matter of high priority the development of a Low-Carbon Development Strategy (LCDS) for Liberia through an open and inclusive process involving all stakeholders.

This study also recommends the development of a mitigation plan to implement the LCDS with the following proposed timeline:

The first five years: 2012 to 2017

- Focus on better understanding of energy sources and uses for good energy balances adequate for sectoral planning and GHG inventory, using existing planning tools such as LEAP.

- Develop a number of demonstration projects that will serve as both educational and practical experiments for learning about various technologies as they are developed.
- Set up sustainable institutions for dealing with climate change and build national capacity.

- Complete and implement an archiving system for GHG inventory for all sectors.

- Create procedures for AD collection in a sustainable manner.

- Form a study committee in 2013 to begin planning for a new inventory.

- Form a study committee in 2012 to assess the mitigation potential for projects and propose inclusion of climate change mitigation in national development priorities.
- Introduce demonstration projects annually to demonstrate various technologies that could be implemented

- Make the Climate Action Plan (CAP) report an integral part of national planning and integrate it into the LLPRS.

The next ten years: 2017 to 2027

- Form a study committee to investigate the technologies that will best replace the engines that use fossil fuel to generate electricity for households and small and medium sized enterprise (SME).

- Form a study committee to review the impact of commuting to campus and develop methods to mitigate some or all of the GHG impact.

- Disseminate solar or possibly wind-powered generation in the country to target 2027 GHG goals.

The years after 2027 Liberia will need technologies that are currently under development, or not yet known, to help eliminate the remaining GHG emissions. For example, improvements in automobile efficiencies such as the electric car will in time reduce GHG from commuting. Further, as Liberia produces more electricity from renewable sources, GHG emissions will be reduced.

CHAPTER → 4

CLIMATE CHANGE VULNERABILITY AND ADAPTATION ASSESSMENT

4.1: CLIMATE CHANGE SCENARIOS USING RCMS

4.1.1: Development of the Climate Change Scenarios

Daily rainfall and air-temperature data are simulated using 10 RCMs at high resolution (0.44°x0.44°). Of these 10 models, 8 are run using the same spatial resolution of 50x50 km, of which 6 are forced with ECHAM5 General Circulation Model (GCM) initial conditions and the 2 others with HadCM3 GCM initial conditions and the A1B scenario. The aim of the ENSEMBLES experiment is to downscale GCM scenarios at finer resolution for impact assessment at regional or locale scale (van der Linden, 2009). These RCMs are known for their good performance in describing the recent climate of West Africa (Paeth et al., 2011) and its potential impacts on local agricultural systems (Oettli et al., 2011; Salack et al., 2011) better than the GCMs might do (Hansen et al., 2006). The simulated data cover West Africa over the period 1950–2100 at a resolution of about 50x50 km on surface. However, some RCM outputs start from 1981 and stop at 2050. The Liberian "window" is the RCM grid mesh which covers the country (Figure 4.1). It is extracted using the classical method of the nearest grid point.

For RCM timeline homogeneity, the 1981–2010 ensemble mean-simulation output is used as a baseline. Due to civil war havoc, updated long-term observational data is missing for the country. The ensemble mean of these RCMs is known to minimize biases in the present day performance assessments as shown by Salack et al., 2012. The data extracted from New_LocClim software are used to describe the average climate conditions. Figure 4.3 depicts the average monthly rainfall and mean temperature at selected locations of Liberia, and it is clear that the extreme northern zone of Liberia experiences unimodal seasonal rainfall while the southern and the eastern zones are under bimodal rainfall regimes. The two modes in these regions are found between April–May and September–November. The breaks in the rainfall regime are experienced in the July–August period. In other months (December–January–February–March) average rainfall does not exceed 50 mm. Only mean temperature is uniformly bimodal over the country. The highest mode (26–27°C) is found between February–March and the lowest (25–26°C) mode is observed in the September–November period (Figure 4.3).

On the basis of the annual cumulated rainfall, two rainfall regions are found: the southern zone with rainfall above 2,800 mm/year and the northern zone with average annual rainfall above the threshold of 1,800 mm (Figure 4.4). This rainfall gradient is associated with low temperature amplitudes in the south (less than 10°C) and larger amplitudes in the north of the country (Figure 4.4).

When the rainy season progresses into April, there is a regular increase in the frequency and amount of rainfall to the extent that it exceeds the potential evapotranspiration (PET) demand. Figure 4.5 shows this clearly. The first end of rainfall is sharp and begins in July–August in the southern zone (e.g., Firestone, Greenville, etc.) and the second growing season starts at the end of August–November. In the north, only one significant length of growing season is observed (Voinjama, Ganta, etc.).

The RCMs ENSEMBLE outputs of air temperature and rainfall are analyzed over the 1981–2050 period. The long-term signals of individual RCMs are aggregated to make the ENSEMBLE mean (Ens-mean). Individual RCM results are compared to the 1981–2010 baseline to obtain climate change scenarios for the period 1991–2050. For air temperature, the future scenarios are estimated on the basis of simple anomaly relative to the baseline climate of the Ens-mean. In order to obtain rainfall rates of change, the relative percent difference Equation 1, modified from Salack et al. (2011) was used.

$$RPD_{ccs} = \left(\frac{\overline{P}_{hori} - \overline{P}_{base}}{\overline{P}_{base}} \right) * 100 \quad (1)$$

where RPD_{ccs} is the relative percent difference (%) between the simulated rainfall at a given time horizon P_{hori} and the baseline values P_{base}

Figure 4.1: Orientation map (a) and regional model grid mesh (b) covering Liberia. The circles are the towns at which rainfall was recorded. The extracted Liberian window is made up of the numbered grid points.

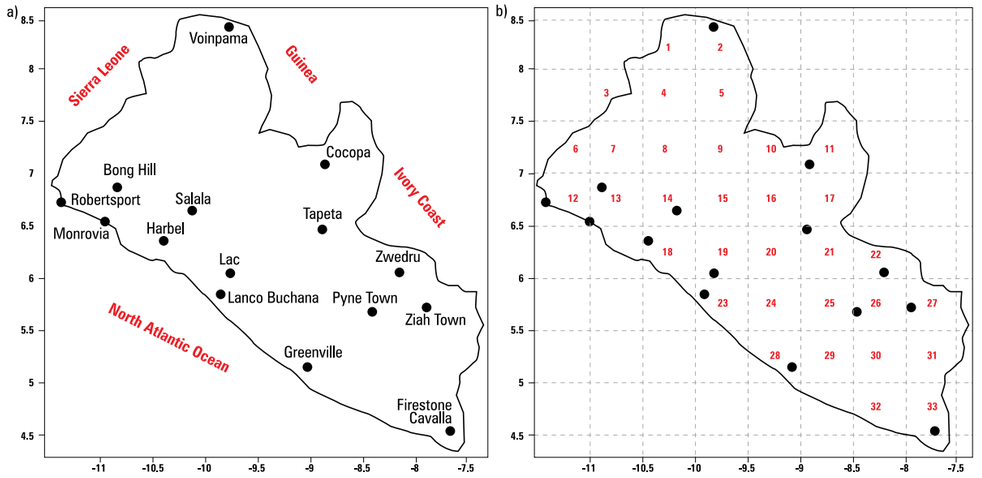


Figure 4.2 illustrates the seasonal cycle of daily rainfall drawn from the RCMs over West Africa, with reanalysis (ERA-Interim and NCEP) for the 1991–2007 in hindcast.

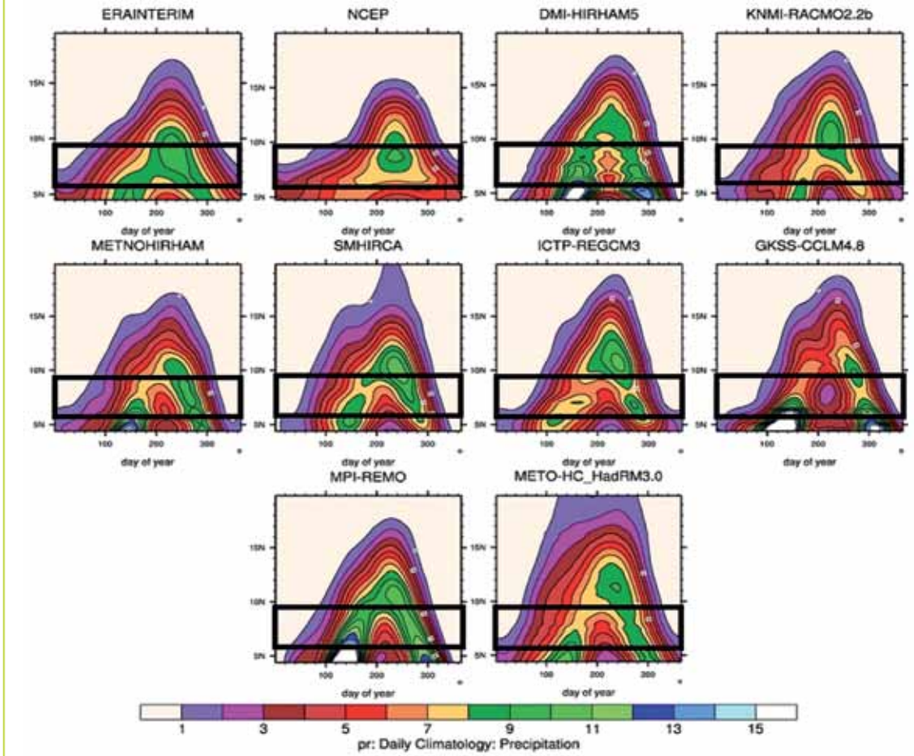
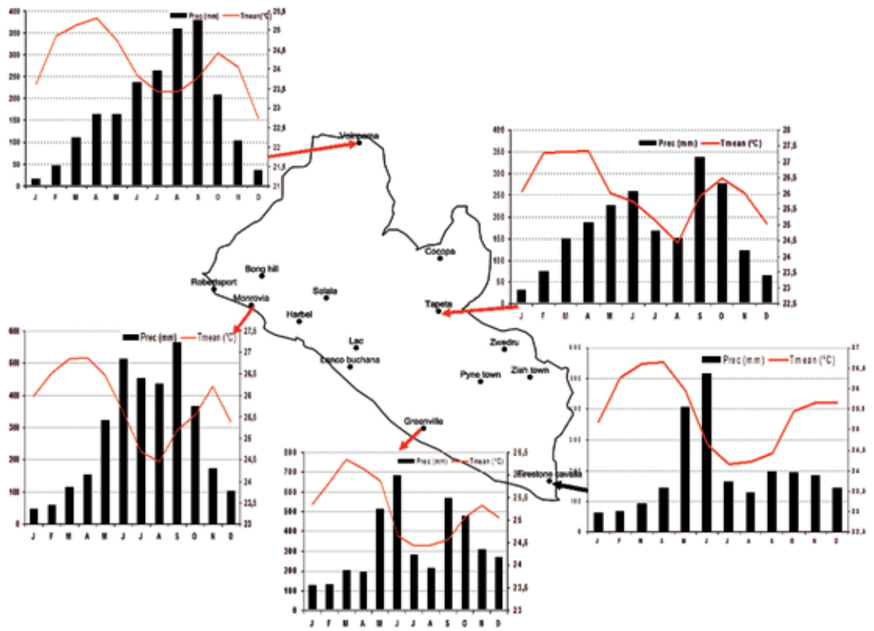


Figure 4.3: Monthly average rainfall (bars) and mean temperature (red curve) observed at selected locations in Liberia over the period 1961–1990.



The time scales considered in this study include the interdecadal (2010, 2020, 2030, 2040, 2050) and the long term interannual variability. The climate-change scenarios are provided with the rates of uncertainties given by the deviation of each RCM with respect to the ENSEMBLE mean (Ens-mean) at all time scales considered in the analysis.

4.1.2: Results and Discussions

The interannual variability of quantified future air temperatures is depicted countrywide for Liberia in Figure 4.6a. The trend of increasing temperature is unanimously simulated by all RCMs in this experiment for both maximum and minimum temperatures. These future perspectives of climate warming are in accordance with those stated in previous reports of the IPCC for Africa (IPCC, 2001). The estimated uncertainties around the projections show that the RCMs deviated less relative to the ENSEMBLE mean (dotted curve).

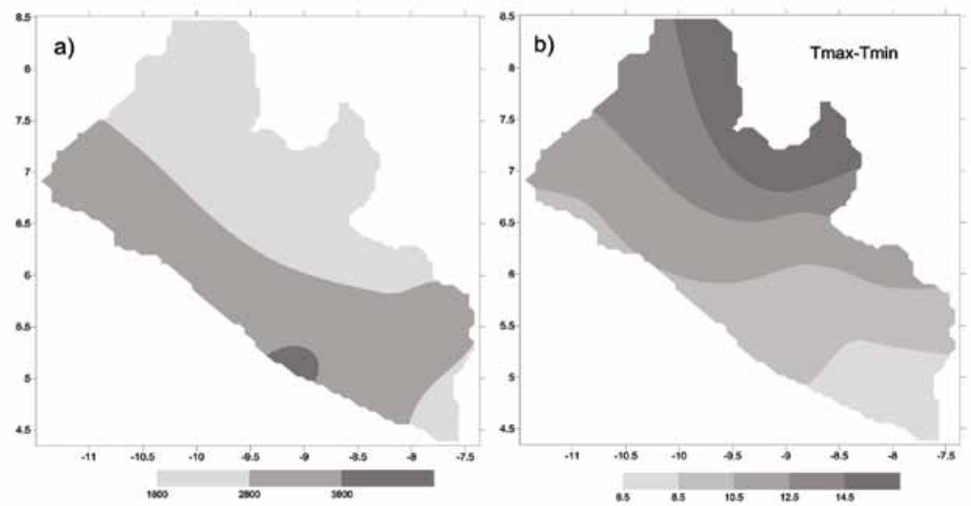
There is no significant increasing or decreasing trend in annual rainfall over half of the 21st century. This is mostly due to the lack of consensus on rainfall rates of change in individual models. The RCM spread around the mean is large, showing that uncertainties as to what the nearest future rainfall will be are very important (Figure 4.6b). Nonetheless, the interannual variability of the ENSEMBLE mean is strong with higher frequency of wetter years.

The average rates of change in interdecadal rainfall and mean air temperature are provided in Table 4.1. The average rates of increased rainfall from 2010–2050 will be between +2.0% and +5.0% under the A1B socioeconomic perspective. Mean air temperature is unanimously projected to increase from 0.4 to 1.3°C. The reference horizons—defined as a 30-year climate

Table 4.1: Mean temperature and precipitation scenarios for Liberia in the 2020s and 2050s using RCM ENSEMBLE simulation to downscale ECHAM5 and HadCM3 A1B scenarios.

Horizon	Precipitation (%)	Mean Temperature (°C)
2010–2019	+2.0	+0.4
2020–2029	+1.6	+0.5
2030–2039	+5.0	+0.8
2040–2049	+2.6	+1.3

Figure 4.4: Average rainfall amount in mm/year (a) and amplitudes of temperature in °C, i.e., Tmax-Tmin (b).



scenario—are named after the central decade they contain. Hence, the horizon 2020 (2020s) includes the thirty years centered on the 2020 decade (2010–2039). The average increase in the 2020s for both rainfall and temperature is estimated at 3% and 0.6°C respectively.

It appears that temperature will increase by 1.3°C in the middle of the 21st century. Rainfall is expected to show strong variability without a strong increasing or decreasing trend.

In analyzing the impacts of climate change on Liberia and the country's subsequent vulnerability, it is important to recognize that gender is a vital element to be taken into account when considering actions both to mitigate and to adapt to climate change. Climate-

Figure 4.5: Seasonal progression of Rain/PET (cropping potential) in 6 locations of Liberia.

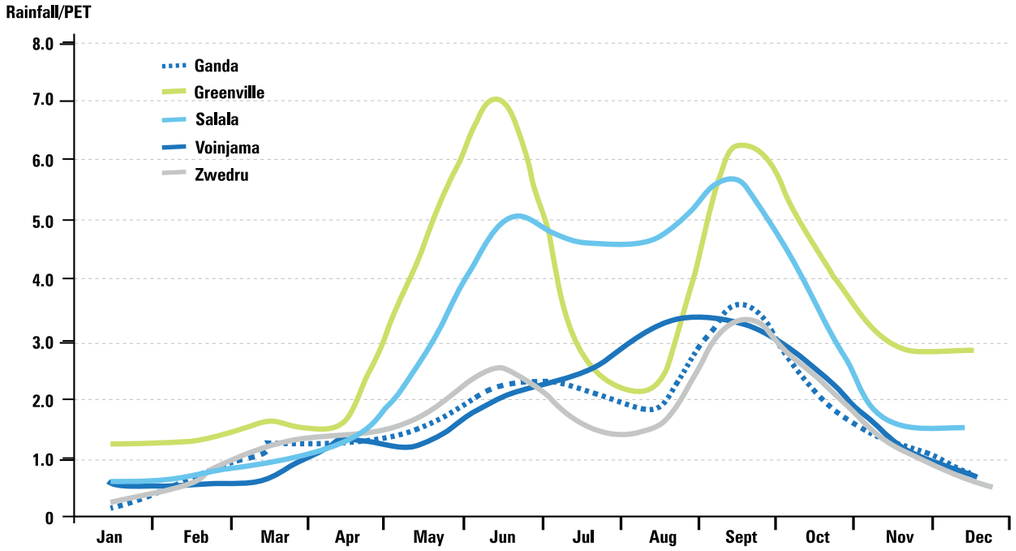
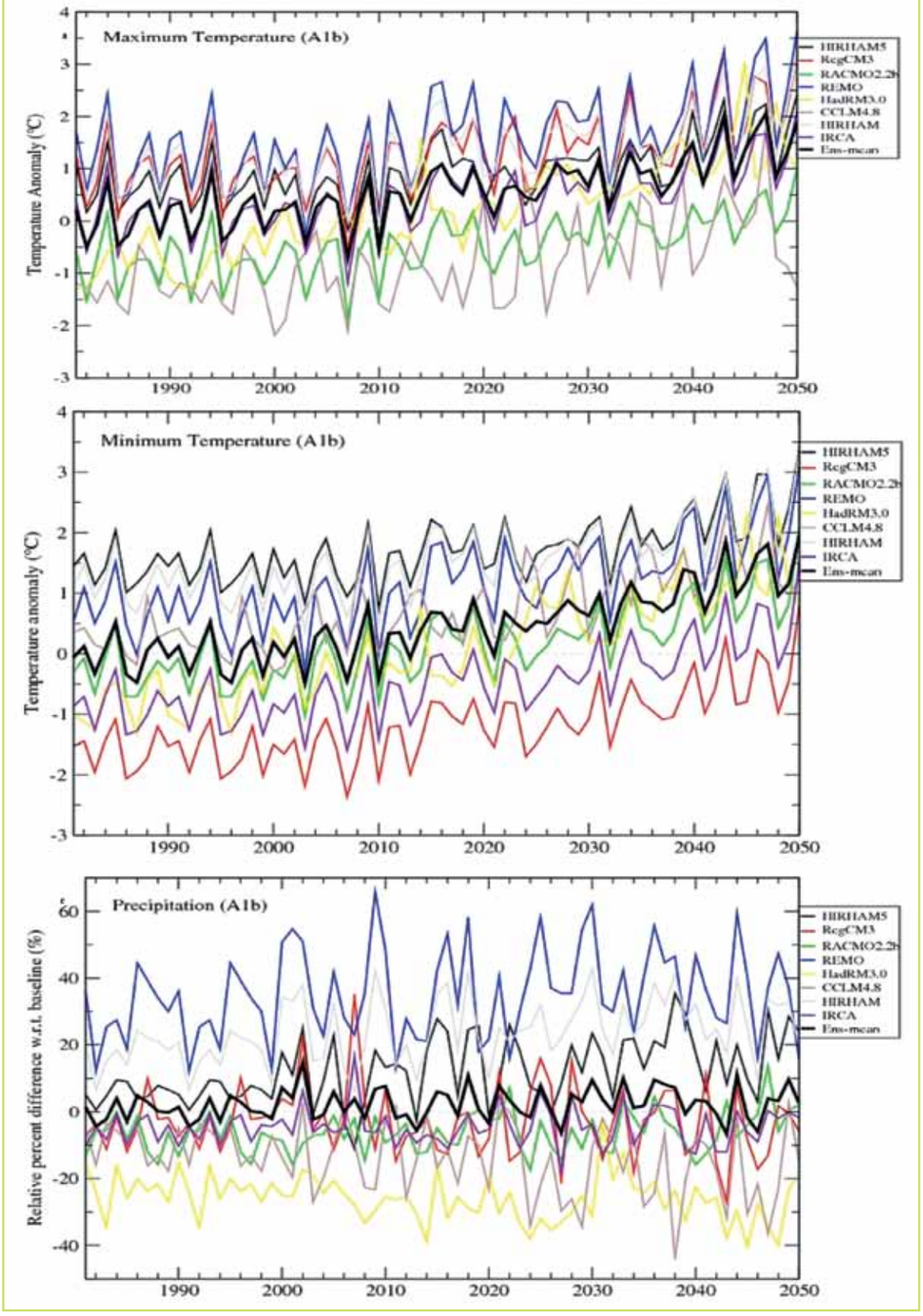


Figure 4.6: Interannual variability of maximum temperature (a), minimum temperature (b), and rainfall (c) in the next century according to the A1B climate change scenario in Liberia. The thick black curve depicts the average consensus of the projected scenarios (Ens-mean). The rates are given in percentage (%) relative to the 1981–2010 average for rainfall and degree Celsius (°C) for mean temperature.



change impacts are not only economic and physical but also social. Because of gender differences in socio-cultural and economic roles and responsibilities, climate change affects women and men in different ways, and often women more harshly.

4.2: ASSESSMENT OF THE VULNERABILITY OF THE WATER RESOURCES OF LIBERIA

4.2.1: Water Governance

4.2.1.1: Policy

Liberia has a water policy, which was developed recently after the end of the civil crisis. This is the first comprehensive national integrated water resources management policy, as there was no such policy in the pre-war era (MLM&E, 2007). The policy has been designed to promote an integrated approach to water resources management and use. It guides development efforts aimed at achieving the maximum net benefit from water resources in a sustainable manner for the livelihood of present and future generations. The policy is underpinned by the objectives and strategies of the Millennium Development Goals (MDG), the guiding principles of the International Drinking Water Supply and Sanitation Decade (1981-1990), and the GOL's overall goals for social and economic development of the country.

The water policy recognizes the state as the ultimate custodian of all water resources in Liberia but aims at achieving a public collective sense of ownership as a way of ensuring effective management, protection, and conservation of the resource. The policy covers two broad areas: water-resources management and water-resources use. While the component on water-resources management encompasses the framework for managing water resources and includes policy objectives, principles, and strategies for monitoring, assessment, allocation, and protection of water, the component on water-resources use covers policy objectives, principles, and strategies for development and use of water for domestic water supply, agriculture, industry (including hydropower), and other water uses, including re-creation, fire hydrants and trucks, and water for the environment (MLM&E, 2007).

The policy rightly identifies the lack of skilled professionals to handle various issues in the water sector and emphasizes the need for massive training and capacity-building at all levels of water management in the country. As the policy is dynamic, the developers of the Liberian National Integrated Water Resources Management Policy have underscored the need to re-assess and modify the policy from time to time to ensure that it addresses new challenges effectively.

4.2.1.2: Water Institutions

The Ministry of Lands, Mines and Energy (MLM&E) has the overall responsibility for managing the water resources of Liberia. This ministry is mandated by law to oversee the development and management of natural resources in general and water resources in particular and to conduct various investigations required for environmental assessments. It is also responsible for granting water permits to water-users and provides technical support to other government agencies and basic information on all aspects of water resources development, including water quality issues (MLM&E, 2007). The MLM&E handles water-related issues through its Department of Mineral and Environmental Research, which houses two key offices: the Liberian Hydrological Service (LHS) and the Liberian Geological Survey (LGS).

According to MLM&E (2007), the LHS is responsible for developing Liberia's hydrological potential and for supporting national-level hydrologic research and planning studies. The LHS collects data on the quantity, sources, and quality of water resources in Liberia and is responsible for monitoring rainfall and stream flow in river basins as well as ground and surface water quality. It also has been involved in the construction of shallow, hand-dug wells, though on a minimal scale.

The LGS is responsible for the geologic aspects of Liberia's natural-resources appraisal and development and environmental protection efforts. It has been involved in special projects on the evaluation of urban sanitation, particularly the provision of guidance for geotechnical investigation of solid-waste landfill disposal sites (MLM&E, 2007).

Other important institutions in the water sectors are the Department of Rural Development, the Ministry of Health and Social Welfare (MOH&SW), MOA, MOT, the LWSC, and the EPA. The Department of Rural Development, which is now part of the MPW, is responsible for providing water supply and sanitation services to rural areas through the provisioning of boreholes, hand-dug wells, spring boxes, and VIP latrines. The MOH&SW is charged with responsibility for setting water-quality standards and monitoring the quality of water supplied for domestic purposes. The LWSC is mandated to provide drinking water for inhabitants in both urban and rural areas. It operates as a commercial entity. Established in 2003, the EPA is responsible for coordinating, integrating, and harmonizing implementation of policies and laws related to the environment, including water.

In the pre-war era, the National Water Resources Supply Board (NWRSB), formed in 1980, was mandated to oversee development in the water sector (MLM&E, 2007). The specific responsibilities charged to the board

were (i) coordinating all activities in water resources development, (ii) reviewing sectoral regulations, and (iii) drafting comprehensive water legislation and policy. Though the NWRSB has not been formally dissolved, it is not functional, and there seems to be no reason why it is not functioning.

4.2.2: Water Balance Parameters of Liberia

4.2.2.1: Rainfall

Analysis of monthly rainfall data for eleven stations for the period 1961–1990 (see Table 4.2) shows that average annual rainfall ranged from 1,793 mm in Zia Town in the southeast to 3,965 mm in Greenville in the southeast. Generally, 60–85% of rainfall is received in the country between May and October, but the water surplus months vary from 7–9 months depending on the location. Reliable rainfall computed on the assumption of 80% probability of exceedance also ranged from about 1,142 mm in Zia Town to about 2,876 mm in Monrovia. PET figures for the same period varied from about 1,230 mm at Firestone in the southwest to 1,366 mm at Voinjama in the north.

Based on total rainfall figures, there was an average annual water-surplus of about 540 mm at Zia Town to 2,729 mm at Greenville. However, there is a water deficit of about 110 mm based on reliable rainfall estimates at Zia Town and still a surplus of about 1,640 mm at Greenville. On average, within the period 1961–1990, Liberia recorded an approximate 1,271 mm water-surplus based on total rainfall estimates of the eleven stations analyzed. Details of the water balance can be found in Table 4.2. The surplus for the same period dropped to about 460 mm based on reliable rainfall estimates. For agricultural purposes, rainfall reliability is important, suggesting that except in the lowlands, the large excess of total rainfall over total PET may not be really important in the planning of agricultural projects.

4.2.2.2: Surface Water

The surface water resources of Liberia are concentrated in major rivers that drain 97% of the country and in short coastal watercourses that drain the remaining 3%. Six of the major rivers, namely, the Mano, Lofa, St. Paul, St. John, Cestos, and Cavalla, are principal and together drain about 66% of the country (FAO-AQUASTAT, 2005). The longest is the Cavalla River (515 km) shared between Liberia and Côte d'Ivoire. The Cavalla drains an area of about 13,726 km2 in the northeastern and eastern parts of Liberia. The St. Paul River is the second longest river (282 km) and has a drainage area of about 12,820 km2. This river plays a very important role in the Liberian economy as it feeds the Mt. Coffee Hydroelectric Plant and provides the bulk of the raw water for Monrovia. The Mano River is an international river shared between Liberia and Sierra Leone. All the major rivers are perennial and flow in a generally northeast to southwest direction and into the Atlantic Ocean through the coastal plain areas. Full information on river runoff for all the major rivers is lacking. Table 4.3 provides information on the drainage area and mean annual flow of the major rivers in Liberia.

Estimates from AQUASTAT (2005) show that the total renewable water-resources of Liberia are 232 km3/year of which 200 km3 are produced internally and 32 km3 come into the country from Guinea and Côte d'Ivoire. All the internal renewable water-resources from surface water sources such as internal groundwater—estimated at 60 km3/year—are believed to be drained by watercourses. According to the UN Department of Technical Co-Operation for Development (UNDTCD) (1987), the flow process of Liberian rivers is highly variable due to the distinct dry and wet seasons experienced in the country. The coefficients of variation and asymmetry of daily flow were estimated to be in the range of 0.8–1.7 and 1.0–1.5, respectively. Mean annual flow of rivers is generally exceeded during 30%–45% of the year. Low flows of main rivers vary from 0.2 m3/s to 0.5 m3/s in the upper part of the channels and from 5 m3/s to 20m3/s in the lower portions.

Liberia has one of the highest per capita renewable water resources in Africa, with per capita water resources of more than 71,000 m3/year (AQUASTAT, 2005). However, water is scarce in many villages and cities during the dry season.

4.2.2.3: Ground Water

There is not much information on the ground water resources in Liberia. The predominant aquifer in the interior uplands is the lateritic aquifer, which is available either as pediplain laterite deposits or saprolite (granitic, weathered in situ). Aquifers in the coastal lowlands are dominated by unconsolidated sediments, mainly sand of fluvial and marine origin.

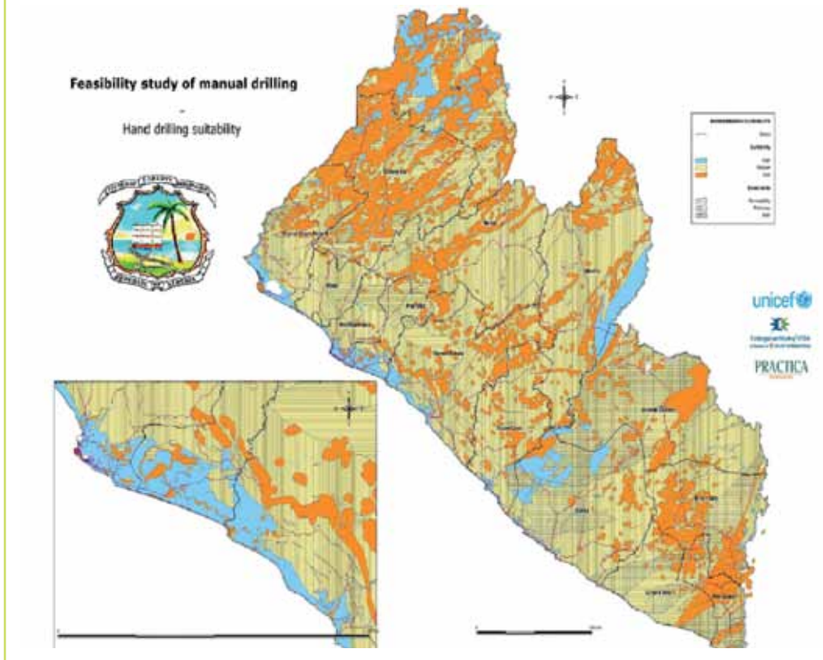
Generally, ground water is available and can be exploited in most parts of the country in amounts needed for rural water supply, which relies on dug wells and to some extent on boreholes. Data from the pre-war rural water-supply program indicate that the depth of the water table in shallow wells can be less than 1 m. Drilled boreholes can be as deep as 100 m. Based on an inventory of 770 wells from 11 counties, the static water-level varies from 7 m in the Nimba and Lofa counties in the uplands to 4 m in the Margibi and Montserrado counties in the lowlands, with an average of 5 m. In areas farther away from rivers, creeks, and the coastal belt, ground-water level fluctuations of 6 m have been observed while in the coastal zone fluctuations of 2.5 m were observed (UNDTCD, 1987).

Table 4.2: Annual water balance for selected locations in Liberia (1961–1990).

	Rainfall (mm)	Reliable Rainfall (mm)	Evapo-transpiration(mm)	Total Water Surplus (mm)	Reliable Water Surplus/Deficit (mm)
Ganda	2071	1458	1351	720	107
Greenville	3965	2876	1236	2729	1640
Monrovia	3296	2184	1260	2036	924
Pinetown	3157	2142	1240	1917	902
Salala	3296	2179	1260	2036	919
Suakoko	2071	1458	1351	720	107
Tappita	2043	1426	1287	756	139
Voinjama	2075	1387	1366	709	21
Zia Town	1793	1142	1253	540	-111
Zwedru	2043	1426	1287	756	139
Firestone	2294	1536	1230	1064	306
Average	2555	1747	1284	1271	463

Data Source: FAO Agroclimatic database

Figure 4.7: Hand-drilling suitability map of Liberia



A hand-drilling suitability map (Figure 4.7) based on a feasibility study of hand-drilling of wells in the country reveals that most parts of the country have medium suitability for drilling. High suitability areas are found along the coast in Montserrado County and pockets of places in the north, northeast, and southeast of the country. Recharge to the groundwater aquifers is said to come from heavy tropical rainfall and a network of water bodies (Brandolini and Tigani, 2006). Aquifers are fully recharged during the wet season (UNDTCD, 1987) and are completely drained by watercourses in the dry season.

4.2.2.4: Water Use

The total annual water withdrawal of Liberia in the year 2000 was estimated to be about 106.8 million m3 (AQUASTAT, 2005). Agriculture used most of the water, at 60 million m3/year (57%), followed by municipalities at 30.4 million m3/year (28%) and lastly industry, using 16.4 million m3/year (15%).

4.2.2.5: Water Quality

Data on water quality both from surface and ground water are scarce. A summary of results of water testing by LHS from 1980 to 1987 under the Water Resources Policy, Management and Legislation indicates that about 80% of the 150 wells tested on 30 water-quality parameters did not meet World Health Organization (WHO) drinking water standards (UNDTCD, 1987). The main pollution was bacterial and heavy-metal contamination. The study recommended the use of concrete lining for hand-dug wells and non-corrosive pumping systems to avoid heavy metal contamination. Many of the rivers in Liberia (e.g., the Mano and Farmington rivers) have been polluted by iron ore mining activities and rubber processing. Improper disposal of domestic sewage is also negatively impacting the quality of water in Liberian rivers. The only conventional sewerage system in the country is currently not functioning. Some sewage water is collected by vacuum trucks and dumped into lagoons and other water bodies (Brandolini and Tigani, 2006). In some areas there are indications that water quality is deteriorating due to mining, logging, farming, and industrial activities.

4.2.3: Climate Change Impacts on the Saint Paul River Basin

4.2.3.1: Study Area Description

As a country, Liberia has an immense supply of water from an average annual rainfall of about 2,390 mm (232 billion m3/year) and relatively low withdrawals of water for its three major water sectors, namely, agriculture, domestic water supply, and industry (106.8 million m3/year) (FAO, 2001). However, rainfall variability and pollution from anthropogenic sources pose serious threats to the sustainability of Liberia's freshwater resources. Climate change could further complicate matters.

This section provides an assessment of the impact of climate change on the water resources of the St. Paul River Basin in Liberia. The aim is to provide decision-support for mainstreaming climate change issues in the management of water resources at the basin level and beyond. Specifically, the study sought to analyze the impact of climate change on the hydrology and stream flow in the study river basin.

The St. Paul River is an international river shared between Liberia and Guinea. The river has its source in the mountains of southeastern Guinea where it is known as the Diana or Niandi River. The St. Paul River Basin was chosen for this study because of the strategic role it plays in the Liberian economy. The basin feeds the Mt. Coffee Hydroelectric Power Plant (currently the only hydropower plant in Liberia) and provides the bulk of raw water for Monrovia.

The St. Paul River has a total length of 332 km (50 km long in Guinea and 282 km in Liberia). In Liberia the river drains a total area of about 12,820 km2 in a southwesterly direction and empties into the ocean. The land-use/-cover, based on the FAO Land Cover Classification System, is predominantly savannah (45% of the basin). This is followed by evergreen broadleaf forest (26%), dryland/cropland/pasture (16%), and cropland/woodland (12%). The savannah consists of grassland interspersed with shrubs and trees. Based on the FAO digital soil-map of the world and derived properties (FAO, 1995), the soils of this basin are mainly ferralsols (61%) and lithosols (28%). The ferrasols occupy mostly the southwestern areas of the basin but also extend to the north. The lithosols are found in the northeast and extend to the central parts of the basin.

The mean annual rainfall in the basin ranges from 1,896 mm in the northeast to 3,177 mm in the southwest towards the outlet of the basin[1]. The basin's mean annual total rainfall (1961–1990) is about 2,306 mm. The mean daily temperature ranges from 24.9°C to 31.4°C. PET exceeds rainfall in four months (January, February, March, and December) of the year and varies from about 1,269 mm in the southwest of the basin to 1,389 mm in the northeast. The mean annual PET over the basin is 1,323 mm.

4.2.3.2: Data Types and Sources

Climate data were obtained from two main sources: the FAO New_LocClim software database (FAO, 2006), which is based on observed data from a few climate stations in Liberia, and the AMMA-ENSEMBLES ensemble-based runs for West Africa (van der Linden et al., 2009; Paeth et al., 2011). The FAO data covers the period 1961–1990 while data from the AMMA-ENSEMBLES covers the period 1961–2040. The periods 1961–1990 and 2011–2040 (2020s) were taken to be baseline and future, respectively. Climate parameters of interest were precipitation and evapotranspiration. Where evapotranspiration data were lacking, data on minimum and maximum temperatures were collected and used to compute evapotranspiration values.

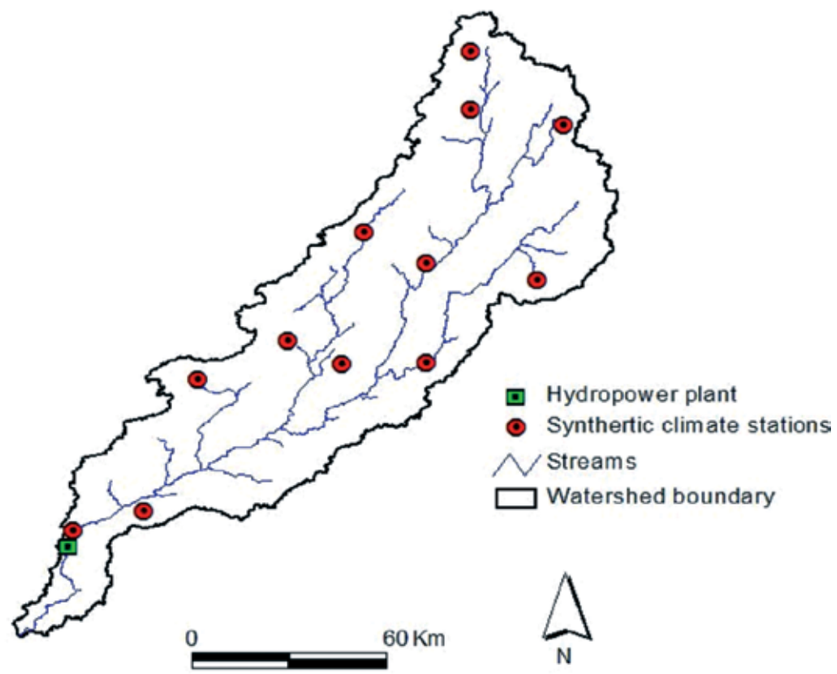
Due to lack of comprehensive observed climate-data for the basin and the whole of Liberia, the FAO data were taken as the observed and used as the baseline data for the impact analyses. Precipitation, temperature, and potential evapotranspiration were extracted for twelve arbitrary locations (synthetic climate stations) within a 50x50 km grid mesh overlaid on the basin. These synthetic climate stations have varying climatic conditions and provide good coverage for the St. Paul River Basin (see Figure 4.8).

Data from the AMMA-ENSEMBLES are modeled data of precipitation and minimum and maximum temperatures from two RCMs (HadRM 3P from the Hadley Centre, UK Met Office, and REMO from the Max Planck Institute, Germany). These were used to determine future changes in the climate of the study basin. The HadRM 3P model was forced by HadCM3 General Climate Model (GCM) boundary conditions, while REMO was forced by ECHAM5 GCM boundary conditions. Simulations from both RCMs were based on the IPCC SRES A1B scenario experiment. The HadRM 3P and REMO models were chosen from the ten RCMs used in the AMMA-ENSEMBLES because they provide the lowest and highest future projections over the basin with respect to precipitation and therefore could take care of the uncertainty in all the RCM projections.

4.2.3.3: Bias Correction and Construction of Future Climate Series

Due to simulation biases of global and regional climate models, the so-called "delta" method was used to adjust the observed data to obtain the future climate series that were used to analyze the impact of climate change on the stream flow in the study basin. The delta method is well documented and has been used widely in climate-change impact studies (Arnell, 1998; Gellens and Roulin, 1998; Middelkoop et al., 2001). In this approach, a climate model output is used to determine future changes in climate with respect to the model's baseline output. These changes are then applied to observed historical climate data to obtain future climate series that are used as input to an impact model. For the purpose of this study, monthly changes in climate output for the 2 RCMs (HadRM 3P and REMO) between the baseline (1961–1990) and future (2011–2040) periods were applied to the observed data (FAO) to obtain input data for the impact analysis.

Figure 4.8: St. Paul River Basin, showing the location of synthetic climate stations.



[1] *Based on the FAO New_LocClim database.*

Table 4.4: RCM projected mean daily temperatures and precipitation for the St. Paul River Basin, Liberia.

Scenario	Daily Mean Temperature (oC)		Mean Annual Total Precipitation (mm)	
Baseline (1961–1990)	24.6		2,299.7	
	HadRM 3P	REMO	HadRM 3P	REMO
2020s (2011–2040)	26.0	25.7	2,217.2	2,345.7
Change	1.3	1.1	-3.6%	2.0%

4.2.3.4: Runoff Estimation

Due to lack of runoff data for the St. Paul River Basin as a result of the civil war, which resulted in the loss of hydrological monitoring equipment and runoff data, this study could not make use of the physically-based hydrological model SWAT (Soil and Water Assessment Tool) or the lumped WatBal model (Water Balance Biophysical Model) to assess the impact of climate change on water resources. Instead, a simple, empirical, annual water-balance approach similar to Budyko's model (Budyko, 1974) was used. Budyko's model and modified versions have been widely used to study water balance in many river basins worldwide (Gerrits et al., 2009; Donohue et al., 2007; Koster and Suarez, 1999), particularly for basins where data availability is limited.

4.2.4: Results and Discussions

4.2.4.1: Baseline Water Balance

The mean annual total precipitation and PET over the St. Paul River Basin for the baseline period (1961–1990) was estimated to be 2,299.7 mm and 1,317.4 mm, respectively. Precipitation exceeds PET in 8 of 12 months. Applying equation (1) to this basin, the long-term mean annual runoff is estimated to be about 982.3 mm and the coefficient of runoff equals 0.43. Given that the St. Paul River Basin has a total drainage area of about 17,000 km2, the runoff value translates into 16.70 billion m3/year. The value obtained for the runoff coefficient in the study basin is well within the range obtained in earlier water balance studies in the three Liberian basins reported in Table 4.1. Additionally, the estimated runoff value compares very well with the 512 m3/s (equivalent to 949.8 mm) reported in literature for the St. Paul River at the outlet of the basin (Brandolini and Tigani, 2006), with a 3.4% difference in estimations.

4.2.4.2: Projected Precipitation and Temperature

Analysis of projections of temperature from the two RCMs used in this study reveals that the St. Paul River Basin is likely to become warmer in the 2020s relative to the baseline, as the two RCMs unanimously project significant increases in the daily mean temperature, ranging from 1.1°C to 1.3°C (Table 4.4). Regarding precipitation in the study basin, the two RCMs provide divergent projections of future conditions. The HadRM 3P RCM projects a slightly drier condition for the 2020s, with a 3.6% reduction in the mean annual precipitation relative to the baseline. The REMO RCM, on the other hand, projects a slightly wetter condition for the 2020s, with a 2% increase in the mean annual value over the baseline value.

4.2.4.3: Projected Water Balance for the 2020s (2011–2040)

The projected mean annual total runoff in the 2020s for the St. Paul River Basin shows a reduction in the future mean annual runoff compared to the baseline runoff value. The basin runoff is expected to reduce by 0.7%–25% in the 2020s (Table 4.5). The higher runoff-reduction projection was based on precipitation and temperature projections from the HadRM 3P model while the lower projection was based on climate series from the REMO model. Even though the REMO model projects an increase in precipitation, the magnitude of the increase was not enough to result in increase in runoff. This is because the 2% increase in precipitation was overshadowed by the increase in PET resulting from a 1.1°C increase in temperature projected by the same model.

The projected reduction in runoff is likely to affect the production of hydroelectricity from the Mount Coffee hydropower plant located in the St. Paul Basin. The supply of raw water to the city of Monrovia could be seriously affected.

Table 4.5: RCM projected mean annual total runoff (mm) for the St. Paul River Basin, Liberia.

Scenario	Estimated Mean Annual Total Runoff (mm)	
Baseline (1961–1990)	982.3	
	HadRM 3P	REMO
2020s (2010–2039)	737.2	975.6
Change (%)	-25.0	-0.68

4.3: ASSESSMENT OF THE VULNERABILITY OF THE AGRICULTURE SECTOR TO CLIMATE CHANGE

4.3.1: Agricultural Situation

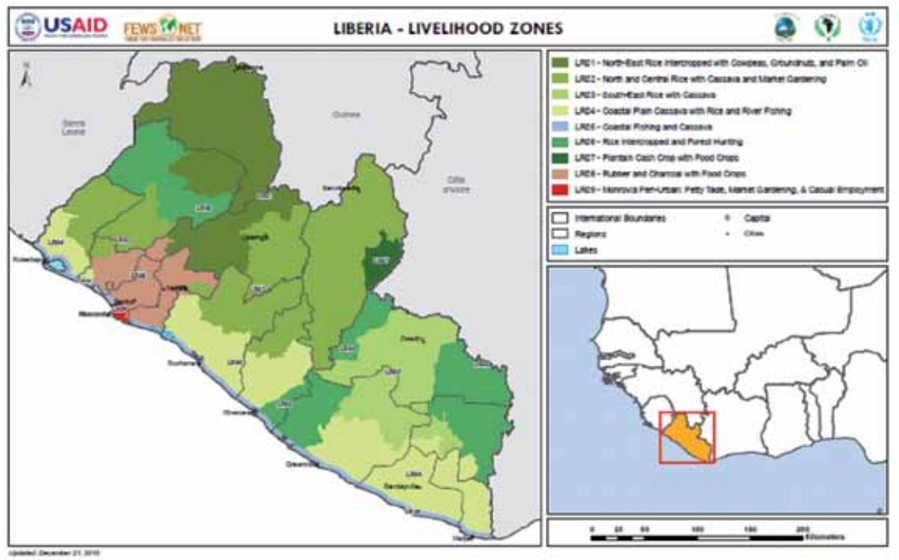
The Liberian National Adaptation Programme of Action (GOL/NAPA, 2008) identified agriculture as the priority sector. It suggested investigating how land-use could be diversified through a cycle of crop rotation and livestock production and pointed out that farming communities are already widely experienced in adapting to variations in climate. In 2003 members of the African Union (AU) through the Comprehensive Africa Agriculture Development Programme (CAADP) pledged to devote 10% of national budgets to agricultural development. However, Liberia is lagging behind, having committed less than 3% of its budget to agriculture by 2009 (Fan et al., 2009). An increase to 10% would be a major policy initiative beneficial to agriculture.

The Liberian economy is predominantly agrarian, with 75% of the labor force employed in the agriculture sector, which is dominated by production of rain-fed subsistence cash- and food-crops. Liberia's cultivated food crops are rice, cassava, groundnuts, coconuts, pawpaw, sweet potatoes, maize, banana, plantain, avocado, mango, pineapple, citrus, guava, breadfruit, grapefruit, cashew nuts, taro root (*Colocasia* sp., eddoes), and vegetables. Plantation crops include rubber, sugar cane, oil palm, coffee, and cocoa. Rubber plantations are widespread, and only rubber has been subjected to any concerted research on genotypic variability and the potential for exploitation of new varieties. Agro-industrial activity includes rubber processing, cocoa plantation, and logging. Livestock production is limited to traditional systems.

About 75% of the Liberian population is dependent on agriculture, which, together with forestry, contributed 91.4% of the country's GDP, dropping to 83% by 2008 (GRM International AB, 2010). One-fifth of agricultural workers (about 220,000 people) are directly employed on farms and plantations, but most (about 860,000) are smallholders cultivating 1.5 ha on average (GRM International AB, 2010). The total area devoted to arable land is about 4.6 million ha with 182,000 ha available for pasture, mostly for sheep and goats. Liberia's National Gender Policy (NGP) highlights that women provide about 80% of the agricultural labor force of the country [2].

Liberian agriculture is run through (a) foreign

Figure 4.9: Livelihood zones of Liberia.



firms that have secured concessions, mainly for rubber and oil palm, (b) commercial farms, and (c) traditional farms. A summary of the current status of agriculture in Liberia is given by the MOA's stocktaking document for the CAADP, part of the New Partnership for Africa's Development (NEPAD). The main agricultural systems contributing to livelihoods in different parts of Liberia are illustrated in Figure 4.9 below.

4.3.2: Location of Study Sites

In Margibi County, 70% of the population depends on agriculture with 22% of household incomes dependant on rubber tapping. The county receives about 9.25 mm/month of rain, based on averages for 1961–1990, peaking at 19.4 mm in September and with lowest amounts (0.43mm) falling in January. Maximum temperatures range from 28°C in August to 33.8°C in April. It is coldest (21°C minimum temperatures) in January and November, with the highest minimum temperatures being recorded in March (27.8°C). Soils are generally lateritic, low in organic matter (4–6%), highly acidic, and deficient in magnesium and calcium.

MAJOR CROPS PRODUCED IN MARGIBI COUNTY INCLUDE:

Rubber

About 24,000 ha in Margibi County support rubber at a density of 73 trees/ha. A limiting factor in rubber production is the quality of seedlings. Higher-yielding clones have been tested in Liberia, but farmers would need to adopt new cultivation techniques and incur higher production costs. Firestone is selling an improved variety of rubber seedlings at a price of US$0.25 (GRM International AB, 2010). Although rubber trees produce more coagulum as they get older, production begins to diminish 25–30 years after planting, when re-planting is advisable. However, due to the civil unrest, more than 75% of trees on Liberian farms have exceeded the age at which they should be re-planted, a process which costs about US$250/ha. Rubber tolerates some water-logging and a wide pH range (4–8) but flourishes in deep, well-drained, loamy acid soil covered with undergrowth or a leguminous crop to prevent erosion. Where rainfall is high, soil drainage needs to be good. Rubber may tolerate drought for 2–3 months. Strong winds may snap trunks and branches, but wind-resistant clones can be planted (World Agroforestry Centre, 2011).

Table 4.6a: Critical temperatures for the development of rice plants at different growth stages

Growth Stages	Critical Temperature (°C)		
	Low	High	Optimum
Germination	18-19	45	18-40
Seedling emergence	12	35	25-30
Rooting	16	35	25-28
Leaf elongation	7-12	45	31
Tillering	9-16	33	25-31
Initiation of panicle primordia	15	-	-
Panicle differentiation	15-20	30	-
Anthesis	22	35-36	30-33
Ripening	12-18	30	20-29

Table 4.6b: Symptoms of heat stress in rice crops

Growth Stage	Symptoms
Vegetative	White leaf tip, chloritic bands and blotches, white bands and specks, reduced tillering, reduced height
Reproductive anthesis	Reduced spikelet number, sterility
Ripening	Reduced grain-filling

[2]*Ministry of Gender and Development. 2009. Liberia National Gender Policy. Government of Liberia: Liberia.*

Rice

Liberians are highly dependent on rice for food, consuming rice at a rate of 500–799 kcal/person/day. There are 8,100 ha of rain-fed lowland rice and 126,900 ha of rain-fed upland rice grown in Liberia (Somado et al., 2008). Table 4.6a presents critical temperature thresholds for the growth and development of rice, while Table 4.6b shows the effects of heat stress on rice. This study takes this data into consideration.

In many parts of Liberia, farmers of rain-fed crops have many coping strategies to deal with climate variability, but some of these strategies may no longer be effective with major changes in climatic patterns. Those coping strategies identified by GRM International AB (2010) included the following:

1 → Changing the timing of crop cultivation in response to changing patterns of rainfall.

2 → Intercropping, irrigating, and optimizing lowland/swamp farming practices.

3 → Controlling pests by fencing-off farms against rodents, scaring birds, weeding regularly, and using high-echoing bells.

4 → Maintaining fast-growing, nitrogen-fixing tree species to improve soil fertility and using multi-purpose tree species to maintain forest cover.

4.3.3: Approach Adopted

Given the diversity of agricultural systems in Liberia, the study concentrated on the climate change vulnerability of agricultural activities in Margibi and Bong counties in central Liberia, where the principal food crops are rice and cassava and the main cash crops are rubber, coffee, and cocoa. In Liberia, agricultural production is mediated through two main systems:

1 → Smallholdings, mostly cultivated traditionally with bush-fallowing or shifting cultivation for food crops.

2 → Large individual and commercial plantations using modern technology to produce rice, rubber, coffee palm kernel, and other export crops.

4.3.4: Results of the Assessment of Climate Change Impacts on Agriculture

The simulations based on an ensemble of RCMs suggest that, on average, the rainfall in Liberia countrywide will increase by 3.4%, 3.7%, and 10% and that temperatures will rise by 1.6°C, 2.5°C and 3.4°C by the 2020s, 2050s, and 2080s, respectively. The increases in rainfall could damage rubber production, as it will be more difficult to keep the soil in plantations adequately drained. Very heavy rainfall over short periods during sudden storms with high winds could lead to broken rubber trees.

Much of the loss in rice production will occur due to lodging, i.e., rice plants bending over and collapsing. Rice grains need to dry out and harden before harvest, and this will become problematic when the humidity increases to levels preventing sufficient drying. Rice seed needs further drying post-harvest, and this too will become increasingly difficult with increasing humidity. If the drying period is extended, it may lead to increased storage risks from pests. Ostensibly, it would be expected that increases in temperature would increase development and reproductive rates of rice plants. However, this is not necessarily true since temperatures in storage are often higher than ambient temperatures, and each pest has an optimum temperature range at which it thrives. Thus, a 3.4°C temperature increase might lead to supra-optimal temperatures, deleterious to the insects' survival. Optimum temperatures for the three most-likely storage pests of paddy rice in Liberia are 32–33°C for the lesser grain borer (*Rhyzopertha dominica*), 26–30°C for the angoumois grain moth (*Sitotroga cerealella*), and 27–31°C for the rice weevil (*Sitophilus oryzae*) (Haines, 1991).

A positive benefit of increasing temperatures is that the time between planting and harvesting will be reduced, possibly leading to opportunities to increase rice production in the more northerly parts of the geographical range where rice can be grown. Negative impacts from increased temperatures will be more heat-stress symptoms in rice and faster development and reproductive rates of pests and diseases. For instance, the development time of rice blast in rice will be reduced and reproductive rates of rodent pests will increase, as will those of vectors of rice yellow mottle disease.

4.3.5: Potential Adaptation Options in Agriculture

The following potential adaptation options have been identified:

1 → Develop an agricultural database-management system for data archiving, accessing, and dissemination. The archiving of data on rubber and rice production and records of these crops' pests and diseases should be integrated with meteorological data to seek trends and initiate the beginnings of monitoring and forecasting systems. A Microsoft Excel Spreadsheet could be created with separate files for rubber and rice production, with worksheets within a file for each pest and disease. Within the sheets for each pest or disease, columns for date (Julian dates/week number)

and numbers of cases, hectarages affected, and losses (kg and/or value) for each county could be recorded with associated rainfall, temperature, relative humidity, wind, solar radiation, and other chosen (or available) environmental variables.

1 → Plant varieties of rice that are resistant to droughts, flooding, and major pests and diseases such as rice blast and rice yellow mottle disease. Plant only good quality, preferably certified, rice seeds and rubber plants.

2 → Increase the efficiency of fertilizer and agro-chemical use. Increase their replacement with soil-fertility-enriching (and carbon-absorptive) production methods that rely on multi-cropping, integrating crop and livestock production and the use of locally available bio-fertilizers and bio-pesticides (Hofmann, 2011).

3 → Expand cultivated land-areas, increase weeding, moving to different sites, and multiple cropping (planting of many crops on the same piece of land).

4 → Harvest ground water.

5 → Mulch/use cover crops and intensive manure application.

6 → Cultivate in wetlands/river valleys.

7 → Construct drainage systems.

8 → Process crops to minimize post-harvest losses.

9 → Use agrochemicals

10 → Change the timing of land preparation activities, planting dates, harvesting dates.

11 → Practice zero/minimum tillage, mixed farming (crop and animal production), relay cropping (planting and harvesting in succession), intercropping (main crops planted with subsidiaries at low densities).

12 → Decrease animal stock, changing from animal production to crop production, and plant early maturing crops (Agwu et al., 2011).

13 → Fallow for 9–12 years rather than the current period of 3–4 years.

4.4: ASSESSMENT OF CLIMATE CHANGE VULNERABILITY AND ADAPTATION FOR THE HEALTH SECTOR

4.4.1: Health and Disease Burden of Liberia

Liberia lies mostly within the forested area of the West African bioclimatic zones, but the land includes some savannah areas in the north. Diseases that occur in Liberia or that have the potential to occur and that will be affected positively or negatively by climate change include those caused by water-borne pathogens, such as cholera, and vector-borne diseases such as malaria, onchocerciasis, and schistosomiasis. The vectors of all the latter have aquatic phases. Therefore, changes in rainfall patterns will affect their epidemiology as will habitat changes. Other climate-sensitive diseases include respiratory diseases such as tuberculosis and diseases associated with, or exacerbated by, malnutrition such as HIV/AIDS.

In the first annual epidemiological report published since the civil crisis, data on Liberia's disease burden was summarized according to causes of visits to Ministry of Health facilities. Table 4.7 below gives the major diseases of the country and provides some statistics on their incidence during the two years of 2007 and 2008. The lack of information for the period of the civil crisis hampers analyses in search of trends.

4.4.1.1: Malaria

Malaria is the leading cause of morbidity and mortality in Liberia, accounting for 38% of patients admitted to hospitals. According to the WHO, the entire population of Liberia is at risk for malaria caused by *Plasmodium falciparum*. The number of reported malaria cases increased from 720,000 during 2006–2007 to 749,000 in 2009, probably due to improved reporting. About 80,000 malaria admissions and 2,340 malaria deaths were reported in 2010, both considerably higher than in the previous two years (WHO, 2011). The incidence of the disease varies both seasonally and regionally. Although the data are probably biased by population densities and accessibility to health care and diagnosis facilities, Montserrado County, in which Monrovia is situated, reported in 2008 the highest number of cases in persons more than five years old, followed numerically by Lofa County, Nimba County, Grand Bassa County, and Bong County. A national survey of malaria was conducted in 2009 (National Malaria Control Program, 2009) which showed that for children the disease is least common in Monrovia (prevalence 15%) and most prevalent in North Central (42%) and South Eastern B (35%) regions.

Table 4.7: Major causes of visits to Ministry of Health facilities in 2007 and 2008.

DISEASE	Incidence per 1000 people (all age groups)	
	2007	2008
Malaria	104	119
Acute respiratory infections	55	41
Sexually-transmitted diseases	24	32
Skin infection	18	15
Diarrhea (bloody and non-bloody)	15	10
Urinary tract infection	13	7
Worms	12	13
Trauma	8	9

Source: Ministry of Health and Social Welfare, 2008.

4.4.1.2: Non-Pneumonia Respiratory Infections

The second most important cause of morbidity was non-pneumonia respiratory infection (see Table 4.8). The highest number of cases reported during 2008 was in Lofa County (>45,000), followed by Bong County (>23,000) and Nimba County (>19,000). These acute respiratory diseases may be exacerbated by heat stress and inhalation of pollutants from stagnant air. Other respiratory ailments such as asthma may increase with warming climates, as there is evidence that when it is hotter, plants produce more pollen, a principal allergen for asthma.

4.4.1.3: Sexually-Transmitted Infections (STIs)

STIs were the third most important cause of morbidity. Between June 2007 and December 2008, 184,000 patients were diagnosed with STIs and treated free-of-charge with drugs supplied by the Global Fund to Fight AIDS, TB and Malaria.

4.4.1.4: Skin Infection

Skin infection was the fourth most important cause of morbidity. It remains unclear if skin complications resulting from onchocerciasis are included in this category or not.

4.4.1.5: Diarrhea (Bloody and Non-Bloody)

Diarrhea (bloody and non-bloody) was the fifth most important cause of morbidity in 2007 but the sixth in 2008, with the reduction attributable to improved sanitation and water supplies. Acute bloody diarrhea is also included as one of the important notifiable epidemic-prone diseases.

4.4.1.6: Urinary Tract Infection

Urinary tract infections were the sixth most important cause of morbidity in 2007 but the eighth in 2008.

4.4.1.7: Worms

Worms, presumably intestinal parasites but possibly also including worms responsible for lymphatic filariasis and onchocerciasis, was the seventh most important cause of morbidity in 2007 but the sixth in 2008.

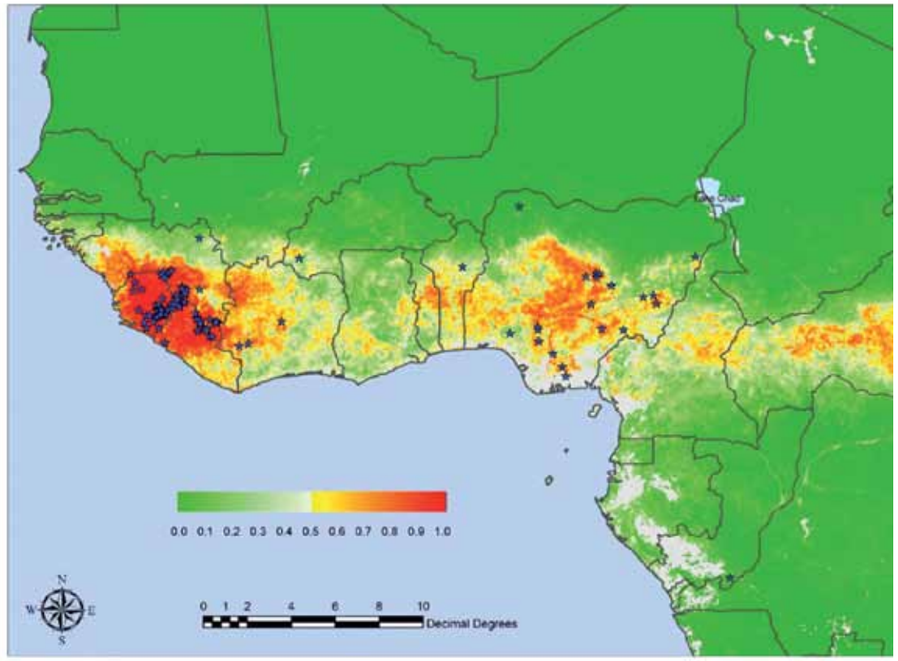
4.4.1.8: Trauma

Trauma was the eighth most important cause of morbidity in 2007 but the seventh in 2008.

4.4.1.9: Notifiable Epidemic-Prone Diseases

The MOH&SW weekly surveillance reports contain information on the number of cases (and sometimes number of deaths) attributable to acute bloody diarrhea, acute flaccid paralysis, cholera, Lassa fever, measles, meningitis, neonatal tetanus, yellow fever, exposure to rabies by dog bite, sudden acute respiratory syndrome (SARS), H1N1 influenza, neonatal death, and other diseases with high fatality rates. During the period for which data were available, the only diseases that occurred with high frequencies were cholera and measles. However, both of these diseases are climate-sensitive, and cholera, which was most common in Montserrado County, is water-borne and so tends to increase with high rainfall and especially when flooding occurs. Measles is temperature-sensitive, occurring at higher frequencies with higher mean air temperatures and has low incidence at times of high humidity.

Figure 4.10: Mean predicted Lassa-risk map for West Africa based on model outputs (from Fichet-Calvet& Rogers, 2009), with sites of known infections indicated by stars. The color scale is from 0 (green, no risk) to 1.0 (red, highest risk)



After cholera and measles, the notifiable disease with the third-highest cause of morbidity was Lassa fever (LF), a viral hemorrhagic fever for which the pathogenic agent is an arenavirus, Lassa virus (LASV), first discovered in 1969 in Nigeria. Further west LF is endemic in the Mano River area of Guinea, Sierra Leone, and Liberia. It occurs in a belt along Bomi, Bong, Lofa, Nimba, and Grand Bassa counties[3]. The most important reservoir host for the virus is the multimammate rat (*Mastomys natalensis*), whose populations are likely to grow with increasing rainfall. The LASV infection has been reported as two to three times higher in the rainy season than in the dry season. The seroprevalence in the human population in NW Liberia is 28% (Fichet-Calvet and Rogers, 2009), but may reach 40% in neighboring Guinea.

Fichet-Calvet and Rogers (2009) examined data on LF in relation to environmental variables and found that rainfall was the most important correlate, with the disease occurring mostly in zones receiving 1,500–3,000 mm of rain per annum. They modeled the likely risks of LF to provide a risk map, in which 80% of Liberia was found to be at risk (Figure 4.10).

Of the other notifiable diseases, yellow fever and meningitis are also likely to be climate-sensitive. Yellow fever is transmitted by mosquitoes (*Aedes aegypti*), which are liable to increase in wet weather, and meningitis is most prevalent in hot, dry months.

4.4.1.10: Tuberculosis

Tuberculosis (TB) notifications have increased recently (National Leprosy and Tuberculosis Control Program, 2009), but this is likely to be related to the close association of tuberculosis with infections of human immunodeficiency virus (HIV). However, the sinusoidal shape of the underlying increasing trend suggests that the variation may be related to some environmental factor or factors. Twenty-one percent of TB patients were found to be HIV-positive.

4.4.1.11: HIV/AIDS

In 2008, 3,429 people tested positive for HIV in Liberia, with most cases reported from Montserrado County (2,494), followed by Nimba County (241), Margibi County (157) and Grand Gedeh County (154). Anti-retroviral therapy (ART) was being administered to 1,925 patients, rising to 2,968 patients by September 2009 when 19 sites in 10 counties were administering ART. According to the National AIDS Commission (undated), in 2007 1.3% of the population aged 15–49 was infected with HIV-1 and 0.2% with HIV-2, with higher rates (1.8%) in women than men (1.2%). Urban infection rates were higher than rural rates (0.8%), with the highest infection rate (2.9%) recorded for Monrovia. Data on HIV/AIDS and other aspects of reproductive health were surveyed in 298 sample points in 2007 and the data reported by LISGIS (2007).[4]

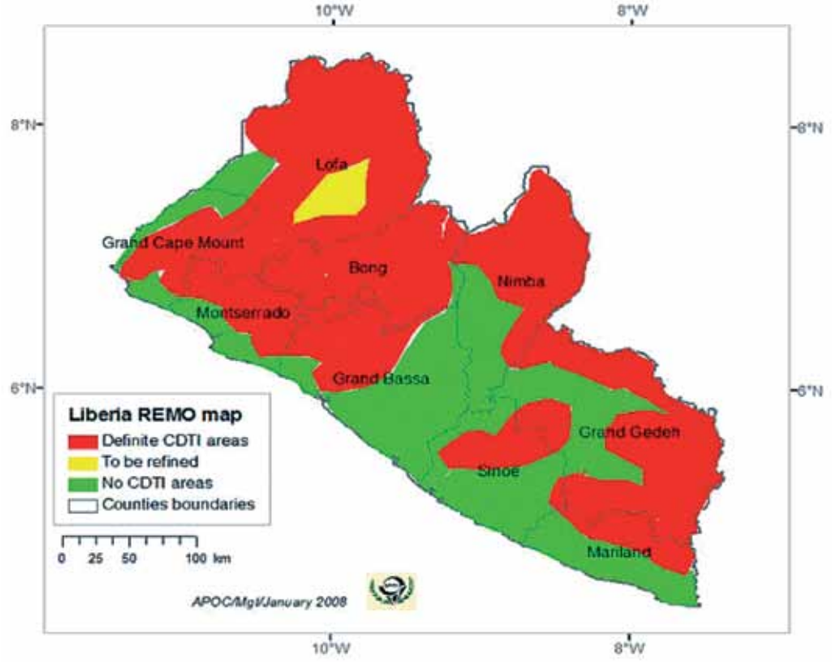
4.4.1.12: Mental Health

According to the MOH&SW (undated), 749 patients were treated for mental health problems at the Grant Memorial Mental Hospital in Monrovia during 2008. Of these, 659 (88%) came from Montserrado County, 29 (4%) from Bong County, 25 (3%) from Margibi County, and 13 (2%) from Grand Bassa County. Psychosis (schizophrenia, organic psychosis, and drug-induced psychosis) was the commonest reason for admission (228 cases), followed in descending order by epilepsy (112), anxiety neurosis (87), dementia (31), post-traumatic stress disorder (31), depression (20), and mania (4).

4.4.1.13: Eye Disorders

The prevalence of blindness in Liberia is estimated at 1% (National Eye Care Program, 2006), with about 35,000 people blind. Causes, in descending order, are cataract (17,500 cases), glaucoma (5,250), unspecified causes (3,220), corneal opacities (2,800), childhood blindness (1,820), and onchocerciasis (2,100). An additional 105,000 people suffer from visual impairment. Eye diseases are being tackled, with emphasis on eliminating blindness due to cataracts (National Eye Care Program, 2010). Onchocerciasis is vector-borne, being spread by black flies, members of the *Simulium damnosum* species complex, which breed in fast-flowing sections of rivers. The developing stages of the causative agent, the filarial worm (*Onchocerca volvulus*), are known as microfilariae, and when these invade the eye they may lead to blindness, known as river blindness. The severest form of the disease is spread by savannah forms of the vector, and there is already evidence that these have spread into formerly-forested zones of Liberia (Garms et al., 1991). Figure 4.11 below shows areas (in red) of hypo- and meso-endemicity for onchocerciasis prevalence in Liberia.

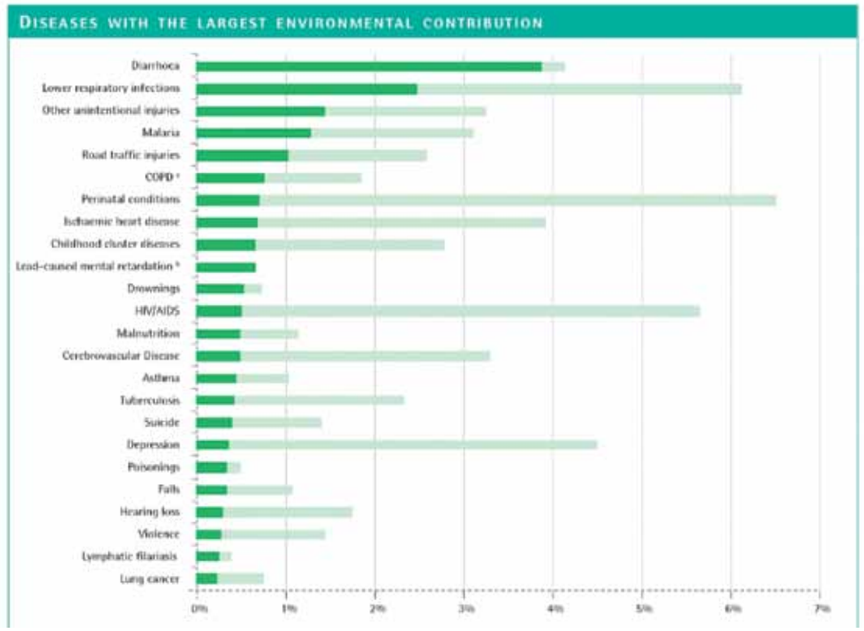
Figure 4.11: Results of rapid epidemiological mapping for onchocerciasis (REMO). Source: WHO, 2011.



[3] *See Table 1 of Fichet-Calvet and Rogers (2009) for details of recorded outbreaks in Liberia.*

[4] *Further details on HIV/AIDS in Liberia are available at:http://apps.who.int/globalatlas/predefinedReports/EFS2008/full/EFS2008_LR.pdf.*

Figure 4.12: Diseases listed according to contribution from the environment



4.4.2: Methodology

During the assignments, the current bioclimatic factors limiting the geographical distribution of diseases were assessed and their likely spread or contraction under different climate change scenarios predicted. The current capacity of the Liberian health and climate change sectors to respond with adaptation policies was assessed and training needs were identified.

4.4.3: Climate Change Impacts on Health

4.4.3.1: Changes in Disease Prevalence

Climate change simulations using an ensemble of RCMs suggest that, on average, the rainfall in Liberia countrywide will increase by 3.4%, 3.7%, and 10%, and that temperature will rise by 1.6°C, 2.5°C and 3.4°C by the 2020s, 2050s, and 2080s, respectively. The diseases likely to be affected can be assessed in relation to those which are most responsive to the environment. This subject has been examined by Prüss-Üstün and Corvalán (2006), and their conclusions about the diseases with fractions attributable to the environment are summarized in Figure 4.12.

Environmental changes are in turn subject to climate changes, and so the climate-vulnerability of diseases can be assessed in terms of likely susceptibilities to the effects of increased or decreased precipitation, climate variability, flooding or drought, and changes in the timing of seasons. More details on specific diseases were compiled by Kuhn et al. (2005), who also listed diseases with a classification in relation to their sensitivity to climate, as shown in Figure 4.12.

4.4.3.2: Assumption of Wetter Environments in the Future

It is likely that global warming will lead to rises in sea level. Monrovia is very vulnerable to flooding from this threat (Wiles 2005, 2007), irrespective of changes in rainfall regimes. It has been estimated that in Liberia 230,000 people are at risk and 2,150 km2 will be lost to a one-meter sea-level rise, including the loss of land and infrastructure and much of Monrovia, valued at US$250 million. Combining the two threats of increasing rainfall and flooding due to sea-level rises leads to greater vulnerabilities to epidemics of malaria, cholera (likely to increase by 10% by 2100) and diarrheal diseases, increased incidences of LF, schistosomiasis, lymphatic filariasis, yellow fever, hepatitis A, and intestinal worms. Very heavy rainfall and flooding could lead to fatal and non-fatal injuries and mental problems. Current expansion of the geographical range of dengue fever could include Liberia. The vectors (*Aedes* spp. mosquitoes) are present, and the disease has been identified in neighboring Côte d'Ivoire (Franco et al., 2010), in line with predictions of the disease's expected spread (Hales et al., 2002). These predictions also imply that dengue fever will become a major problem throughout Africa, with the entire population of Liberia becoming at risk by 2085 (Figure 4.13).

Table 4.8: Changes in disease prevalence due to climate change in Liberia.

Classification Key	Strength of Climate Relation	Diseases Relevant to Liberia	Remarks
*	Climate link is very weak.	Intestinal nematodes *(worms)* Schistosomiasis	Sensitive to changes in temperature and soil moisture. Increase in temperature and rainfall lead to higher transmission rates.
**	Climate plays a moderate role.	Lymphatic filariasis African trypanosomiasis Yellow fever	The mosquito vectors depend on temperature and rainfall. Epidemics may be related to temperature and rainfall. Epidemics are associated with high rainfall and high temperatures (Reiter, 2001).
***	Climate plays a significant role.	Meningococcal meningitis	Hot, dry, and dusty conditions are main causes (Colwell and Patz, 1998, Molesworth et al., 2003, Sultan et al., 2005).
****	Climate is an important factor.		
*****	Climate is the primary factor in determining at least some epidemics.	Cholera Malaria	Epidemics associated with increases in sea and air temperatures as well as El Niño events. Sanitation and human behavior are also important. Regional epidemics occur seasonally and are associated with periods of excessive rainfall, warm temperatures and increases in plankton populations. (Colwell and Patz, 1998; Shope, 1991; Lipp et al., 2002). Relations between outbreaks and rainfall are well known (Faye et al., 1995; Rogers et al., 2002; Paaijmans et al., 2009). Temperature, vector species, drug resistance, and other factors are important in the dynamics of malaria transmission.

4.4.3.3: Assumption of Warmer Environments in the Future

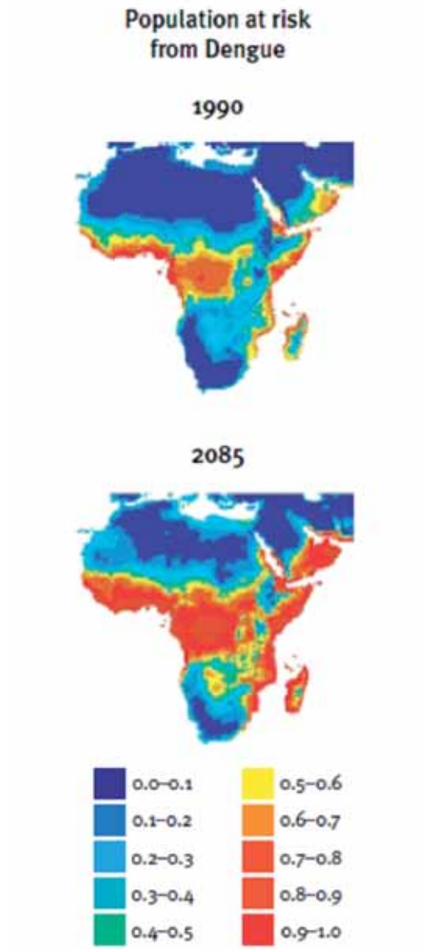
If climate changes lead to warmer environments as projected, then associated land-use changes are likely to lead to the spread of the savannah form of onchocerciasis. Increased temperatures will allow insect vectors of disease such as mosquitoes and tsetse flies (*Glossina* spp., vectors of human trypanosomiasis) to complete their life cycles faster and thus their populations will increase. For mosquitoes, a combination of wetter and warmer conditions will also lead to more breeding sites becoming available, which will also exacerbate the transmission of malaria, lymphatic filariasis, etc. Higher temperatures will also indicate high rates of measles amongst the community.

4.4.4: Potential Adaptation Options (see Project Profiles in Annex 2)

4.4.4.1: Development of a Health Database Management System

The archiving of data on health should be integrated with meteorological data to seek trends and initiate monitoring and forecasting systems. In the first

Figure 4.13: Predicted expansion of dengue in Africa. (This projection uses the IPCC IS 92a scenario predicting a three-fold increase in CO_2 by 2100). Figure taken from Conway (2009), derived from Hales et al. (2002).



instance, the routines used by the MOH&SW to report on notifiable diseases should be expanded to include reports on other diseases and climate data. Thus a spreadsheet system within Microsoft Excel could be used with separate sheets within a file for each disease. Within the sheet for each disease, columns for the date (week number), numbers of cases, and numbers of deaths for each county could easily be recorded with associated rainfall, temperature, relative humidity, wind, solar radiation, and other chosen (or available) environmental variables.

4.4.4.2: Policy and Strategic Initiatives

1 → Attention should be paid to prioritizing Monrovia and its environs as an area vulnerable to climate change-induced health problems associated with expected sea level rises and increasing rainfall. This has already been addressed in Liberia's NAPA, which identified broad national adaptation strategies. For the coastline, the NAPA proposed a program of sea defenses for the urban regions of Monrovia and Buchanan, which was priced in 2008 at US$60 million.

2 → Climate-change sensitive diseases should be prioritized in the next national health policy plan and steps taken to strengthen health systems responsible for dealing with climate-sensitive diseases such as malaria and cholera.

3 → Education on climate-change related threats to health should be encouraged to strengthen advocacy and communication about climate change adaptation in Liberia.

4 → Links should be forged with international agencies such as the African Climate Policy Centre (ACPC)[5].

5 → A climate and health working group (CHWG) should be set up to link health authorities with meteorologists, climatologists, and other stakeholders. The CHWG would be responsible for collating data on diseases and seeking relationships with climatic variables. This would be a necessary precursor to developing early-warning models for climate-sensitive diseases as part of an applied research program on health protection from climate change, integrating environmental and health surveillance. The data to be collected would include weekly or monthly incidence data and regularly updated data on rainfall, temperature, humidity, river discharges, vegetation indices, entomological indices, parasitological indices, drug resistance, population displacements, etc.

6 → Existing health systems should be maintained and strengthened with capacity development and infrastructure development geared towards coping with climate-sensitive disease management by delivery of preventive and curative interventions.

7 → Preparedness is necessary to be ready to respond to extreme weather events likely to lead to outbreaks of climate-sensitive diseases and population displacements. Liberia was affected by floods in 2007, attributable to exceptionally high rainfall and thunderstorms leading to much run-off, and such events are likely to occur with increasing frequency in the future.

8 → Water-safety plans and treatment of water to reduce incidence of water-borne diseases should be promoted.

9 → Integrated vector management to reduce incidence of malaria and other vector-borne diseases should be promoted.

10 → Support and promote the key adaptation strategies reported in the Liberia NAPA (2008). Ongoing work in Liberia is confirming the correlation between temperature and precipitation patterns and malaria, cholera, dysentery, giardiasis, amoebiasis, typhoid fever—diseases that afflict thousands throughout the country. While the NAPA consultation process confirmed that malaria is the highest concern, the other diseases were also considered for adaptive measures. Adaptation activities will need to take into account the diversity of factors that influence the capacity to cope with health outbreaks. Specifically, major adaptation activities and needs that have been identified are as follows:

- Identify and disinfect stagnant water sources that are breeding grounds for insects.

- Promote hygiene and sanitation education and awareness, including clinical interventions and community health education programs.

- Strengthen the Roll Back Malaria program and provide a range of herbal treatments.

4.4.4.3: Capacity Strengthening

There is currently no Vulnerability and Adaptation Team for the health sector in Liberia. Given the quality of the progress of the MOH&SW since the cessation of civil strife and its clear policy initiatives and plans to combat malaria and maternal and newborn mortality and morbidity (MOH&SW, 2010, 2011)), a small team needs to be established and trained to form a section dealing with climate change and health that could be integrated into the MOH&SW.

[5] *Contact: acpc@uneca.org.*

CHAPTER → 5

TECHNOLOGY TRANSFER AND DEVELOPMENT

5.1: INTRODUCTION

The Technology Needs Assessment (TNA) is the country's primary step towards defining its technology transfer priorities and identifying the most effective mechanisms for transfer. Technology transfer is a broad set of processes covering the flows of know-how, experience, and equipment for mitigating and adapting to climate change. The broad and inclusive term "transfer" encompasses diffusion of technologies and technology cooperation across and within countries. It comprises the process of learning to understand, utilize, and replicate the technology as well as the capacity to choose and adapt the technology to local conditions and integrate it with indigenous technologies (Bert Metz et al., 2001). The first step in the process is to conduct a TNA using the framework illustrated in Figure 5.1 below.

The needs assessment process is tailored to fit each country's particular circumstances and proceeds through the following sequence of steps:

1 → Establish criteria for selecting technology transfer priorities.

2 → Define priority sectors and subsectors.

3 → Compile and supplement technology and market information.

4 → Select priority technologies and sectors.

5 → Further technology and barrier assessment and stakeholder consultations.

6 → Define alternative actions.

7 → Select high-priority actions for further development and implementation.

8 → Prepare a needs assessment report.

Figure 5.1: Analytical framework for a TNA.

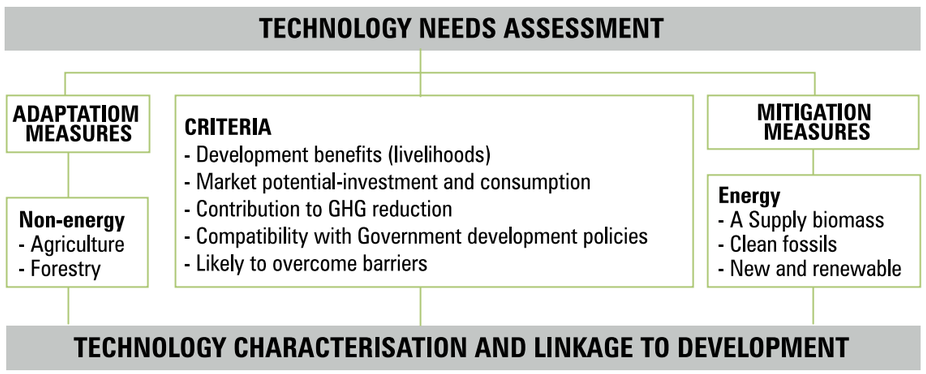


Table 5.1: Adaptation options, mitigation measures, and identified technologies.

ENERGY SECTOR		
SUBSECTOR	**ADAPTATION OPTION AND MITIGATION MEASURE IDENTIFIED**	**APPROPRIATE TECHNOLOGY IDENTIFIED**
Electricity	1. Promote hydroelectricity. 2. Promote energy efficiency and the use of renewable energy. 3. Reduce losses in electricity supply system.	a) Hydroelectricity. b) Energy-efficient appliances and solar, wind and biomass. c) Retrofitting electricity transmission and distribution lines and equipment.
Residential, commercial, and institutional (RCI)	1. Use of renewable energy sources. 2. Promote energy efficiency. 3. Switch to lower GHG-emitting energy sources.	a) Solar home systems for lighting and heating. b) Energy-efficient compact fluorescence lamps. c) LPG for domestic cooking.
Transport	1. Switch from fossil to renewable fuel (solar, gas, biomass).	a) Renewable fuels.
Industrial	1. Use renewable energy. 2. Promote low-carbon fuel for industrial boilers. 3. Use more energy-efficient and clean technology.	a) Photovoltaic panels for electricity generation. b) Industrial water heaters. c) Energy-efficient lighting equipment.
	AGRICULTURE SECTOR	
SUBSECTOR	**ADAPTATION OPTION AND MITIGATION MEASURE IDENTIFIED**	**APPROPRIATE TECHNOLOGY IDENTIFIED**
	1. Enhance production through efficient irrigation. 2. Switch to deep-rooted, drought-tolerant, and salt-tolerant crop species. 3. Enhance food security and self sufficiency.	a) Sprinkler and drip irrigation systems. b) Improved rice varieties. c) Post-harvest technologies. d) Food-preservation technologies. e) Food processing technologies. f) Aquaculture
	FORESTRY SECTOR	
SUBSECTOR	**ADAPTATION OPTION AND MITIGATION MEASURE IDENTIFIED**	**APPROPRIATE TECHNOLOGY IDENTIFIED**
	1. Reduce wood fuel consumption through the promotion and use of efficient cook stoves. 2. Treat plant and animal waste to produce biogas for energy use in households and cottage industries.	a) Energy-efficient and wood-saving cook stoves. b) Biogas plant and equipment.
	WASTE MANAGEMENT SECTOR	
SUBSECTOR	**ADAPTATION OPTION AND MITIGATION MEASURE IDENTIFIED**	**APPROPRIATE TECHNOLOGY IDENTIFIED**
	1. Reduce quantity of waste through recycling. 2. Reduce emissions through composting of waste. 3. Incinerate waste to reduce emissions from landfills. 4. Capture methane from landfills and convert to energy.	a) Recycling technologies. b) Composting technologies. c) Incineration technologies. d) Methane-recovery technologies.

In this study it was not possible to conduct all the steps in the TNA process identified above due to lack of expertise and inadequate financial resources. Only steps 1 through 4 of the TNA process could be considered, discussed, and reported. A more detailed study covering all the steps will be required in the future process of implementation of the UNFCCC in Liberia.

5.2: TNA PROCESS

In conducting the TNA process for Liberia the following steps were carried out:

5.2.1: STEP 1. Identification of Priority Sectors, Adaptation Options, and Mitigation Measures

Step 1 consisted of conducting a desk review of climate change studies, documents, and reports available in Liberia. The purpose of the desk review was to collect data and information on climate-change related programs, projects, and activities existing or planned for implementation in Liberia. Based on this review it was possible to come up with a list of priority sectors with identifiable adaptation options and mitigation measures and the required technologies for addressing climate change in Liberia (Table 5.1). The data and information collected included climate data, sectoral data, energy data, energy and environmental laws and regulations, technical, financial and economic data, etc.

5.2.2: STEP 2. Assessment of the Technologies and Sectors

It was assumed that the identified adaptation options and mitigation measures have already gone through rigorous assessment and prioritization. Therefore in Step 2 there was no need to go through such an assessment of the relevant and associated mitigation technologies. However, in consideration of the barrier analysis in Step 3, it was necessary to consider the social, environmental, economic, and developmental goals of the sectors and the national economy. In that way it was possible to consider some of the factors that may present barriers to and opportunities for the implementation of the identified technologies. For example, it was important to consider the contribution of the technologies to the wider Liberian policy goals of development, climate change mitigation or adaptation, and market potential.

Step 2 required the determination of criteria to be met for the selection of the appropriate technologies. The identified criteria include:

- Highest developmental benefit in terms of value added and improvement of the quality of life for the majority of the Liberian population.
- High market potential in terms of attracting investment and demand.
- High potential to reduce GHG emissions as per the requirements of this TNA.
- Potential to build on existing/on-going national programs already receiving government support.
- Implementation barriers that can be overcome at a reasonable cost.

Adaptation options and mitigation measures for the selected sectors were therefore considered according to the criteria above.

5.2.3: Adaptation and Mitigation Technologies

The technologies identified in Table 5.1 (last column) are described briefly in the following section.

5.2.3.1: Energy-Efficient Technologies

Energy-efficient technologies are employed to achieve energy conservation, cost-effective operations, environmental quality, economic security, and sustainability. These technologies include efficient lighting systems such as compact fluorescent lamps (CFLs) and fluorescent lighting, which produce energy savings relatively easily in residential, commercial, and industrial use. Fluorescent lighting technology (Figure 5.2a, b) uses a gas-discharge lamp that converts electrical power into useful light more efficiently than an incandescent lamp. While larger fluorescent lamps have been mostly used in commercial or institutional buildings, the compact fluorescent lamp is now available in the same popular sizes as incandescent and is used as an energy-saving alternative in homes.

The advantages of fluorescent over incandescent lighting include:

- Fluorescent lamps convert more (about 22%) of the input power to visible light than incandescent lamps (about 2%).
- A fluorescent tube is a more diffuse and physically-larger light source than an incandescent lamp.
- About two-thirds to three-quarters less heat is given off by fluorescent lamps compared to an equivalent installation of incandescent lamps.

Figure 5.2a: Fluorescent and incandescent light bulbs.

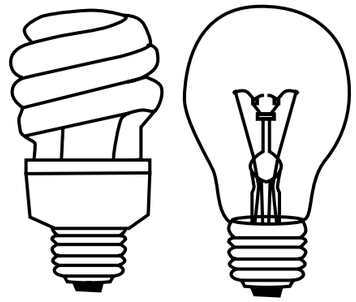
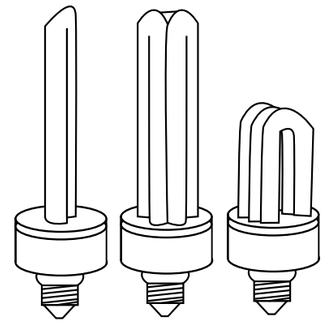


Figure 5.2b: Assorted types of fluorescent light bulbs.



5.2.3.2: Fuel-Efficient Technologies

Only about 15% of the energy from the fuel put into a vehicle tank is used to move the car down the road or to run accessories such as air conditioning. The rest of the energy is lost to engine and driveline inefficiencies and idling. The potential to improve fuel efficiency with advanced technologies is enormous, and these include modern and environmentally-friendly engine and transmission technologies, performance-enhancing and fuel-saving technologies.

5.2.3.3: Solar Technologies

Solar photovoltaic (PV) technology (Figure 5.3a, b) is used to provide electricity in different forms and for various uses. Stand-alone PV systems are usually installed in remote areas where there is no main grid or where it is difficult or impossible to use any other source of power. Solar water-pumps powered by PV offer a clean and simple alternative to fuel-burning engines and generators for domestic water-use, livestock watering, and irrigation. Solar electricity has become an attractive energy source for telecommunications. On a larger scale, solar PV technology is used to power street lighting in many parts of the globe (Figure 5.3c) but particularly in developing countries where the cost of petroleum products is growing beyond the national budget system. A portable PV system can be used as an uninterrupted power supply (UPS) or as a back-up power unit when electrical power is unreliable or subject to outages.

Solar cooking uses a technology that harnesses solar radiation and transforms it into heat energy. The basic principles include the concentration of sunlight, conversion of sunlight to heat, and trapping the heat of the sun. A reliable solar cooker used outdoors (Figure 5.3d, e) has no or little health and environmental effects. Solar PV-powered refrigeration technologies (Figure 5.3f below) provide a complete system for food storage and can cool or freeze food or medicines at required temperatures in remote or emergency locations. These refrigeration technologies include vehicle-mounted 12 V DC refrigerated trailers, vaccine refrigerators, and ice-block machines. These products are ideal for use by grassroots communities and at remote accommodation facilities for government and civil society organizations, aid agencies, mission stations, and relief and disaster response teams.

Figure 5.3a: Solar home system.

Figure 5.3b: Solar water-pumping system.

Figure 5.3d: Sunstove.

Figure 5.3c: Solar street lighting.

Figure 5.3e: Solar cooker.

Figure 5.3f: Solar-powered refrigerator for storage of food and medical equipment.

5.2.3.4: Wind Energy Technologies

Wind power has now become affordable enough to compete with and replace fossil fuels for sustainable and environmentally-friendly power generation. The main technology is the windmill and wind turbines (Figure 5.4a, b), which produce no pollution and even offset pollution. Over its lifetime, a small residential wind turbine can offset approximately 1.2 tons of air pollutants and 200 tons of GHG (carbon dioxide and other gases that cause climate change).

Figure 5.4a: Typical old-fashioned windmill.

Figure 5.4b: Typical wind farm.

Figure 5.5a: Improved cook stove.

Figure 5.5b: Improved Lorena stove.

5.2.3.5: Biomass Energy Technologies

Biomass, a renewable energy source, is biological material from living or recently living organisms such as wood and organic waste. Biomass is also common plant-matter grown to generate electricity or produce heat, and biodegradable wastes that can be burned as fuel.

The improved cook stove (Figure 5.5a, b) is a popular technology that reduces fuel consumption, vents the smoke out of the house through a chimney (thus dramatically improving a family's health), reduces the pressure placed on local forests by reducing the amount of wood consumed, and allows savings in the money spent on wood or charcoal to be translated into more money being available for food, education, and medical care.

5.2.3.6: Bioenergy Technology for the Transport Sector

Biofuels are renewable because the energy they contain comes from the sun. Industrial biomass can be grown from numerous types of plants, including corn, sorghum, sugarcane, and a variety of other tree and plant species, ranging from the jatropha plant (Figure 5.6) to the oil palm. Currently the oil from *Jatropha curcas* seeds is used for making biodiesel fuel, and a hectare of jatropha produces 1,892 liters of fuel (about 6.5 barrels/acre). If irrigated, jatropha will produce seeds year round.

Figure 5.6: Jatropha plant with fruits and jatropha seeds.

5.2.3.7: Irrigation Technologies

Irrigation is used to grow crops in dry areas and during periods of inadequate rainfall. Irrigation technologies differ in how the water is distributed in the field. In general the goal is to supply the entire field uniformly with water so that each plant has the amount of water it needs. The following modern irrigation technologies are efficient enough to achieve this goal:

- Sprinkler or Overhead Irrigation. In sprinkler or overhead irrigation, water is piped to one or more central locations within the field and distributed by overhead high-pressure sprinklers or guns. Guns generally operate at very high pressures and flows of 3–76 L/s, usually with nozzle diameters in the range of 10–50 mm.

Figure 5.7: Overhead sprinkler irrigation system.

Figure 5.8a: Drip irrigation - a dripper in action.

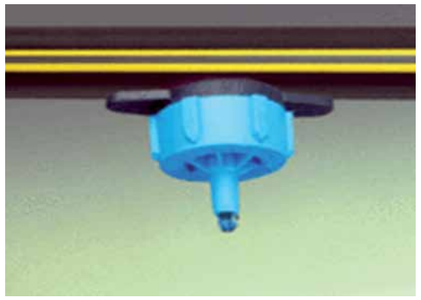


Figure 5.8b: Drip irrigation with black tubes.

- Drip Irrigation. Drip irrigation (Figure 16a, b), also known as trickle irrigation, functions in a way that allows water to be delivered drop-by-drop at or near the root zone of plants. If managed properly, the technology can be the most water-efficient method of irrigation since evaporation and runoff are minimized. In modern agriculture, drip irrigation is often combined with plastic mulch, further reducing evaporation. Recent advances in technology for drip-irrigation installation place the line underground and cover the slit, leaving no soil exposed.

Figure 5.9: Drought-tolerant (left) and submergence-tolerant (right) rice genes from the IRRI.

5.2.3.8: Crop Types and Cultivars

Salt-tolerant crops and plants tolerate salt spray, alkaline soils, and sandy, infertile soils. Liberian soils generally are high in excess soluble salts, alkaline in pH, and sandy with low nutrient-content and poor water-holding capacity. A large percentage of crops is grown in lowland and flood-prone areas. A gene (Figure 5.9) that enables rice to survive complete submergence has been identified at the International Rice Research Institute (IRRI) in the Philippines, and the discovery allows for development of new rice varieties that can withstand flooding, thus overcoming one of agriculture's oldest challenges and offering relief to millions of poor rice farmers around the world.

5.2.3.9: Post-Harvest Technologies

Post-harvest handling is the stage of crop production immediately following harvest. It includes cooling, cleaning, sorting, and packing. The instant a crop is removed from the ground or separated from its parent plant, it begins to deteriorate. But effective handling decreases post-harvest losses (Mrema, C. G. and Rolle, S. R., 2002). Regardless of the scale of harvest, the basic principles of post-harvest handling for most crops are the same:

- Handle with care to avoid damage (cutting, crushing, bruising).
- Cool immediately and maintain in cool conditions.
- Cull to remove damaged items.

5.2.3.10: Food Processing Technologies

Food processing is the set of methods and techniques used to transform raw ingredients into food or to transform food into other forms for consumption by humans or animals either in the home or in the food processing industry itself. Food processing typically takes clean, harvested crops or slaughtered and butchered animal products and uses them to produce attractive, marketable, and often long shelf-life food products. Similar processes are used to produce animal feed. The following are two commonly-used food processing technologies:

- Processing Line: used to produce chips from fresh fruits and vegetables by low-temperature vacuum frying. The chips maintain the original color, flavor, and nutrition of the fruit and vegetable without the use of chemical additives.
- Fruit Juice Extractor: suitable for extracting juice from grapes, tomatoes, and other fruits and vegetables.

5.2.3.11: Food Preservation Technologies

Food preservation is the process of treating and handling food to stop or retard spoilage (loss of quality, edibility, or nutritive value) caused or accelerated by microorganisms. Preservation usually involves preventing the growth of bacteria, fungi, and other microorganisms, as well as retarding the oxidation of fats which cause rancidity. However, some methods use benign bacteria, yeasts or fungi to add specific qualities and to preserve food (e.g., cheese, wine). Preservation also includes processes to inhibit the natural aging and discoloration that can occur during food preparation. Some methods require the food to be sealed after treatment to prevent recontamination with microbes. Other methods, such as drying, allow food to be stored without any special containment for long periods. Common techniques for applying these processes include drying, spray-drying, freeze-drying, freezing, vacuum-packing, and canning.

Figure 5.10: A typical dump site familiar in Monrovia.

Figure 5.11a: Typical groyne system.

Figure 5.11c: Revetment.

Figure 5.11b: Sea wall.

Figure 5.11d: Offshore breakwaters.

Figure 5.11e: Beach nourishment device.

5.2.3.12: Aquaculture

Aquaculture is the farming of freshwater and saltwater aquatic organisms such as fish, crustaceans, mollusks, and aquatic plants under controlled conditions. Particular kinds of aquaculture include fish farming, shrimp farming, oyster farming, and the cultivation of ornamental fish. The commercial farming of fish involves raising fish in tanks, ponds, or ocean enclosures, usually for food. Aquaculture thus has the potential to enhance food security under a changing climate scenario in Liberia. Species raised by fish farms include salmon, tilapia, and catfish.

5.2.3.13: Land-Filling Technology

Gases are produced in landfills (see Figure 5.10 below) from the anaerobic digestion of organic matter by microbes. The gas produced can be collected and flared off or used to generate electricity in a gas-fired power plant, referred to as gasification and considered a mitigation technology (methane recovery) in this report.

5.2.3.14: Composting

Composting has been suggested as a viable mitigation measure and technology in Liberia. The technology converts decomposing organic materials from plant and animal matter into useful, stable products, largely through aerobic decomposition. The process of composting is simple and is practiced by farmers on their land and industrially by industries and cities. Composting requires mechanical sorting of mixed waste-streams to separate biodegradable from non-biodegradable materials. In this way, the biodegradable waste is treated before it enters a landfill and fugitive methane, a potent GHG, is reduced.

5.2.3.15: Coastal Protection Technologies

The following are soft and hard technologies that have been used or can be used to address the climate-change induced sea-level rise and land loss in the coastal zone of Liberia:

- Groynes (Figure 5.11a) are wooden, rock, or concrete barriers or walls built perpendicular to the sea. Where littoral drift is predominantly in one direction, beach material builds on the updrift side of the groyne, creating a wider and more plentiful beach and enhancing protection of the coast as the sand filters and absorbs wave energy. However, there is a corresponding loss of beach material on the downdrift side, requiring another groyne to be built there.

- Sea walls (Figures 5.11b) are made of concrete or rock and are used to protect the shoreline against erosion or flooding. Modern seawalls in the form of sloping revetments aim to dissipate most of the incident wave energy and result in low-reflected waves and reduced turbulence. Sea walls are probably the second most traditional method used in coastal management.

- Revetments (Figure 5.11c) are constructed of upright blockades built parallel to the sea on the coast, usually towards the back of the beach to protect the structures and property beyond. Waves break against the revetments, which dissipate and absorb the energy thus reducing erosion.

- Offshore breakwaters (Figure 5.11d) are constructed by sinking enormous concrete blocks and natural boulders offshore to alter wave direction and filter the energy of waves and tides. They facilitate the breaking of the waves farther offshore and therefore reduce the waves' erosive power. This leads to wider beaches, which absorb the reduced wave energy, protecting infrastructure and property behind.

- Beach nourishment or replenishment (Figure 5.11e) is one of the most popular soft-engineering technologies in coastal defense management. Nourishment involves importing alien sand onto the beach and piling it on top of the existing sand. The imported sand must be of a similar quality to the existing beach material so that it can integrate with the natural processes occurring there without causing adverse effects.

5.2.4: STEP 3 Assessment of Barriers to and Opportunities for Implementation of Technologies

Under Step 3 of the assessment process, the range of potential barriers or obstacles to the promotion and adoption of the identified technologies was examined. The barriers could be generic as well as specific. They could be social, cultural, or regulatory; a lack of access to capital or lack of information. Once the barriers have been identified, the necessary policy measures need to be put in place to lift them. Table 5.2 shows the main barriers to the uptake and penetration of the identified technologies and the policy options needed to lift these barriers.

5.3: CONCLUSIONS AND RECOMMENDATIONS

This assessment of the technologies needed for mitigation of and adaptation to climate change in Liberia has been based on the best available information and expertise. The assessment is not as comprehensive as expected, and this is due mainly to inadequate data, information, and expertise. The list provided in Table

Table 5.2: Main barriers to technology uptake and policy options to lift the barriers.

TECHNOLOGIES	BARRIERS AND OPPORTUNITIES	POLICY OPTIONS
1. Hydroelectricity. 2. Energy efficient appliances, solar, wind, and biomass. 3. Retrofitting electricity transmission and distribution lines and equipment. 4. Solar home systems for lighting and heating. 5. Energy-efficient compact fluorescence lamp. 6. LPG for domestic cooking. 7. Renewable fuels. 8. Photovoltaic panels for electricity generation. 9. Industrial water heaters. 10. Energy efficient lighting equipment. 11. Sprinkler and drip irrigation systems. 12. Improved rice varieties. 13. Post-harvest technologies. 14. Food preservation technologies. 15. Food processing technologies. 16. Aquaculture. 17. Energy-efficient and wood-saving cook stoves. 18. Biogas plant and equipment. 19. Recycling technologies. 20. Composting technologies. 21. Incineration technologies. 22. Methane-recovery technologies.	1. Inadequate or absent systems, tools, data, and information, and inefficient networks. 2. Lack of buy-in and ownership of the process. 3. Non-existence of technology development and diffusion policy. 4. Inadequate human and institutional capacities. 5. High initial-cost associated with some of the technologies. 6. Inadequate knowledge and access to technology information. 7. Inadequate capacities in estimating and certifying environmental benefits, particularly potential GHG reductions associated with the technologies. 8. Interventions distorting markets such as subsidies for polluting industries. 9. Regulated markets that create disincentives for new technologies. 10. Monopoly powers or dominant (oligopoly) interests that reduce incentives to innovate and that erect barriers to new entrants. 11. Split incentives, e.g., situations where investors are not the consumers of more efficient technologies. 12. Where new technologies are capital-intensive, even if operating- and lifetime- costs are low, potential investors may lack the financial resources to bear the upfront cost. 13. Information barriers where, for example, potential purchasers are ignorant of new technology possibilities and/or lack access to technology information. Purchasers may also be faced with multiple and conflicting information and limited ability/time to absorb it, and thus choose a known option in preference to a new alternative. 14. Externalization of pollution costs.	1. Enhance the understanding and knowledge of the public, responsible authorities in the government and business sectors, and development partners about the benefit of the identified technologies to the national economy and the improvement of the livelihoods of the citizenry. 2. Reform or modification of unhelpful regulations and tightening of regulatory standards can remove barriers without any requirement for financial intervention. 3. Modest financial intervention in the provision of information and pilot/demonstration schemes will also remove barriers. 4. Closer cooperation and collaboration between the public and private sectors through, for example, voluntary agreements that reduce the need for new regulation and encourage compliance with modest subsidies that are capable of securing improved financing terms from private lenders and assisting potential purchasers in accessing capital. 5. Internalization of external costs, through carbon taxation, for example, can encourage the uptake of climate-friendly technologies.

5.2 is still too long and needs to be subjected to further analysis and prioritization, despite the fact that it is based on mitigation and adaptation projects already identified in national reports submitted to the UNFCCC Secretariat. Strategies and cost of acquiring the technologies, cost of implementation of the techniques and technologies, benefits of the technologies, and future sustainability of the technologies need to be further assessed. Potential barriers to acquiring and adopting the identified technologies have also been identified in Table 5.2.

Acquisition of these technologies and implementation of the adaptation options and mitigation measures will improve the economy and the wellbeing of the people of Liberia. This will be achieved through the development of appropriate investment, procurement and implementation plans and programs, and will take into account the needs of both women and men.

It is recommended that a detailed independent study be conducted following the full UNFCCC process of development of a TNA including detailed analysis of barriers (technical, social, and economic), costs, and sustainability of the actions. Many of the technologies identified in this study need to be adapted to the social, cultural, economic, and environmental priorities of Liberia. As technology issues are mostly in the hands of the private-sector development partners, efforts should be made to fully engage the private sector of Liberia not only in the identification and adoption of environmentally-sound technologies but also in the broader implementation of the climate change convention in Liberia. To this end, there should be capacity-building activities for training major stakeholders to be engaged in a future TNA process.

CHAPTER → 6

TECHNOLOGY TRANSFER AND DEVELOPMENT

6.1: INTRODUCTION

In Article 4.1, paragraph 1(g) and Article 5, the Climate Change Convention calls on parties to promote and cooperate in research and systematic observation of the climate system, including through support to existing international programs and networks. In doing so, the Convention commits parties to cooperate to improve the capacities of developing countries to participate in research and systematic observation. A key dimension to the implementation of these articles has been cooperation with the Global Climate Observing System (GCOS) of the WMO and with other agencies participating in the WMO's Climate Agenda. The GCOS was established in 1992 to ensure that the observations and information needed to address climate-related issues are made available to all potential users including the UNFCCC. The GCOS addresses the total climate system including physical, chemical, and biological properties, and atmospheric, oceanic, hydrologic, cryospheric, and terrestrial processes.

In 2000 Africa had 155 stations in the Global Surface Network (GSN) and the Global Upper Air Network (GUAN). In the 2001 GCOS report to the Subsidiary Body for Scientific and Technological Advice (SBSTA), only 8% of these stations were classified as "good," i.e., at least 90% of the required reports were received at the relevant monitoring center, and 47% were classified as "silent," i.e., no data were received (FCCC/SBSTA/2001/Misc.9). This situation has not improved and could be deteriorating further. Liberia is a contributor to this problem because of the deplorable status of the country's meteorological and hydrological services, which is mostly a consequence of the civil war.

6.2: CURRENT AND PLANNED RESEARCH AND SYSTEMATIC OBSERVATIONS

6.2.1: Research Institutions and Funding

There are no research institutions on weather, climate, and the environment in Liberia. Therefore, there is no funding.

Table 6.1: Meteorological stations operating in Liberia.

Station Type	Location	METEOROLOGICAL ELEMENTS MEASURED							
Synoptic	Roberts International Airport (RIA)	Wind speed and direction	Visibility	Cloud	Dew -point	Atmospheric pressure	Air temperature	Relative humidity	Rain-fall
Observational station	James Spriggs-Payne Airport	Wind speed and direction	Visibility	Rainfall	-	-	-	-	-

6.2.2: Systematic (Land, Marine, Atmosphere, and Space) Observations

Liberia does not produce marine-based, ocean-based, or space-based observations due to lack of observing networks and stations in this domain.

Land and atmospheric observations are provided by the National Meteorological Service (NMS) of Liberia. The Liberian NMS, one of the earliest in Sub-Saharan Africa, was established in 1952 in the Ministry of Public Works (MPW) and later transferred to the Ministry of Transport (MOT) as a directorate. Other sections dealing with meteorology are spread across other ministries and agencies of the government. Liberia is no exception to the inadequate response of Africa to the provision of atmospheric and earth observations, as currently there are only two meteorological stations operating in the country, as shown in the Table 6.1 below.

6.2.3: Ongoing Programs of the NMS

Meteorological activities in the country are spread across three ministries and two agencies of government. They are:

a) → The MOT, which has three meteorologists and one meteorological technician. There are no observational stations.

b) → The Ministry of Agriculture (MOA), which has no trained staff. An African Monitoring of the Environment for Sustainable Development (AMESD) station was installed at its Central Agricultural Research Institute (CARI).

c) → The Ministry of Lands, Mines and Energy (MLME), which has one meteorologist, two meteorological technicians in on-the-job training, and a manual rain gauge installed by the Liberian Hydrological Service (LHS). Scheduled to be installed or established in 2012 are five hydrometric stations, six rainfall stations, one meteorological training station, and one hydrometric training station.

d) → The RIA, which has one meteorologist, five meteorological technicians-in-training, and three additional meteorological technician trainees. There is no ICAO/WMO-certified or -trained weather forecaster. The RIA is equipped with:

i) *One Automatic Weather Observing Station (AWOS).*
ii) *An outdated Aeronautical Message Processor System (AMPS) for transmitting and receiving weather information for aviation globally using an Aeronautical Fixed Telecommunications Network (AFTN) system. This system has been replaced by the Aeronautical Message Handling System (AMHS) at RIA.*
iii) *An MSG-PUMA station has been upgraded to PUMA Synergie.*
iv) *An obsolete Stevenson Screen containing dry and wet bulb thermometers as well as maximum and minimum thermometers. It needs to be replaced.*
v) *One manual rain gauge.*

e) → The Liberia Domestic Airports Agency (LDAA) that has one meteorologist and three meteorological technicians being trained on-the-job. The agency has one wind vane for measuring wind direction and speed and one manual rain gauge.

The Liberian NMS currently has insufficient technical and support staff. As of 2011, there were only six meteorologists backed by fourteen meteorological technicians. The NMS also has no centralized or well-managed database, and data rescue services are not available either. Although some data could be traced as far back as 1928, most of these records were either misplaced or totally lost as a result of the long civil war. As far as data collection is concerned, observation stations are still not dense enough and are unevenly distributed. Most of the collected data are processed and provided on a non-real-time basis, and the observation equipment is already old, has exceeded its life span, and needs to be replaced.

Draft legislation for the establishment of a National Meteorological Agency (NMA) has been validated by stakeholders and sent to President Ellen Johnson-Sirleaf for review and submission to the Legislature for enactment into law. The NMA would be responsible for the monitoring and systematic observation of the atmosphere and the provision of weather and climate information and services. In November 2009 the GOL through the MOT requested the WMO to assist in the preparation of a national development/strategic plan and project proposal to serve as a roadmap for the proposed NMA. In response the WMO sent a mission to Liberia for four weeks (November 9–December 8, 2009) and carried out a comprehensive assessment of the meteorological services of Liberia. A national development/strategic plan and project proposal was prepared in May 2010. Key elements of the plan include:

a) → Human resources training.

b) → Establishment of weather- and climate-observing stations.

c) → Acquisition of communication, data processing/management, and weather forecast dissemination facilities.

d) → Upgrading of the unserviceable MSG-PUMA station in a project funded by the European Union (EU) through the European Organisation for the Exploitation of Meteorological Satellites (EUMETSAT).

e) → Installation of the AMESD Station-EU funded project through EUMETSAT.

f) → Establishment of a Central Forecasting Office (CFO).

g) → Establishment of an effective Early Warning System (EWS).

h) → Participation in the WMO GCOS Program.

Through the African Union (AU) Commission, EUMETSAT has installed one satellite receiving station in Liberia in the second quarter of 2011 under the AMESD program. The satellite receiving station under the PUMA project which was installed at the RIA in September 2005 has been upgraded. The overall objective of the AMESD program is to enhance monitoring, preparedness, and adaptation to environmental change, including sustainable management of the environment that would alleviate poverty. The AMESD program increases the information-management capacity of African regional and national institutions in support of decision makers at different levels and facilitates sustainable access to Africa-wide environmental information derived from earth observation technologies. The AMESD program is being funded by the European Commission through the European Development Fund and is managed by the AU Commission. In addition, the Norwegian government through the MLME is funding a project to upgrade hydrometric and rainfall stations.

6.2.4: Planned Programs of the NMS

Research and Observation

Currently there are no organized or coordinated programs on meteorological, hydrological, and climate research and observation in Liberia. Only fragmented and limited services are available. Reasons and constraints being put forward include inadequate training and observation networks, as well as inadequate or non-existent weather and climate research, data processing and management facilities, instruments and equipment, public weather services, and early warning systems.

Under the Spain-WMO Voluntary Cooperation Programme (VCP), Liberia is expected to receive technical assistance from the Spanish state meteorological agency, Agencia Estatal de Meteorología (AEMET), to train 200 farmers and establish ten rainfall stations throughout the country. Through the program, a selected focal point/person will participate in a Training of Trainer (TOT) seminar at one of the WMO Regional Training Centers in Africa to enable him/her to conduct the training of the 200 farmers. The GOL has already received 200 rain gauges and 200 stickers under the program. The objective of this assistance is to enhance Liberia's agricultural production and food security.

Under a memorandum of understanding between the WMO and AEMET signed in July 2007, a marine meteorology project was designed for West African coastal countries including Liberia. Currently the project is being implemented in four countries—Senegal, Gambia, Cape Verde, and Mauritania—as a pilot program that is expected to be extended to rest of the coastal countries of West Africa. The overall objective of this marine meteorology project is to enhance the capacity of the National Meteorological and Hydrological Services (NMHSs) of West African coastal countries and provide them with the tools to develop sustainably and deliver products and services to socioeconomic sectors related to marine activity.

Early Warning Services

There are plans to establish an effective EWS in the country to issue early warning messages and advisories on extreme weather events such as floods, mudslides, droughts, extreme temperature, and precipitation. The proposed EWS is expected to provide timely and effective information through identified institutions, allowing individuals exposed to hazard to take action to avoid or reduce their risk and prepare for effective response. An EWS requires the integrated documentation and utilization of the following four components:

1.→ **Risk assessment** to generate maps and provide essential information for setting priorities for mitigation, preparing and implementing prevention strategies, and designing the early warning system.

2.→ **Monitoring and predicting** to provide timely estimates of the potential risk faced by communities, economies, and the environment. Hazard monitoring and prediction services are developed and utilized to support the generation of accurate and timely warnings based on sound scientific information.

3.→ **The dissemination of early warning information**, using effective communication systems, to alert local and regional government agencies in potentially affected locations with messages that are reliable, synthetic, and easily understood by authorities and the public.

4.→ **Building effective national and subnational response systems** by enhancing public awareness and education and developing and regularly updating response plans.

Failure in any one part means failure of the whole system.

Provision of Forecasts, Warnings, and Advisories

The existing forecasting technology in Liberia is quite limited, but it enables the NMS to issue warnings on significant meteorological phenomena such as flash floods, thunderstorms, and windstorms. However, the technology for data processing, quality control, and archiving is old and ineffective and needs upgrading. Most forecasting results do not meet the increasing demands for disaster prevention and preparedness or for sustainable socioeconomic development.

The three methods of seasonal forecasting include statistical, dynamical, and statistical-dynamical.

In the statistical method, forecasts are based on empirically determined linkages within the climate system. The four approaches to a statistical forecasting method include persistence, trends, cycles, and relationships between atmospheric variables. All of them assume that future conditions can be extrapolated from historical conditions and information.

The dynamical method is a process based on the solution of a set of mathematical equations governing the atmospheric state to give the future state of the atmosphere. It refers to models that use time-dependent relationships between atmospheric variables to extrapolate future states. The equations are solved using an approximate solution technique called numerical modeling. The basis of the dynamical method is Numerical Weather Prediction (NWP).

The combined dynamical-statistical method is a hybrid model designed to improve the results.

Forecasting is conducted in the following four temporal scales:

a) → Now-casting refers to forecasting limited to a few hours (e.g., two to six hours).

b) → Short-range forecasting refers to forecasting longer than a few hours but less than three days.

c) → Medium-range forecasting refers to forecasts that last between three and fourteen days.

d) → Long-range forecasting refers to forecasts exceeding fourteen days.

6.2.5: Gaps and Barriers in the Provision of Systematic Observations

There are several gaps in the provision of systematic observations that must be addressed. These include:

a) → No national institution/entity designated for the monitoring and systematic observation of the atmosphere and for the provision of weather and climate information and services.

b) → No national development/strategic plan and/or project proposal for the development of the meteorological sector prior to May 2010.

c) → Only two existing meteorological stations, which are not measuring all parameters.

d)→ No data processing and forecasting facilities.

e) → No public weather services.

f) → No public education and awareness on weather and climate.

g) → No EWS.

h) → No communication facilities or links.

i) → No Information and Communication Technology (ICT) facilities for data processing.

j) → Inadequately-trained human resources.

k) → No participation in the GCOS program of the WMO.

l) → No link to the Global Telecommunication System (GTS).

m) → No participation in the WMO Data Rescue (DARE) program.

n) → Inadequate data-processing instruments and equipment.

o) → No support for atmospheric research.

p) → No technology transfer.

To address the gaps and deficiencies in trained human resources caused by the prolonged civil war, the institutions needing capacity building and the number of individuals they require are indicated in Table 6.2 below.

Table 6.2: Institutions and number of individuals required for capacity building.

Institution	Number of Individuals
Ministry of Transport	30
Ministry of Agriculture	20
Ministry of Lands, Mines and Energy	25
Environment Protection Agency	5
Roberts International Airport	20
Liberia Domestic Airports Agency	40
National Port Authority	13
Forestry Development Authority	10
Liberia Maritime Authority (formerly Bureau of Maritime Affairs)	10
TOTAL:	173

The barriers encountered in the provision of systematic observations include:

a) → Fragmented and limited services for meteorological/climatological and hydrological activities.

b) → No policy or legal framework.

c) → No budget support.

6.2.6:Development of Research and Systematic Observations

Development of research and systematic observation in Liberia would require the following:

a) → Establishment of a thorough policy/ legal framework and a national institution/entity responsible for the monitoring and systematic observation of the atmosphere and the provision of weather and climate information and services.

b) → Implementation of the five-year national development/strategic plan and the two-year project proposal prepared by the WMO for the development of the meteorological sector in the country.

c) → Establishment and maintenance of representative observational networks for continuous monitoring of weather, climate, and the environment.

d) → Development of IT/ICT facilities and establishment and maintenance of data processing and forecasting facilities.

e) → Establishment of public weather services.

f) → Institutionalization of public education and awareness on weather and climate.

g) → Establishment of an effective EWS.

h) → Establishment of communication facilities/links (i.e., the GTS).

i) → Development of an optimum critical mass of human resources.

j) → Participation in the GCOS program of the WMO.

k) → Participation in the WMO DARE program.

l) → Support for atmospheric research (i.e., weather and climate).

m) → Acquisition of data processing instruments and equipment.

n) → Transfer of new technologies.

6.3: IMPROVING THE NMHS

6.3.1: Improving Service Delivery

As the impacts of weather-related hazards continue to unfold, there will be increasing demand for accurate and timely weather and climate forecasts and other relevant hydrometeorological information for public safety and planning purposes. To address these demands, Liberia needs to improve and expand its meteorological service to meet the emerging needs of the various economic sectors. It is therefore urgent to put in place the basic requirements for these services to function effectively. The basic requirements are enumerated as follows:

a) → Adequate networks of stations to monitor meteorological parameters.

b) → A robust communication system for data transmission, dissemination of forecasts, and sharing of information with sister agencies in other countries, particularly in the West African subregion.

c) → High-speed computing systems for data assimilation and numerical weather prediction for early warnings.

d) → Personnel equipped with appropriate training and skills.

e) → Close interaction with users of weather and climate information.

The transboundary nature of severe weather phenomena also requires closer collaboration for enhanced data-sharing among meteorological services in the subregion through the GTS of the WMO. Improved observing/ monitoring systems could provide reliable data to produce customized, accurate, and timely forecasts of great value to the various sectors and promote sustainable economic development.

6.3.2: Upgrading the Facilities of the NMHS

The Liberian NMHS needs to be transformed into a fully fledged agency to enable it to perform its mandate of advising the GOL on climate and weather issues that have a critical impact on the socioeconomic development of the country. All sections of the NMHS which were moved to other government ministries or departments need to be retrofitted back into the service in line with international best practices. The NMHS needs to be assisted to gain the ISO 9001 certification required by the WMO Quality Management Systems (QMS) for the provision of weather information. Such assistance would cover the following areas:

a) → Communication systems.

b) → Data management and Geographic Information System (GIS).

c) → Meteorological observation network for surface, upper air, and marine data.

d) → Hydrological observation network.

e) → Maritime observation network.

f) → Remote sensing network.
1. *Upper air observations (radiosondes, wind profilers).*
2. *Weather radars.*
3. *Weather radar operation and maintenance.*
4. *Satellite receiving stations including imagery from polar orbiters.*
5. *Low Level Windshear Alert Systems (LLWAS).*

g) → Forecasting tools.

h) → Training of additional personnel (meteorologists, IT personnel, climate change experts, etc.) to the required WMO qualifications.

In addition, the Liberian NMS needs to be institutionally and technically capacitated to fully meet its mandate, particularly its terms for provision of services to other sectors of the economy as shown in Table 6.3 below.

6.4: RECOMMENDATIONS

In addition to sections 6.4.1 and 6.4.2, the following actions are recommended:

a) → There is an urgent need to increase human capacity in the Liberian NMS.

b) → Observation stations which were affected during the war need to be refurbished and new ones set up to increase the network density.

c) → A substantial amount of good climate data was lost during the civil war, and efforts should be made to recover some of these lost data.

Table 6.3: Major services to be provided by the NMS to other sectors of the Liberian economy.

FOOD SECURITY (AGRICULTURE AND FISHERIES)	FORESTRY	WATER AND ENERGY RESOURCES		TRANSPORT	CONSTRUCTION	LAND USE AND PLANNING
Provide more accurate ten- to fifteen-day forecasts and long-term seasonal forecasts (up to six months). Issue frequent forecasts to the general public, particularly on the situation over the river basins in Liberia. Issue marine forecasts to support the fishing industry. Provide accurate and reliable forecasts for maritime traffic..	Establish meteorological observation stations in forest areas to facilitate monitoring. Provide near real-time data on critical parameters (including soil humidity). Conduct modeling and provide forecasts of fuel load in forests. Provide forecast information on dispersion of smoke from bush fires. Assess the impacts of climate change on the forest sector.	Provide historical data and observations for modeling of solar radiation for planning and development of energy production Provide accurate site-specific weather forecasts for estimation of energy consumption and optimization of power production. Provide wind data for assessment of wind energy potential and for risk mapping. Share hydrometeorological data for transboundary and international cooperation.		Enhance cooperation and dialogue with subregional NMS to enable exchange of data relevant to the transport (road, water, and air) industry. Monitor river discharge and water level and provide needed forecasts on potential flooding. Provide real-time data, forecasts, and warnings specific to transport (road, air, and water), particularly on precipitation, fog/mist, hazy conditions, and cloud cover.	Provide site-specific weather outlooks and forecasts to enable effective construction planning and execution. Provide historical meteorological and hydrological data and information needed by the construction industry. Improve the quality and dissemination of data information to the industry.	Provide long-term data series on climate variability and change. Integrate climate change in land-use policies, plans, and programs.

INSURANCE	HEALTH	AIR QUALITY		DISASTER RISK REDUCTION	MEDIA
Provide site-specific data and information on weather phenomena concerning claims (e.g., use high resolution models and new observation technology). Provide long-term historical data for risk evaluation.	Provide improved forecast on high temperatures and air quality. Provide statistics on air quality, warnings of poor air quality, and flood forecasts.	Provide data and information on meteorological conditions of dispersion and dispersion modeling. Monitor transboundary transportation of airborne pollutants. Monitor urban air quality. Establish a national database for air quality measurements. Provide forecasts and warnings on air quality.		Provide more accurate and frequent site-specific and general weather and hydrological forecasts. Establish a database on weather- and climate-related disasters. Improve flood forecasting systems. Improve communication systems for timely dissemination of forecasts. Provide outlooks and predictions on drought incidences. Create and provide inundation and flood hazard maps. Monitor water level as well as water quality.	Conduct sensitization and public awareness campaigns to increase understanding and awareness of meteorological and hydrological events and their relationships with the livelihoods of the population. Enable media access to real-time data, warnings, advisories, and forecasts for dissemination to the public. Facilitate the media in providing required services to the public.

CHAPTER → 7

EDUCATION, TRAINING, AND PUBLIC AWARENESS

7.1: INTRODUCTION

Implementation of the Climate Change Convention at the national, regional and international levels hinges heavily on creating and improving education, training, and public awareness and understanding of climate change issues. The UNFCCC, through its Article 6, and the Kyoto Protocol, through its Article 10(e), calls on all governments to educate, empower, and engage all stakeholders and major groups on policies relating to climate change. In particular, Article 6 of the convention, which addresses the issue of climate change-related education, training, and public awareness, is the main vehicle through which the convention fosters action to develop and implement educational and training programs. The international community is encouraged to cooperate in scientific and technical research, promote the development and exchange of educational and public-awareness material on climate change and its effects, promote the development and implementation of education and training programs including the strengthening of national capacity building, in particular human and institutional capacities, and facilitate at the national level public awareness of and access to information on climate change. Many governments and intergovernmental organizations are already working in partnership with various stakeholders, particularly civil society and the media, to fulfill the commitments in Article 6. However, the scale of challenges posed by climate change requires outreach activities of a greater magnitude.

The primary laws regulating and facilitating the education and training sector of Liberia are the 1986 Constitution, the Education Law of A.D. 2001, and the 1989 National Commission of Higher Education Act establishing the National Commission of Higher Education (NCHE). Articles 6 and 15(b) of the 1986 Constitution pronounce the right of citizens to education. Article 6 specifies that "[t]he Republic shall … provide equal access to educational opportunities and facilities for all citizens to the extent of available resources. Emphasis shall be placed on the mass education of the Liberian people and the elimination of illiteracy." Article 15 (b) grants individual citizens "the right to knowledge." The Ministry of Education (MOE) interprets "the right to knowledge" as being "the right to education." The Education Law of A.D. 2001 was passed in January 2002, repealing the Education Law of 1972 and all amendments to it. The 2001 law, which is divided into five chapters, has a number of shortcomings and is in the process of being restructured and revised to reflect present-day realities. The NCHE was established in 1989 to formulate broad policy guidelines for the establishment of institutions of higher education; to monitor, evaluate, and accredit all institutions of higher learning; to approve new and existing programs of higher education for funding according to national needs, and to review existing programs with the aim of establishing priorities based on national needs.

Accordingly, the GOL, through the MOE and its development partners, are making every effort to provide all Liberians with the opportunity to access and complete affordable education of a quality, relevance, and appropriateness that meets their needs and that of the country. The democratically-elected government which took power in 2006 established a framework for implementation of the 2001 Education Law, which called for free and compulsory primary education. The Liberia Primary Education Recovery Program (LPERP), which also informed the education components of the Liberia Poverty Reduction Strategy (PRS) of 2008, set out to create accessible quality education at the primary level.

While LPERP goals and PRS deliverables have focused on the primary subsector, the implementation process has strengthened the coordination between the MOE and its donor partners, strengthened MOE planning and management systems, provided a platform for inter-ministerial collaboration for educational development, and created an environment for a sector-wide approach.

Following a joint sector review with a broad range of national and international education partners, the Education Sector Plan (ESP) of Liberia has been ratified through an extensive process of national consultations. The consultations also ensured that education leaders at the county, district, and community levels have a role in shaping the policies and programs they will implement. The ESP is fully aligned with the PRS, and further sharpens the MOE's focus on interventions across the education sector.

7.2: EDUCATION, RESEARCH, AND PUBLIC AWARENESS IN LIBERIA

It is acknowledged that in this complex and technologically orientated world, access to knowledge is a key driver of social and economic development and that Higher Education Institutions (HEIs) play key roles in the production and dissemination of knowledge. In addressing faculty, staff, students, and guests at the University of Liberia (UL) in 2009, President Johnson-Sirleaf emphasized the university's role in national development and stressed her expectation of the university's key leadership role in providing research and analytical inputs to post-war reconstruction and rehabilitation efforts of the country. The fourteen-year civil war led to a massive brain drain of highly qualified faculty and staff that resulted, for example, in a drastic reduction at one unit of the UL from 27 PhDs and 24 MScs to 2 PhDs and 4 MScs (AASCU, 2007).

In 2000 the GOL established the NCHE. According to the Education Law of A.D. 2001, higher education encompasses all educational programs and institutions above the senior secondary (senior high) level. In Liberia these include junior colleges, community colleges, polytechnics, theological schools, seminaries, and universities. The main goal for higher education in Liberia is better regulation and monitoring while ensuring an improvement in the quality and relevance of programs as well as the institutions of higher learning. Linked with this is the development of the research capacity of universities. The specific policy objectives for higher education are the improvement of the regulatory and governance mechanisms, the funding mechanisms, and the quality of the teaching faculty; the establishment of mechanisms that result in programs and research relevant to the needs of the society, and the reduction of inequities in access to higher education.

In the short and medium terms, the national strategy for higher education aims to strengthen the capacity of the NCHE, provide strategic and relevant courses and programs at universities, enhance research capabilities, improve the quality, competence, qualifications, and relevant experience of teaching faculty at institutions of higher education; establish networks between foreign universities and national institutions with a view to setting up program improvement and faculty training and exchange arrangements; and develop partnerships in the funding of higher education.

The oldest public HEIs in Liberia are the UL, Cuttington University, and the William V.S. Tubman College of Technology (WVSTCT), now known as Tubman University (TU). These institutions had the mandate for training and research. The number of HEIs has increased significantly in the last few years from three to 26. The new HEIs are primarily private institutions and include universities, colleges, community colleges, theological seminaries, and polytechnics. However, the supply of HEIs is limited to Monrovia and other large towns. Therefore, as a way of extending access to densely populated but under-served regions, the MOE has recently approved the establishment of five new middle/community Colleges (later to become fully fledged universities) in Lofa, Nimba, Grand Bassa, Grand Gedeh and Bomi counties (MOE, 2009). In addition, the government plans to reconstruct and expand the institutional capacities of UL and TU, the flagship public institutions (MOE/ESP, 2009).

One of the important roles of HEIs is producing good quality and relevant research. While the government acknowledges that research is an important role for higher education, research capacity in most HEIs, particularly at UL, has significantly diminished (AASCU and MOE, 2007; PRS, 2008). Furthermore, many of the newer private higher education institutions are teaching institutions where lecturers conduct little or no research. The government is considering supporting research and researchers by instituting a research fund to encourage quality research from HEI faculties. The challenges facing HEIs include a limited number of qualified instructors, outdated curricula, limited library and laboratory resources, socioeconomic and regional inequities in access, weakened governance and quality assurance mechanisms, and weakened capacity to mobilize adequate resources, i.e., funding, human, technology, and equipment.

During the consultations that led to the development of the ESP of 2009, the main views expressed relative to strengthening of research included the need to establish a college/university for every four to five counties, correlate university and college programs to labor and market requirements, encourage the establishment of college and university internships at private and public enterprises, encourage the establishment of technical and vocational education and training (TVET) programs at universities,

institutionalize visiting professorship programs at universities while more professors are being trained, and facilitate the admission of more women to universities.

7.3: TERTIARY EDUCATION AND INSTITUTIONS

There is no institution in Liberia that offers climate-change education or research programs. However, the UL, serving as Liberia's oldest public HEI, offers programs on the environment. The UL is a publicly funded institution of higher learning located in Monrovia, Liberia. Authorized by the national government in 1851, the school opened in 1863 as Liberia College and became a university in 1951. The UL has six colleges, three professional schools, and three graduate programs with a total of approximately 18,000 students at its three campuses in and around the country's capital city.

One of the UL colleges is the T. J. R. Faulkner College of Science and Technology where one may study the traditional natural sciences and obtain a bachelor's degree in biology, physics, applied mathematics, etc. However the range has extended greatly in the past decades, and there are now opportunities to obtain a bachelor's degree in environmental science, for example, which incorporates the areas of geography, environmental science, chemistry, biology, earth science, and physics, and may also include the study of maths and statistics to understand measurements and data. One may even incorporate a year of law in order to better understand areas such as environmental protection.

The MOE, responsible for education and training programs in Liberia, has not incorporated climate change into its education curricula. However, climate change issues are presented within the broad educational framework of sustainable development. At the higher-education level, environmental protection issues including climate change are addressed in the training programs of the University of Liberia (UL) College of Agriculture and Forestry. In addition, climate change-related programs are enshrined in the curricula of the Department of Geography in the College of Social Science and Humanities at the UL.

The world of science, along with traditional disciplines such as physics and biology, has broadened

The UL campus in 2009.

Fendell campus.

significantly in the last two decades or so. This is reflected in master's programs as well, and one such new discipline at UL is analytical science, which may include modules such as Principles of Analytical Science, Advanced Separation Science, Advanced Mass Spectrometry, and Novel and Emerging Technologies, with a research project. This master's program typically leads to further doctoral study, laboratory-based research, or other science-related careers.

In addition to schools and departments of study, UL, which is a member of the Association of African Universities (AAU), also houses several institutes including the Institute for Research and the Center for Millennium Development Goals.

7.4: PUBLIC EDUCATION, SENSITIZATION, AND AWARENESS

7.4.1:Education and Outreach Unit of the Environment Protection Agency

As a commitment to the environment, the GOL established the Environment Protection Agency (EPA) in 2003, and the agency became a fully functioning entity in 2006. Through the Environment Protection Agency Act, the agency is mandated to protect the Liberian environment by implementing policies that ensure the long-term economic prosperity of Liberia through sustainable social and economic development—meeting the needs of the current generation without compromising the potential of future generations. The EPA is the principal authority responsible for implementing national environmental policy and sustainable management laws for the protection of natural resources in Liberia.

Since its establishment in 2003, the EPA has made significant and visible progress in building Liberia's environmental governance framework. This progress includes:

1 → Publication of Liberia's first State of the Environment (SOE) Report in June 2006, which established a baseline for monitoring environmental conditions and trends.

2 → Deployment of environmental inspectors at the county level beginning in 2007.

3 → Establishment of a basic environmental laboratory facility at the EPA to help monitor environmental conditions and trends and enforce legislation.

4 → Establishment of environmental units in some government ministries and agencies.

5 → Development and implementation of Environmental Impact Assessment (EIA) administrative procedures.

6 → Establishment and operationalization of the certification of environmental consultants for conducting environmental impact assessments.

7 → Development of a National Biodiversity Strategy and Action Plan (NBSAP).

8 → Active participation in multilateral environmental agreements (MEAs) on climate change, biodiversity, and desertification; regional cooperation initiatives, and projects supported by the Global Environment Facility (GEF).

9 → Preparation of a national action plan and strategy to address land-based sources of marine pollution.

10 → Development of a National Adaptation Programme of Action (NAPA) for climate change and implementation of projects identified therein.

11 → Development of a dedicated website to improve access to environmental data and information and contribute to the implementation of Article 6 of the UNFCCC and Article 10 of the Kyoto Protocol.

7.4.2: Priorities in Education, Training, and Public Awareness for Improving the National Communication (NATCOM)

Before the GHG inventory was done, the EPA financed a study titled "Technologies and Measures for Mitigation of Greenhouse Gas Emissions." The report highlighted the dire need for human resource training because of the lack of trained personnel. Focus on education, training, and public awareness should be as indicated in the following Table 7.1.

7.4.3: Mass Media and Public Awareness

Media Policies and Regulatory Frameworks

The legal and regulatory frameworks governing the media are generally moribund and not on a par with international best practices, though there have been efforts since 2003 to review and reform the country's media laws and policies to suit international standards (PMCPWA, 2007). The absence of a national communication policy has slanted the flow of information from the government to the media and from the media to the public.

Table 7.1: Suggested interventions in education, training, and public awareness.

EDUCATION/TRAINING	PUBLIC AWARENESS	RESEARCH
Periodically train and retrain national experts on the assessments required for the NATCOM process.	Increase public awareness on climate change through dramas, jingles, town hall meetings, spot messages, street theaters, radio and TV talk shows. Translate key messages into local vernaculars using town criers, community performances, printing of billboards and flyers with key messages in simple Liberian English, and use the print media to inform a wide range of people about the requirements of the country for implementing the	Provide recurrent funding from the national budget for government institutions obligated to carry out specific research and assessments to fill the data and information gaps in the NATCOM process.
Review and revise college and university curricula, establish degree programs, and train lecturers on climate change to improve the critical mass of climate change specialists in Liberia.	Climate Change Convention. Institute the quarterly publication of an EPA newsletter to create awareness on climate change, particularly on in-country and regional emerging climate change issues. This will require the EPA establishing networks and links with national and regional websites such as UNEP, UNDP, CDKN, UNISDR, etc.	Fund and conduct more research on themes that need to be understood for the completeness of the NATCOM development process including projection of GHG emissions, development and costing of mitigation and adaptation measures, modeling for scenario development, and biophysical simulation of impacts of climate change on critical economic sectors.
Train and retrain media personnel, civil society organizations (NGOs, CBOs, etc.), and extension agents about the environment and climate change and about methods of communicating climate change issues to the public, particularly to local communities and policy makers.	The EPA should forge closer working relations with special and key stakeholders whose sectors are major contributors to global warming and climate change. These sectors include energy (electricity and transport corporations including driver unions, civil aviation, maritime, and the Liberia National Police [LNP]), waste management (municipalities and industries), and others. The objective is to create awareness of their contributions to climate change and how to address the negative impacts on the national economy.	Conduct research on how the media can effectively disseminate environmental information related to GHG.

The Ministry of Information, Culture, Arts and Tourism (MICAT), is under-resourced and lacks the technical capacity to perform a number of its core functions. In addition there are conflicting responsibilities among departments dealing with the media—namely, the MICAT), the Ministry of Posts and Telecommunication (MOPT), and the recently established Liberia Telecommunications Authority (LTA). With an annual budget of less than L$1 million, most of the MICAT)'s work has been reactionary and concentrated in the capital of Monrovia.

In 2004 efforts were started to review the legal framework governing the media. The goal was holistic reform. Under the direction of the Partnership for Media and Conflict Prevention in West Africa (PMCPWA), the relevant stakeholder groups, including the Ministry of Information, Cultural Affairs and Tourism (MICAT), were urged to better articulate and define a new media policy and legal framework. The purpose of this comprehensive and consultative legal and institutional reform process was to gather and codify the laws and statutes used in regulating the media and to engender a free and productive environment.

Subsequently in October of 2004, a National Conference on Media Law and Policy Reform was convened in Liberia. The initiative led to the drafting of two bills: the Freedom of Information Act and a Broadcast Regulatory Act. A third law to transform the Liberia Broadcasting Service (LBS) from a state broadcaster into a public service broadcaster had already been commissioned by the Liberia Transitional Initiative. All three bills have been validated and enacted by the Legislature.

Mass Media Houses of Liberia

There are three organized media groups in Liberia. These are the Liberia Media Center (LMC), the Liberia Media Initiative for Peace, Democracy and Development (LMI), and the Center for Media Studies and Peace Building (CEMESP).

The LMC, a joint initiative led by the Press Union of Liberia (PUL) and the PMCPWA, was established in 2005 as a center of professional excellence to advance the growth and development of independent, plural, and mass media in Liberia. It assists media and civil society with professional services in a wide range of areas including research, training, outreach, and mass communication. Operating within the wider context of enhancing citizens' access and right to information, protection, expansion, and free expression, and promoting an accountable, responsible, professional, and sustainable media, LMC has diligently stood up to the challenge of fulfilling this responsibility since its founding.

The LMI also advances professionalism in the media industry by providing training to both community and national radio outlets. It has partnerships with thirty community radio stations across the country and five national radio stations based in Monrovia. The LMI is currently partnering as the communication arm with Fauna and Flora International (FFI) and the REDD Technical Working Group.

CEMESP, for its part, facilitates the growth of free expression by annually providing information about attacks on the media and freedom of speech. It also does research on media and media-related issues and provides regular training to journalists

Radio is by far the cheapest source of information for the people and has a huge potential for fulfilling key development goals. As most Liberian people listen to the radio daily, radio has deep penetration and reach in the country. There is massive consumption and demand for news and information in Liberia, and a viable public service broadcaster could fill the information void. Community-based radio stations are growing professionally and provide a good platform for information delivery and feedback to people living in rural Liberia. However, even with the proliferation of radio, the vast majority of rural Liberians still receive little content, if any at all. Most community-based media reach no farther than a 40–50 km radius due to a number of factors including but not limited to transmission strength, population distribution, and geographical settings. Additionally, there is a low incidence of self-generated content and high incidence of music, syndicated tapes, rebroadcasts of national and international programs, etc.

The newspaper industry has a poor penetration level even in the most urban areas. Poor distribution and circulation and lack of diversity in content are responsible for low consumption of print media products, evident in the surge in readership of internet-based newspapers. Papers were devoting a good number of pages to advertorial. Illiteracy and poverty are also high-ranking issues affecting print media circulation, and this situation could well continue without significant improvement in the overall socioeconomic conditions of the country. The rather small media market has denied the newspaper industry the required revenue to develop, and unless serious investment is made, standards and ethical issues associated with the print media will remain huge challenges for a long while.

Television was introduced into Liberia in 1964 by the Liberia Broadcasting Corporation (LBC), previously known as the Eternal Love Broadcasting Corporation (ELBC), which created ELTV. The LBC was privately owned by a British company, Rediffusion, until 1968 when management passed to the GOL. Up until 1990, the government-run ELTV was the sole television station in the country. However, during the 1990s independent commercial television came into being, with DC TV as the first. DC TV, owned by Ducor Broadcasting Corporation, began televising in 1996. This was followed by Liberian Communications

Network (LCN) TV in 1997, privately owned by then-president Charles Taylor. Television has a stronger reach and penetration in urban areas, especially areas with stable electricity, and could be a strong vehicle for advancing climate change issues. However, ownership of televisions still remains out of the reach of most, as prices are high and electricity scarce. Most local stations are dominated by foreign content, entertainment especially, and access to the medium outside the capital is primarily for entertainment. Foreign television channels (DStv, etc.) are growing in numbers and could eclipse domestic programming if local content-generation by TV stations is not improved.

The cellular phone revolution in Liberia began with the entry of ICOM in 1999. This was quickly followed by Atlantic Wireless, now the Libercell network; Lonestar Cell in 2001, Comium Liberia, and Cellcom. Since then cellular phones have grown rapidly in numbers and hold promising potential for driving development and democracy agendas. With huge potential for growth in local markets, cellular phone use could accelerate development even in the most remote areas if issues of cost and accessibility are addressed. The widespread use of cellular phones has a strong potential for enhancing access to information and promoting grassroots platforms since they are common amongst low-income earners and even the poor. Use of mobile phones prevails in all fifteen counties and major districts in Liberia, and strong competition between providers could open more space for access to information. These rapid developments required the LTA to develop and implement a new licensing regime.

According to the LTA, the major Internet Service Providers (ISPs) in the country are Comium, Cellcom, Consolidated Groups, and Power Tech. Most users rely on access to the Internet through public cyber cafes, but more people could have access if subscription prices were reduced. However, the Internet is scarcely available in most rural areas and some peri-urban areas, and purchasing power is lowest in areas with least access.

Some national and international Internet sites that carry Liberian news including information on the environment are:

- Allafrica–Liberia, a site based in Washington, D.C., USA, http://allafrica.com/liberia/
- Daily Observer, based in Silver Spring, Maryland, USA, http://www.liberianobserver.com/
- Liberian Heritage, http://www.liberianheritage.com/
- The Liberian Times, produced by Lonestar Liberia, based in New York City, USA, http://TheLiberianTimes.com
- The Liberian Collections at Indiana University, Bloomington, IN, USA, http://www.onliberia.org/
- Topix–Liberia, http://www.topix.net/world/liberia
- Environmental news from UNEP, www.unep.org/

There is no national television coverage. Newspapers and other media (excluding new media sources like cell phones and satellite television channels) reach no farther than 100 km from the capital. A number of research studies on citizens' access to information attest to this situation.

Although not much research has been carried out on climate change in Liberia, there are many environmental issues that require public awareness and sensitization at a decentralized level. However, most of the awareness-raising campaigns that have been conducted recently have been based on print and electronic media institutions limited to Monrovia and its environs. Most of the radio stations do not cover the entire country. There has been no adequate multimedia approach to public awareness of climate change information, education, and communication (IEC) or advocacy programs in Liberia. In order to succeed in creating adequate awareness of climate change, there is a need to encourage relevant ministries and agencies, business sectors, NGOs, and media institutions to join in the process, using a multimedia approach as a major strategy. Some local NGOs, engaged in limited climate change activities in agriculture, transport, and waste management, do not carry out public-awareness campaigns because of the lack of financial capacity and a multimedia strategy. The EPA has not yet benefited sufficiently from training programs and activities based on international cooperation because environmental protection interventions only began in Liberia in 2003.

Developing and Preparing the Liberian Media for Climate Change

The Liberian media requires an extended period of revitalization in order to play its rightful role as the 'Fourth Estate,' which should include acting as a watch-dog, contributing directly to development and to poverty reduction, as well as functioning as a tool for sensitization and public awareness on climate change and environmental issues. The GOL and development partners in collaboration and cooperation with the Liberia EPA should continue to facilitate closer working relations with the media and CSOs of the country.

In the short term, the Liberia EPA should initiate a program for the development of a critical mass of "agents of communication" from media houses, CSOs, and public-sector extension workers. Engaging the extension services and CSOs will pay dividends as these agents are closer to the local communities and understand and speak the same language. This program can be achieved through the design and implementation of a comprehensive training program on climate change, development and provision of media materials on climate change and environmental issues, and facilitation of nationwide sensitization of the public to environmental issues, particularly climate change, by these "agents of communication."

Liberia needs enhanced knowledge, skills, and partnerships on climate change issues, including cross-sectoral efforts that are critical to dealing with climate change in a systematic manner. This can be best achieved by building partnerships between the Liberia EPA and key stakeholders mandated to carry out education, research, training, and public sensitization and awareness campaigns. These stakeholders include the MOE, the MIB, local government authorities, extension services, and CSOs. In the long term, the MOE, the MIB, and the EPA should work towards integrating climate change in the education curricula at all stages from the basic, secondary, and tertiary to the university levels. Closer working relations with media-training institutions should be forged and supported with concrete investment over a long period for sustained growth and institutional development.

7.5:CONCLUSIONS AND RECOMMENDATIONS

This study concludes that education and training about and awareness of climate change are grossly inadequate in Liberia, as is the case with many countries, particularly in Africa. The major causes are low prioritization of climate change at the policy level. It is also due to the slow pace of connecting scientific and technical issues of climate change to policy making. Many policy and decision makers consider education, health, agriculture, water, and security issues the highest priorities. However, the same policy and decision makers fail to understand that development gains in these sectors can be wiped out by climate change impacts in a tenth of the time spent on developing those sectors. With better understanding of the inherent opportunities for considering climate change in our daily lives and in our planning process and of the differentiated impacts on women and men, it is possible to develop sustainably.

Thus it is recommended that the climate-change institutional framework of Liberia be revisited and coherently developed. The Liberia EPA, in its capacity as the national institution charged with coordinating the implementation of the MEAs, including climate change, should be adequately resourced to carry out its mandate.

The EPA, when adequately resourced, should continue facilitating capacity building and awareness among the Liberian population in collaboration and cooperation with national, bilateral, and multilateral development partners. The EPA should continue to make education, training, research, and public sensitization and awareness a major program of the agency.

CHAPTER → 8

CONSTRAINTS, GAPS, AND RELATED FINANCIAL, TECHNICAL, AND **CAPACITY NEEDS**

8.1: INTRODUCTION AND CONTEXT

In every country, more so in poor, vulnerable Least Developed Countries (LDCs) including Liberia, climate change should be viewed and implemented as a development issue in a development pathway. Hence, the Climate Change Convention and its Kyoto Protocol are being implemented with sustainable development guiding all future activities and programs in Liberia. The development of this Initial National Communication (INC) of the Republic of Liberia to the UNFCCC Conference of Parties (COP) has not been easy and has met many challenges. A lot of data and information gaps exist that make the document comparatively incomplete.

8.2: CONSTRAINTS AND GAPS

In the preceding chapters of this document, constraints on and gaps in data and information and technical and institutional incapacities have been presented and discussed. The following is a summary of the constraints, gaps, and capacity deficiencies:

1 → Current policies, strategies, and regulatory mechanisms have limited or no consideration of climate change issues.

2 → There is no dedicated technical committee or task force to implement the Climate Change Convention and its Kyoto Protocol.

3 → Expertise is limited at the national level for assessment of mitigation and adaptation options, participation in the Kyoto Protocol process, and development of appropriate implementation strategies. The major constraint lies in the lack of expertise for adequately and appropriately analyzing, developing, and costing mitigation and adaptation options and projects.

4 → There has been no development of national- and/or regional-specific emission factors with the ultimate objective of improving and updating the national GHG inventory by reducing uncertainties in the statistics.

5 → The institutional framework and technical expertise for the development of a comprehensive and integrated vulnerability (impacts and adaptation) assessment is limited.

6 → Sustained access to a reliable body of scientific and technical information does not exist.

However, it should be noted that capacity building is not gained all at once but through a continuous, progressive, and iterative process. At the same time, adequate human and institutional capacity is a necessary condition for the implementation of the UNFCCC. Based on stakeholder consultations and the effective dialogue between agencies that participated in the development of this INC, the following capacity-building issues are considered urgent and immediate priorities for the Republic of Liberia. These issues and the efforts to tackle them will build on the limited national capacity developed over the years and on other capacity needs identified in preceding sections of this report.

8.3: ASSESSMENT OF CAPACITY CONSTRAINTS FOR PRIORITY ISSUES AT THE VARIOUS LEVELS

Capacity constraints identified in section 8.2 above exist at the systemic, institutional, and individual levels and are fully discussed in the following subsections.

8.3.1:Capacity Constraints at the Systemic Level

At the systemic level the limited or non-existent enabling environment is a constraint. Current global, regional, and national policies, strategies, and regulatory measures do not adequately take climate change into consideration. Re-orientation and development of national policies and programs to take fully into account climate change as a sustainable development path should be initiated in the shortest possible time. What is needed are policies and measures to facilitate sustainable development strategies that make climate-sensitive sectors resilient to climate variability and change and that allow development to proceed in a low- or carbon-neutral pathway. The policies should lead to reduced pressure on resources and enhance adaptive capacity. Liberia urgently needs to develop a climate change policy and a Low-Carbon Development Strategy (LCDS).

The stakeholder consultations and various workshops on climate change have contributed to increasing the awareness of the Liberian public about climate change issues. A sensitized population is capable of changing attitudes towards building a better climate system. Sustaining this awareness through continuing consultations is necessary. However, this activity needs adequate and sustained flow of financial resources, the lack of which is a current constraint in Liberia.

8.3.2: Capacity Constraints at the Institutional Level

At the institutional level the Liberia EPA and its collaborating institutions are constrained by inadequate financial resources and insufficient human resources with the appropriate scientific and technical expertise. Specifically there are limited financial resources for and limited technical and scientific expertise in:

1 → Integrated and comprehensive assessment of mitigation and adaptation options.

2 → Effective participation in the Kyoto Protocol process.

3 → Development of a comprehensive climate change policy, LCDS, Climate Change Action Plan (CCAP), and an integrated implementation strategy.

4 → Development of national- and/or regional-specific emission factors with the ultimate objective of reducing uncertainties in the national inventory statistics.

5 → Development of a comprehensive vulnerability assessment.

6 → Access to a reliable body of scientific information due to the near absence of enabling facilities.

Long-term and accurate data and information are prerequisite for conducting research and assessments of climate change. These are available only from an extensive and reliable network of recording stations. The greater part of Liberia's observation network has been lost, and the remaining stations have deteriorated during the past few years. This is a major constraint as data and information gaps are increasing, and this will continue to lead to uncertainties in climate change research and modeling results.

8.3.3: Capacity Constraints at the Individual Level

The absence of a dedicated climate change committee or task force means that at the beginning of any activity on climate change, the EPA struggles to assemble a body of capable experts. Technical experts who have been trained in the development of national inventories and assessment of vulnerability to climate change in previous activities may be available from their parent institutions, but in most cases fresh technicians are nominated to participate in the implementation of the activity. The rate of turnover is high, as is the number of fresh members with no previous knowledge of climate change issues. Generally these new members have no hard exposure to or training on issues related to climate change. This is a constraint.

Most of the technicians that participate in the implementation of climate change activities and gain knowledge and expertise in climate change are from the central government. This is an important constraint, especially when it comes to using the services of contractors and consultants who cannot be employed by the government. There is hardly any individual in the private sector who has been or is currently engaged in climate change activities.

On the other hand, the membership of a dedicated climate change committee or task force is relatively stable. These technicians are involved in the implementation of most of the climate change activities and thus continuously receive knowledge and develop their expertise.

8.4: OPPORTUNITIES FOR CAPACITY BUILDING TO ADDRESS THE CONSTRAINTS AND GAPS

A high priority is strengthening the capacity of the Liberia EPA and its collaborating institutions to enable their effective participation in the implementation of the convention and its Kyoto Protocol process. This will involve the following program of activities:

a) → Institutionalization of a dedicated technical National Climate Change Committee (NCCC) with an open-ended membership from all sectors of the Liberian economy.

(b) → Improving the capacity of the EPA and the membership of the institutionalized NCCC in the science, economics, and politics (negotiations) of climate change through participation in appropriate in-country or regional and international training programs. For a start, it is necessary to train three staff members of the EPA and five members of the NCCC (two from the government and one each from an NGO, CBO, and private sector entity) on specific themes such as climate change negotiation skills. This can be achieved through training at the national level or enabling the participation of Liberians in regional training programs. With a nominal cost, the UN Institute for Training and Research (UNITAR) has been conducting training courses for countries and regions in the developing world. Opportunities for web-based and on-line training are also within reach.

(c) → Enabling the development of a climate change policy, a comprehensive LCDS and a CCAP with an integrated implementation strategy. The process of developing the LCDS and CCAP will take into consideration the outputs of this INC, the 2005 National Capacity Self-Assessment (NCSA), the 2008 National Adaptation Programme of Action (NAPA), and national and sectoral policies, development plans and programs. Both short-term and long-term issues in the implementation of the UNFCCC in Liberia will be taken into consideration. The short-term and long-term issues include:

i) *Revising education curricula and developing education and training programs and specialized skills and expertise.*
ii) *Developing and strengthening scientific and technical institutions of higher learning with the necessary equipment and scientific information.*
iii) *Enhancing public awareness at all levels.*
iv) *Re-orienting and developing appropriate policies and regulations that facilitate sustainable development, reduce pressure on natural resources, and enhance mitigative and adaptive capacities.*

In updating and improving the national inventory of GHG emissions, the members of the NCCC assigned the study will need to move beyond the mechanical use of the IPCC Inventory Guidelines and Guidance materials and the default emission factors contained in those guidelines. This is likely to be achieved through conducting studies at the national or at the regional level to determine emissions factors that are relevant and applicable to Liberia, with the ultimate objective of reducing uncertainties in the national inventory statistics. It will be necessary to train at least ten members of the NCCC through an industrial attachment (IAP) or crash program at the national level. Upon completion of such training, the candidates will be capable of conducting experiments in the Liberian environment and developing emissions factors for the categories.

In conducting vulnerability (impacts and adaptation) assessments, technical experts acquire coarse General Circulation Model (GCM) outputs and use these to develop national-level climate and climate change scenarios. These scenarios are then used as input to biophysical models such as DSSAT, WATBAL, SPUR2, GAP, etc. in assessing vulnerability of the economy to climate change. However, the technicians have very limited expertise in influencing the source codes of these models in order to fine-tune them to the national circumstances of their own countries such as Liberia. For a comprehensive vulnerability assessment, the technical capacities and skills of experts need to be developed and enhanced beyond those acquired through workshops. It will be necessary to train the lead agency of each of the sectoral teams (agriculture, forestry, water resources, coastal resources, health, etc.) in the execution of the model required for the sectoral vulnerability assessment. It will also be necessary to train two members of the EPA and some of the members of the committee on integrated assessment. Effective capacity building in these areas can be achieved and sustained through the promotion and institutionalization of networking and collaboration between the leading global climate modeling groups and the NCCC of Liberia. These efforts will build and sustain the capacity of NCCC members to develop and execute climate change and biophysical models. The collaborative efforts should include the transfer of the model technology to Liberia.

Development and implementation of climate change programs is a process that depends on access to a reliable body of scientific information. The information is developed from raw data acquired from national, regional, and global systems of observation networks. Liberia has limited historical climate data (less than 100 years) and as already alluded to in Chapter 7, meteorological and hydrological networks have deteriorated and gaps in data have occurred, especially in the 1980s and 1990s. Inadequate or non-available equipment for systematic, long-term observation and collection of climate system variables has the consequence of limiting vital data required for the development of adequate and accurate inputs to model and simulate climate and climate change. It is thus a priority in Liberia to reverse this deterioration of the observation networks and improve the data and information availability. Improvement will entail acquisition of Automatic Weather Stations (AWS) and rehabilitating and stocking meteorological stations with the required number of instruments and automatic recorders. An adequate number of replacement parts and spares should also be stocked for timely replacement. Instrument and electronic technicians should be trained to maintain the networks.

CHAPTER → 9

NETWORKING AND KNOWLEDGE AND INFORMATION SHARING

9.1: INTRODUCTION

According to Harvey et al. (2009), knowledge sharing is the exchange of ideas and experiences through networks of relationships and knowledge sharing only occurs "when people are genuinely interested in helping one another develop new capacities for action; it is about creating learning processes." On the other hand, information sharing is typically concerned with channeling messages between knowledge producers and target audiences.

Historically, the creation and dissemination of "valid" knowledge was the monopoly of certain persons or institutions. This resulted in the marginalization of segments of society based on gender, race, language, and other discriminating factors. However, the emergence of new participatory tools such as web-based social media including Twitter, wikis, blogs, participatory video, and mobile phones has led many to argue that a new "architecture of participation" is emerging and will democratize access to and production of knowledge (Thompson, 2008, as cited by Harvey et al., 2009). These developments present both exciting opportunities and important challenges to complex concerns such as climate change, development, and global environmental governance, as this chapter will explore.

9.2: KNOWLEDGE SHARING AND CLIMATE CHANGE IN AFRICA

In order to increase the resilience of vulnerable local communities in Africa, there is a need to ensure they have access to information on appropriate adaptive practices. The diversity of stakeholders involved in adaptation processes (from policy makers to CSOs, researchers and, most importantly, local communities) and the barriers imposed by poverty, limited infrastructure, and illiteracy, among other things, make knowledge exchange a challenge. Thus, knowledge sharing requires the use of approaches that are tailored to the needs and constraints of particular stakeholders. Local communities, for example, may require non-text-based communications such as video or theater, face-to-face discussions, or local-language radio broadcasts. Similarly, local and indigenous knowledge must be translated into different languages and forms if it is to be appropriately communicated to research and policy communities.

The urgency of the adaptation challenge for Africa, paired with a growing acknowledgement that successful adaptive practice must take into account local practices and engage with local institutions (Agrawal and Perrin, 2009), highlights the importance of addressing the issues mentioned above if current research is to be effective. Further, as we begin to recognize the potential for adaptation of indigenous knowledge (which is often transmitted orally at very local scales and not formally documented), it becomes important to consider how to appropriately encourage collaboration with and between the bearers of this knowledge. Good examples are already emerging, including collaborations between indigenous rainmakers and meteorologists on climate prediction in Kenya (http://tinyurl.com/ik-nganyi), and the use of Geographic Information Systems (GIS) and participatory mapping with nomadic hunters in southern Africa to assess climate change (www.ipacc.org.za). These examples offer proof of the feasibility of innovative knowledge sharing and the complementarities between indigenous and scientific knowledge.

9.3: CLIMATE CHANGE NETWORKS

The following are some of the climate change networks that institutions in Liberia can connect with in order to access climate change knowledge and information:

Africa Adapt's Knowledge Sharing Network
Hosted by four institutions, AfricaAdapt (http://www.africa-adapt.net/) is a network dedicated to sharing African adaptation knowledge within a community of practice. In addressing the need for tailored approaches to sharing, the network uses both online and offline forms of engagement in both French and English to reach adaptation stakeholders. The AfricaAdapt website serves as an online hub for sharing knowledge among researchers, policy makers, and NGOs in particular. It features user-generated profiles of adaptation projects where members can have discussions and post documents and blog-style news. The site also hosts thematic resources on adaptation and a dedicated space for sharing community contributions. The network's engagement with African communities and community-based organizations, however, occurs primarily offline and on the ground. It collaborates with community radio—a key medium for local debate and awareness-raising—to increase and deepen discussion on climate change. It produces print-based summaries of pertinent information and hosts forums for diverse stakeholder groups to exchange perspectives. The network also encourages local innovation on knowledge sharing with small grants to initiatives that engage hard-to-reach communities.

GenderCC—Women for Climate Justice
GenderCC (www.gendercc.net) is a platform for information, knowledge, and networking, and a global network of women, gender activists, and experts from all world regions working for gender and climate justice. It was created as a response to the growing public attention to climate change and the increasing need for information about women's perspectives and gender aspects of climate change policies and measures. The website is based on knowledge available through the GenderCC network and is one element of an envisaged International Competence Centre Gender & Climate Change (CCGCC).

Information accessible on the network includes research on gender, climate change, and related areas, and on case studies that clarify and illustrate gender aspects of climate change activities. It focuses on campaigns to make visible women's contributions to climate protection, as well as on campaigns, mechanisms, and tools to integrate gender dimensions into climate change policies and measures. With a base of numerous organizations and institutions standing up for a gender perspective on climate policy, the website serves as a networking platform for those organizations and gender and climate experts. It assists those who want to become acquainted with gender and climate change issues as well as those who wish to contribute. The knowledge base and information platform is a work in progress. GenderCC is always interested in ongoing and future research projects and publications, and welcomes information and publications through the GenderCC platform. The platform also runs the GenderCC-listserv which is accessible to everyone committed to gender equality in climate change debates and policies. Topics are related to gender and climate change, women's rights, gender relations, and gender justice in the context of climate change and climate-related policy making.

Civil Society Network on Climate Change (CISONECC)
In a bid for common understanding and participation of all sectors dealing with climate change, the CISONECC (http://www.cepa.org.mw/cisonecc/) was established in Malawi with the goal of developing communities resilient to the impacts of climate change. The core functions of the network include:

a) → Researching and analyzing policy to promote and facilitate research, document the progress and impact of intervention measures, and foster shared learning from climate change interventions in Malawi.

b) → Enhancing the capacity of CSOs to lobby and advocate for management of climate change and its impacts on Malawi, the region, and internationally.

c) → Sharing information and building the capacity of CSOs, CBOs, and communities to manage the impacts of climate change and variability.

d) → Promoting mitigation and adaptation initiatives to reduce suffering due to climate change and to build resilient communities.

e) → Coordinating and promoting networking amongst its membership.

Community Based Adaptation Exchange Network
At the 2nd International Workshop on Community Based Adaptation to Climate Change in Dhaka, Bangladesh, in February 2007 (http://www.iisd.ca/ymb/sdban/), delegates heard about communities adapting to heat waves in mountainous areas of India, floods in Bangladesh and Nepal, drought in Kenya, soil salinity in Sri Lanka, and health problems in Zimbabwe. Those present decided to form the Community Based Adaptation (CBA) Exchange network (http://community.eldis.org/cbax/) to promote sharing knowledge about CBA activities across the world.

Volunteer Communities and Information and

Communication Technologies: New Approaches to Building Climate Change Resilience

The increasing role of local communities in the response to climate change-related events reinforces the importance of volunteerism, self-organization, and community engagement in more resilient and adaptive systems. This is an area in which the supportive role of information and communication technologies (ICTs) and specifically of Web 2.0 tools will continue to increase, enabling more effective collaboration and sharing, strengthening networks, empowering local actors through access to new information and skills, and supporting novel mechanisms of participation that enhance resilience at the local, national, and international levels.

The Volunteer Technology Communities (VTC) Network for climate change resilience (http://www.niccd.org/) provides effective and efficient response through:

a) → Facilitating borderless community action through the use of Web 2.0 tools by networks of experts and practitioners that collaborate, both virtually and face to face, in identifying and solving pressing problems for vulnerable populations.

b) → Virtual networking and information sharing which can raise awareness on local priorities and foster a culture of collaboration around climate change topics. Dynamic information sharing and discussions through Web 2.0 tools can also foster problem-solving skills.

c) → Collectively developing solutions that are widely shared in almost-real time (e.g., community mapping), contributing to a more efficient, effective, and transparent allocation of resources (from humanitarian aid in times of crisis to long-term adaptation funds), as well informing decision-making processes at the local level.

d) → Engaging a diverse set of actors as part of climate change strategies. VTC can foster new multi-sectoral partnerships and cross-level information sharing practices, which play a key role in disaster response and adaptation.

e) → Providing greater flexibility in the response to an external disturbance by allowing access to a wider set of human and economic resources and expertise. Virtual communities are practiced in climate change-related fields (e.g., mitigation, disaster preparedness and response, monitoring and adaptation).

f) → Responding rapidly. As suggested in the WB/GFDRR report, the bottom-up/decentralized structure of virtual communities allows for more rapid responses, as community members interact online and develop and share solutions without the bureaucracy of other types of organizations.

Ethiopian Civil Society Organizations Working on Climate Change (ECSNCC)

ECSNCC (http://ecsncc.org/Default.aspx) is a loose network of Ethiopian CSOs working on climate change. It was first conceived during the 2007 Green Forum and has stirred the establishment of a civil society coalition on climate change. The network was launched in January 2009. The objectives of the network are raising awareness about climate change, building capacity, documenting and sharing experiences, conducting action-oriented research, establishing a platform that will synergize civil society's efforts in combating climate change, and facilitating consultations among stakeholders on climate change issues.

The Southeast Asia Climate Change Network (SEAN-CC)

Working primarily through the UNFCCC National Focal Points (NFPs) designated in each country and mobilizing other key actors, the SEAN-CC—a United Nations Environment Programme (UNEP) initiative funded by the government of Finland—aims to guide countries in the Association of Southeast Asian Nations (ASEAN) in making sound policy, technology, and investment choices that lead to a reduction in GHG emissions and potential co-benefits, with a specific focus on promoting action on energy efficiency and energy conservation (EE&C) and on clean and renewable energy sources. In line with the priorities identified and agreed upon by the NFPs or in response to direct requests from countries, SEAN-CC activities cover technical assistance (including policy advice), capacity building, and knowledge generation and information sharing with a view to:

- Strengthening coordination and collaboration among decision makers for low-carbon development.
- Addressing the capacity gaps of energy professionals in the region and supporting countries in strengthening energy institutions in order to design, implement, and monitor mitigation activities.
- Expediting development of good policies to accelerate the transfer of climate friendly technologies.
- Engaging the private sector in national and regional efforts for low-carbon development.
- Improving the development of knowledge, disseminating best practices, and fostering interactions and exchange of experiences among climate change professionals in the region.

Through the SEAN-CC, policy makers are able to:

- Interact and exchange experiences with climate change professionals in the region and with international experts.
- Gain a better understanding of the benefits of low-carbon development and related technologies.
- Engage with energy professionals and the private sector in order to respond jointly to the climate change challenge.

Since the network was founded in 2009, SEAN-CC has:

- Supported the climate change offices in the ten member countries in preparing their participation in UNFCCC negotiations (Conference of Parties [COP] 15 and COP 16) and strengthening their capacities to conduct GHG inventories, produce national communications, and develop programmatic CDM projects.
- Promoted action on energy efficiency through climate technology trainings, feasibility studies, and market assessments for the harmonization of standards and the development of energy efficiency technology manuals.
- Promoted south-south cooperation for intra-regional climate technology transfer through developing and engaging in regional initiatives, organizing regional workshops and meetings, and online engagement.
- Strengthened communication, collaboration, and synergies between climate change offices and energy institutions for joint action on mitigation and low-carbon development.
- Produced a series of regional analyses and reviews and targeted analysis documents on key climate change issues of mutual interest to network members.
- Supported a number of country-led initiatives presenting high potential for relevance and/or being replicable in other contexts in response to direct requests from member countries.
- Established partnerships with a number of regional institutions and centers of excellence for the promotion of energy efficiency and climate technology transfer.

The Communication for Development (C4D) Network

The C4D Network (www.c4dnetwork.ning.com/) is open to all who are interested in the role of communication in development. Communicating and sharing knowledge and learning about climate change issues and responses can contribute towards a better understanding of this complex issue and its impact on lives and livelihoods—as well as being the first step to finding ways of mitigating the worst effects of climate change. The following information provides links to key organizations, case studies, ideas, and discussions around the C4D Network theme of communication for development and climate change:

a) → **Climate Change Media Partnerships (CCMP)** is made up of Panos (http://panos.org.uk/), Internews (http://www.internews.org/), and the International Institute for Environment and Development (IIED). The goal of the partnership (http://www.climatemediapartnership.org/) is to increase the capacity of journalists in developing countries to report on climate change issues, widen understanding, and stimulate debate about climate change, and to increase the number of stakeholders involved in decision making. CCMP has a useful support-materials section on their website, including papers relating to media and climate change.

b) → **The IIED** (www.iied.org/) is an independent international research organization focusing on sustainable development. Its mission is to build a fairer, more sustainable world using evidence and action and to influence in partnership with others.

c) → **Soul Beat Africa** (http://www.comminit.com/africa/category/sites/africa) is the **Communication Initiative Network**'s e-magazine focusing on Africa. It explores intersections between climate change and communication for development and features information on climate change and its impact on communities, its relationship to and effect on women, the media's role in climate change alerts, climate change, and youth awareness; and offers global information-sharing on climate issues.

d) → **"Time to adapt? Media Coverage of Climate Change in Nonindustrialised Countries"** is the title of Chapter 12 (www.iied.org/pubs/pdfs/G02512.pdf) in the book, *Climate Change and the Media*, published by Peter Lang (August, 2009). Written by

Mike Shanahan and the basis for this chapter of the Liberia INC, "Time to Adapt" reviews recent studies from Brazil, China, Honduras, India, Jamaica, Mexico, Mozambique, South Africa, Sri Lanka, Swaziland, Vietnam, and Zambia, and discusses efforts to improve climate change journalism in these and other nonindustrialized countries.

e) → ***A Journalist's Guide to Reporting Research Findings,*** published by Panos, London, (http://panos.org.uk/resources/a-journalists-guide-to-reporting-research-findings/) provides an online resource for journalists and other media professionals who seek to help tackle the impact of climate change by providing the public with good-quality information.

f) → **"Africa Talks Climate: Understanding of climate change"** is a BBC World Service Trust policy briefing (http://www.bbc.co.uk/mediaaction/resources/policy.html) examining the public understanding of climate change across ten African countries.

g) → ***Red Cross/Red Crescent Climate Guide*** **(2007)** is an initial guide to the basics of climate change followed by six thematic models, with communications and communications case studies and step-by-step guidance (http://www.climatecentre.org/site/publications/85). Available in English, French, Arabic, Spanish, and Russian.

h) → **The International Conference on Broadcast Media and Climate Change** in 2009 was a high-level international event organized by the UN Educational, Scientific and Cultural Organization (UNESCO) in partnership with UNEP, regional broadcasting unions, and other international broadcasting organizations to consider a global consensus on raising public awareness of the challenges of climate change. Webcast recordings of the conference are available (http://portal.unesco.org/ci/en/ev.php-URL_ID=29082&URL_DO=DO_TOPIC&URL_SECTION=201.html).

i) → ***Media as partners in education for sustainable development:*** A Training and Resource Kit (2008) is part of the UNESCO Series on Journalism Education (http://unesdoc.unesco.org/images/0015/001587/158787E.pdf). This training kit provides media professionals with basic information about priority issues, including environmental and climate change, for sustainable development. It also provides practical exercises to inspire investigative reporting and draws links to existing experience that may enrich the information resources of media professionals.

j) → ***Planting the knowledge seed: Adapting to climate change using ICTs*** (www.bcoalliance.org/Climate-Change), edited by Patrick Kalas and Alan Finlay, is a downloadable publication from the Building Communication Opportunities (BCO) Alliance exploring the practical links between climate change, access to and sharing of information, and knowledge and communication for development.

k) → **Africa Talks Climate** (www.africatalksclimate.com/) is a groundbreaking, African-led research and communication initiative founded on the belief that those worst affected by climate change must be better informed in order to understand and effectively respond.

l) → **Earth Journalism Network (EJN)** (www.earthjournalism.org/) was developed by Internews Network to empower and enable journalists from developing countries to cover the environment more effectively. EJN aims to establish networks of environmental journalists in countries where they don't exist - and build their capacity where they do - through training workshops, support for production and distribution, and dispersing small grants.

m) → **The Environmental Change Institute** at the University of Oxford in the UK has an online section focusing on stakeholder engagement and the influence of mass-media climate-change communications (www.eci.ox.ac.uk/research/climate/communication.php).

n) → **The Tyndall Centre for Climate Change Research in the UK** (http://www.tyndall.ac.uk/) brings together a wide range of people who are working to develop sustainable responses to climate change through transdisciplinary research and dialogue at both a national and international level—not just within the research community but also with policy advisors, the media, and the public in general.

o) → **Communication for Sustainable Development Initiative (CSDI)** is a joint project of the Food and Agriculture Organization (FAO) and the Italian Ministry of the Environment and Territory (http://www.csdinitiative.org). It was launched to apply communication strategies and approaches to climate change adaptation, sustainable natural resource management (NRM), and food security.

p) → **The Center for Climate Change Communication at George Mason University in the USA** (www.climatechangecommunication.org/) conducts public-engagement and behavior-change research that can be used to improve climate change communication and social marketing programs.

Climate Change Information Network (CC:iNet)
CC:iNet (http://unfccc.int/cc_inet/cc_inet/items/3514.php) is a web portal serving as a clearinghouse for information sources in support of Article 6 of the Climate Change Convention and its implementation. The full-scale version of CC:iNet was launched in October 2010 to enable visitors and registered users to make use of enhanced features.

CHAPTER → 10

CAPACITY BUILDING

10.1: INTRODUCTION

At the 1995 Conference of Parties (COP) in Berlin, Decision 1/CP.1, known as the Berlin Mandate, launched the process of strengthening the commitments of the Annex I Parties to Article 4.2(a) and (b) of the UNFCCC, which led to the development of the Kyoto Protocol. Article 10(e) of the Protocol encourages all parties to cooperate in and promote the development and implementation of education and training programs, including the strengthening of national capacity building, in particular for developing countries, and to facilitate public access to information on climate change. At the 2001 COP in Morocco, Decision 2/CP.7, part of what is known as the Marrakesh Accords, adopted the Capacity Building Framework (CBF) for developing countries and decided that this framework should guide capacity-building activities related to the implementation of the convention and effective participation in the Kyoto Protocol process. The objective of the CBF in developing countries is to build, develop, strengthen, enhance, and improve their capabilities to achieve the objectives of the convention and its Kyoto Protocol. The scope of needs and areas for capacity building in developing countries included institutional capacity building, enhancement and/or creation of enabling environments to implement the convention, research and systematic observation, including meteorological, hydrological and climatological services; development and transfer of technology, education, training, and public awareness; and information and networking, including the establishment of databases.

Under CBF, it is the prerogative of developing countries to identify their specific needs, options, and priorities for capacity building on a country-driven basis; to promote the coordination and sustainability of activities undertaken within this framework, and to facilitate the dissemination and sharing of information on capacity-building activities conducted by them. To effectively implement the CBF, the developing countries should be supported through bilateral and multilateral efforts using the Special Climate Change Fund (SCCF), Adaptation Fund (AF), and bilateral and multilateral financial sources.

The Republic of Liberia, through the Environment Protection Agency (EPA) as the National Climate Change Focal Agency, has coordinated the building of capacities at the national, regional, and international levels through facilitating the participation of experts in climate change projects embedded with capacity-building components, in climate change enabling activities such as the development of National Capacity Self-Assessment (NCSA), National Adaptation Program of Action (NAPA), and the National Communication (NATCOM) process, in the negotiation process, and also through technical support and special programs for Least Developed Countries (LDCs) under the UNFCCC process.

10.2: ASSESSMENT OF EXISTING CAPACITY

The EPA has coordinated and collaborated with national experts and international consultants to develop the NAPA under the LDC Program of the UNFCCC. Implementation of some of the project profiles has begun. In the preparation of this Initial National Communication (INC) of Liberia to the UNFCCC, the capacities of national experts have been developed in the assessment of GHG emissions, assessment of mitigation measures, vulnerability and adaptation assessment, and the technology and capacity needs assessment. Coordinated by the EPA, the GOL has developed and submitted its NCSA report. The implementation of these programs and studies has enabled Liberia to acquire some level of institutional and human capacity on climate change.

10.3: CAPACITY NEEDS FOR FUTURE IMPLEMENTATION OF THE CLIMATE CHANGE CONVENTION

10.3.1: Enhancement and/or Creation of an Enabling Environment

As the science and politics of climate change progress, the mandate of the EPA and national experts broadens and becomes more challenging in its scientific and technical capacity needs. For effective implementation of the Climate Change Convention and its Protocol, it will be necessary for Liberia to enhance, as appropriate, the enabling environment for capacity building through:

1 → Reviewing and strengthening the appropriate policy, regulatory, and institutional frameworks to identify and remove barriers to capacity building and create supportive backup for enactment and implementation.

2 → Strengthening the technical and human resources capacity of the EPA and collaborating stakeholder institutions to effectively and efficiently implement the convention.

3 → Strengthening existing and, where needed, establishing:

a) *Systematic observation and monitoring networks (sea-level rise, meteorological and hydrological monitoring networks, land degradation, floods, and droughts).*

b) *Centers and institutions for the provision of research, training, education, and scientific and technical support in specialized fields relevant to climate change, and utilizing information technology as much as possible.*

c) *Research programs on climate variability and climate change oriented towards improving knowledge of the climate system and scientific capability.*

4 → Supporting education and training in and public awareness of climate change related issues.

10.3.2: Institutional Capacity Building, Including Strengthening the EPA

Cross-sectoral measures such as public awareness and education, research, technology development and transfer, and capacity building are vital in addressing climate change issues of any nation or region. These measures are required to ensure a coherent approach to implementing the adaptation and mitigation actions and strategies contained in this INC, NAPA, and the NCSA. The EPA Outreach Unit has undertaken outreach activities, which included public meetings to solicit support and collaboration, educational campaigns, and media events. However, the Outreach Unit and the EPA as a whole are under-resourced both in funding and human capital. It is necessary for the EPA to be adequately resourced from the domestic budget through subvention and cost recovery. The EPA should be facilitated to establish a National Multi-Donor Trust Fund (MDTF) for mobilization of the domestic and international financial resources necessary to meet the cost of implementation of multilateral environmental agreements (MEAs) including climate change.

It is a high priority to strengthen the capacity of the EPA to participate effectively in the implementation of the convention and its Kyoto Protocol process. This will involve:

a) → The development of a comprehensive Climate Change Action Plan (CCAP) and integrated implementation strategy that take into account the capacity building needs, particularly in research and training, of the institutions participating in climate change activities.

b) → The development of education and training programs, specialized skills and expertise, and scientific institutions with the necessary equipment and scientific information.

c) → Enhancement of public awareness at all levels with the ultimate objective of improving decision and policy making through re-orientation and development of appropriate policies.

10.3.3: Institutional Strengthening for Research and Systematic Observations

Key Institutional and Research Issues and Constraints

The team of national experts of Liberia is weak in the development of sectoral and national GHG inventories, vulnerability analysis, economic analysis of mitigation and adaptation measures, and project development. In developing the inventory of national GHG emissions, the members of the team of experts will be transitioning from the 1996 to the 2006 IPCC Guidelines. Extensive training of the team will be necessary for the development of the next round of inventories. The team of experts should be capacitated and involved in the development of national- and/

or regional-specific emission factors with the ultimate objective of reducing uncertainties in the national inventory statistics.

For a comprehensive undertaking and involvement in the mitigation of greenhouse gases and adaptation to climate change, the capacity of the members of the national team needs to be enhanced through continuous training, especially on the economic assessment of mitigation and adaptation measures and project development. Members of the national team have very limited expertise in influencing the source codes of biophysical models to fine-tune them to the Liberian environment. For a comprehensive vulnerability assessment, the technical capacities and skills of experts need to be developed and enhanced beyond those acquired through workshops. The experts need to be trained on modeling at institutions of higher learning through fellowships and/or internships. In the longer term, appropriate curricula and degree programs need to be institutionalized in Liberian colleges and universities to enable development of a critical mass of experts on climate change.

Institutional reforms are necessary. Currently, climate change appears to be fragmented among different institutions making it ripe for competition for meager resources, duplication of efforts, and undermining of mandates. This makes the coordinating role of the EPA difficult, inefficient, and ineffective.

Connecting the science of climate change with policy, developing relevant policies, and influencing the policy and decision making processes is a serious constraint at this stage of understanding and prioritizing climate change in Liberia. It is necessary to realign current practices, programs, and policies to take into account climate variability and climate change. Hence, one of the key areas of research is to initiate a process that will re-orient most of the present policies, particularly those related to finance and natural resources management, in the direction of sustainable economic and environmental development and management. This will also lead to mainstreaming climate change into the national development programs of Liberia.

Systematic Observation

The Liberian National Meteorological Service (NMS) has been a victim of vandalism during the civil unrest of the country. Major equipment and installations have been destroyed. It is unreliable, unsafe, and a security breach for meteorological products generated from other sovereign states to be used in Liberia, but this appears to be the case, especially in the aviation and maritime transport sectors.

Hence, the following institutional and human capacity-building priority activities need to be implemented in Liberia:

1. Replacement and upgrading of Liberia's conventional meteorological equipment to digital equipment to minimize human interaction and also to provide continuous recording of meteorological, hydrological, and climatological elements and phenomena.

2. Rehabilitation and expansion of the existing station networks for more representative monitoring of weather, climate, and other aspects of the environment.

3. Provision of better and bigger capacity for data processing and storage and for the upgrading, networking, and interconnectivity of the data base systems of the NMS and other collaborating national and regional institutions.

4. Rebuilding and strengthening the human resources and capacity of the institutions involved in collecting, processing, and maintaining data and information related to meteorology, hydrology, and climatology.

Technology Development and Transfer

In Chapters 3 and 4 of this INC, mitigation and adaptation measures have been determined as the means to implement the Climate Change Convention in Liberia. In Chapter 5 appropriate technologies to support the implementation of these measures have been determined and discussed. These include solar and photovoltaic technology, cook stoves, and efficient and clean energy, of which Liberia is aware and receptive because of the opportunities these technologies represent for the sustainable development of the country. It is most urgent that the capacities of institutions and their personnel are built and strengthened for the sustainable uptake of these technologies.

Information and Networking, Including the Establishment of Databases

Climate change management is a science- and technology-intensive process requiring a considerable body of scientific information and technologies. In Chapter 9 appropriate networking and information sharing avenues, tools, and technologies have been identified and discussed. The ability of the Liberia EPA and collaborating stakeholder institutions and agencies to effectively implement the Climate Change Convention and its Kyoto Protocol depends on the nature and level of scientific and technical capacity that they acquire and utilize. This level of scientific and technical capacity is currently too low in Liberia, and its elevation to an appreciable level depends very much on cooperation and collaboration with regional and global scientific and technical institutions and networks. Science networks exist at the regional and global levels that can play important roles in the development of the scientific and technical capacities of Liberia. These roles include mobilization and provision of scientific and technical skills and information, and training of Liberian scientists in specific aspects of climate change. Another role that some of the science networks could play in the development of national scientific and technical capacity relates to the procurement of relevant equipment and technologies such as specialized computer hardware, software, and models. These would be particularly useful in the development of databases, websites, and electronic communications systems at the EPA for data and information acquisition and exchange and the development and sharing of media and outreach materials.

Included in this category of networking and information sharing is the ability of members of the team of experts and staff of the EPA to participate in on-line training programs of the UNFCCC, UN Institute for Training and Research (UNITAR), and other networks. A few of these on-line learning networks are:

1 → **Climate Change: Risks and Opportunities for the Finance Sector Online Course** (http://www.unepfi.org/training/climate_change/index.html).

2 → **One UN Training Service Platform on Climate Change: UN CC:Learn** (www.uncclearn.org).

3 → **Global Climate Crisis & Sustainability Panorama - Public Awareness International Node** (http://www.frogboiled.org).

4 → **Global Change SysTem for Analysis, Research and Training (START)** (http://start.org/). Assistance for developing countries in building the expertise and knowledge needed to explore the drivers of and solutions to global and regional environmental change.

5 → **African Climate Change Fellowship Program (ACCFP)** (http://start.org/programs/accfp1). Supports African professionals, researchers, educators, and graduate students in activities that enhance their capacity to advance and apply knowledge for climate change adaptation in Africa.

6 → **The Climate Change Information Network (CC:iNet).** Promotes action on Article 6 of the convention through its web portal, which serves as a clearinghouse for information sources. (http://unfccc.int/cc_inet/cc_inet/items/3514.php).

10.4: TECHNICAL, TECHNOLOGICAL, AND FINANCIAL REQUIREMENTS FOR CAPACITY BUILDING

Implementation of the Climate Change Convention and its Kyoto Protocol at the national level in Liberia is technically, technologically, and financially expensive. However, it is also agreed that lack of action is irreversibly more expensive.

Through the identification of mitigation and adaptation activities and the development of project cost profiles, the national experts and consultants involved in the development of this INC of Liberia have estimated the technical, technological, and financial requirements for addressing climate change in the country, especially for the required capacity building efforts. These are preliminary estimates as indicated in Annex II from experts with limited knowledge of and expertise in designing and conducting economic costing of climate change activities. Better estimates will be forthcoming during the development of full-scale projects.

CHAPTER → 11

CONCLUSIONS AND RECOMMENDATIONS

11.1: THE GHG INVENTORY PROCESS

Liberia's base year of 2000 for the national GHG inventory was selected in recognition of the national circumstances in the post-conflict period. The concentrated activities in Monrovia and environs facilitated the collection of source-specific activity data (AD) for estimation of category-specific energy emissions. International data sources (e.g., FAO database) and in-country data collection under various collaborative studies by the UNDP, UNICEF, and the World Bank also provided some AD for the agriculture, forestry, and waste sectors for 2000. However, the inventory results are reasonably representative of the national circumstances of the country. Liberia is classified as a net sink because of the uptake of carbon dioxide by the Land Use, Land Use Change and Forestry (LULUCF) category of the country.

The national inventory team and the international consultants applied the UNFCCC reporting guidelines, the Revised 1996 IPCC Guidelines, and the 2000 IPCC Good Practice Guidance (GPG). From now on the 2006 IPCC Guidelines and the 2000 GPG will be used for the development of national inventories. The Liberian national inventory team should be capacitated to use the guidelines for subsequent inventory development. The team should also employ the National Inventory Improvement Plan (NIIP) developed under this Initial National Communication (INC) for implementation under the next national communication activities.

For future inventory development, involvement of sectoral institutions should be enhanced in inventory preparation, methodological development consistent with the national circumstances in accordance with the GPG 2000, Quality Assurance/Quality Control (QA/QC) activities, and the archiving of national inventory data to ensure institutional memory, the development and delivery of Liberia's energy balances, and formalization of institutional arrangements. The inventory team should also take advantage of knowledge and information networks identified in this INC and multilateral and bilateral data collection studies to improve data quality and maximize the use of resources for data collection and delivery for the preparation of the next national inventory report.

11.2: MITIGATION ASSESSMENT

In conducting the mitigation assessment as a component of this INC of Liberia, attempts have been made to develop the baseline situation and make projections into the future. Success in this endeavor has been constrained by data and information gaps. The good data and information that existed before the civil war was lost, no appreciable data and information gathering and archiving was carried out during the war, and the data and information gathered and stored since 2003 have too short history to effectively inform the mitigation assessment and provide credible projections into the future. It is recommended that the data situation of Liberia be addressed. The technicians and consultants that conducted the studies and the stakeholders that reviewed and validated this report have the belief that through consultations with institutions managing global data bases in the developed world, some historical data from Liberia can be retrieved. It will then be possible to use hind-casting and extrapolation to build a reasonable historical data set for Liberia. It is recommended that the Environment Protection Agency (EPA) and Liberia Institute of Statistics and Geo-Information Services (LISGIS) through their ministries explore this option of building the Liberian historical data.

11.3: VULNERABILITY (IMPACTS AND ADAPTATION) ASSESSMENT

The assessment of the vulnerability of the economy of Liberia to climate change suffered from the same inadequacies in historical data and expertise. Similarly, this process can benefit from efforts to build the historical data of Liberia.

In addition, technicians tasked with the assessment lack the skills and expertise in modeling the Liberian atmosphere in the medium and long term. Most of the climate and biophysical models used in vulnerability assessments are available free of charge or at nominal fees. However, Liberian technicians lack the knowledge and skills to influence the source codes of the climate and biophysical models used in the assessment. It is recommended that a critical mass of knowledgeable and skilled technicians be built around the process of gender-differentiated assessment of the vulnerability of the national economy to climate change.

11.4: ASSESSMENT OF TECHNOLOGIES

The assessment of the technologies needed for the implementation of climate change responses in Liberia has been based on the best available information and expertise. It is not so comprehensive as expected, and this is due mainly to inadequate data, information, and expertise. The list provided in Table 5.2 is still too long and needs to be subjected to further analysis and prioritization, despite the fact that it is based on mitigation and adaptation projects already identified in national reports submitted to the UNFCCC Secretariat. Strategies and cost of acquiring the technologies, cost of implementation of the techniques and technologies, benefits of the technologies, and future sustainability of the technologies need to be further assessed. Potential barriers to acquiring and adopting the identified technologies have also been identified in Table 5.2 in Chapter 5.

Acquisition of these technologies and implementation of the adaptation options and mitigation measures will improve the wellbeing of the people of Liberia and the economy. This will be achieved through the development of appropriate investment, procurement, and implementation plans and programs. Lack of adequate capacity for research and for provision of extension services hampers the spread of technologies suited to local conditions. Adoption of new technology is also hindered by small farm size, credit constraints, risk aversion, lack of access to information and human capital, inadequate rural infrastructure, and unreliable supply of complementary inputs. For these reasons the adoption of new technologies may be accelerated by (i) the expansion of credit and saving schemes, (ii) shifting international research funding towards water-use efficiency, irrigation management, and adaptation to salinity; and (iii) rationalization of input and output prices of agricultural commodities, taking into consideration issues of development, equity, and sustainability (DES).

It is recommended that a detailed independent study be conducted following the full UNFCCC process for developing a technology needs assessment (TNA) including a detailed analysis of barriers (technical, social, and economic) and costs and sustainability of the actions. Many of the technologies identified in this study need to be adapted to the social, cultural, economic, and environmental priorities of Liberia. As technology issues are mostly in the hands of private sector development partners, efforts should be made to fully engage the private sector of Liberia not only in the identification and adoption of environmentally-sound technologies but also in the broader implementation of the Climate Change Convention in Liberia. There should be capacity-building activities such as training major stakeholders to be engaged in a future TNA process.

11.5: RESEARCH AND SYSTEMATIC OBSERVATIONS

The Liberian National Meteorological Service (NMS) is the authority responsible for the management of weather and climate service delivery. As described in this report, the NMS is in a deplorable state due to more than a decade of civil war. The institution is weak, having lost most of its weather observing stations and most of its qualified and skilled staff.

As the impacts of weather-related hazards continue to unfold, there will be increasing demand for accurate and timely weather and climate warnings, advisories, forecasts, and other relevant hydrometeorological information for public safety and planning purposes. To address these demands, Liberia needs to improve and expand its meteorological services to meet the emerging needs of the economy. It is therefore necessary to put in place the basic requirements for a meteorological service to function effectively. Improved observation and monitoring systems could provide reliable data to produce customized, accurate, and timely forecasts of great value to all sectors and promote sustainable economic development.

The transformation of the NMS into a fully

fledged agency has begun but needs to be fast-tracked so that the institution can perform its mandate of advising the government of Liberia (GOL) on climate and weather issues that have a critical impact on the socioeconomic development of the country. The NMS is currently fragmented to such a point that users are not sure who has the real mandate to provide services. All sections of the NMS which were moved to other ministries or departments need to be retrofitted back into the service in line with international best practices. The NMS needs to be assisted to gain the ISO 9001 certification required by the World Meteorological Organization (WMO) for quality management systems providing weather information.

The NMS conducts no research related to climate change. Only climatological data-processing is conducted to provide users with processed data and information. Liberia also has no institution of higher learning engaged in research on climate variability and climate change. The country relies on research results coming from the region and from global centers. It is recommended this situation be reversed.

11.6: EDUCATION, TRAINING, AND PUBLIC AWARENESS

This study concludes that, as with research on climate variability and change, education and training on climate change are grossly inadequate in Liberia. The major cause is low prioritization of climate change at the policy level. The EPA has close working relationships with media houses and conducts environment and climate change outreach and public sensitization campaigns within the limit of budgetary constraints.

Thus it is recommended that the Liberia EPA, in its capacity as the national institution charged with the coordination of the implementation of the Multilateral Environmental Agreements (MEAs), including climate change, should be adequately resourced to implement its mandate. When adequately resourced, the EPA should continue facilitating capacity building and awareness among the Liberian population in collaboration and cooperation with national, bilateral, and multilateral development partners. The EPA should continue to make education, training, research, and public sensitization and awareness a major program of the agency.

11.7: CONSTRAINTS AND GAPS IN DEVELOPMENT OF THE INC

During the course of development of this INC of Liberia, teams of experts and consultants experienced constraints and gaps. These include the absence of appropriate enabling environments, the disconnect between science and policy, and deficiencies in institutional and technical capacities.

Current policies, strategies, and regulatory mechanisms have limited or no consideration of climate change issues. The institutional framework for the mobilization and the building of capacities of technicians is absent. It is recommended that a dedicated technical committee or task force be constituted, placed under the guidance and coordination of the EPA, and used to carry out technical implementation of the Climate Change Convention and its Kyoto Protocol. Coordination and monitoring of the implementation of climate change measures in Liberia is difficult for the EPA not only because of the absence of a technical team but also because some government ministries and departments claim to have a supervisory and coordinating stake in climate change issues. These overlaps in mandates should be addressed so that other institutions of government are aware that the overall coordination of the MEAs, including climate change, is the mandate of the EPA.

There are gaps in the meteorological and socioeconomic data and information necessary for climate change analysis and research. This has made the results from the studies that have contributed to the development of this INC relatively incomplete. Basic AD is an essential requirement for GHG inventory, for development of the baseline conditions and projections required for mitigation assessment, and for input into biophysical models in the vulnerability assessment.

It is recommended that the EPA, in collaboration with the LISGIS, establish a metadata base at the EPA which will be mirrored at the LISGIS, as the LISGIS is the mandated custodian of Liberia's statistical data and information.

11.8 IMPROVING THE IMPLEMENTATION OF THE CLIMATE CHANGE CONVENTION

To improve the implementation of the Climate Change Convention and its Kyoto Protocol in Liberia, the knowledge, information, and capacity gaps and deficiencies should be addressed. The institutional framework also needs to be addressed.

Education, training, and public awareness of the citizenry about climate change must be a high priority of the GOL. The education curricula of the country should be revisited, reviewed, and revised to integrate climate change. Degree-level training and research programs should be established in most of the colleges and universities. The EPA and the Ministry of Information, Cultural Affairs and Tourism (MICAT) must collaborate and support each other in efforts to mobilize journalists, civil society organizations, and extension workers; sensitize them and build their capacities for awareness about climate change, and facilitate them as communication and information agents about climate change and the environment of the country. These agents of communication possess the knowledge-sharing methods and approaches that are tailored to the needs and constraints faced by particular stakeholders. Local communities, for example, require non-text-based communications such as video or theatre, face-to-face discussions, or local-language radio broadcasts. Similarly, local and indigenous knowledge must be translated into different languages and forms if it is to be appropriately communicated to research and policy communities. It is journalists, civil society organizations, and extension workers that are skilled and better placed to provide these translation tools. Such collaborative and cooperative efforts between the EPA and these agents of communication will increase the resilience of vulnerable local communities in Liberia.

During the course of preparation of this INC of Liberia, it was shown that knowledge and information gaps exist and pose serious barriers to the completion of the studies. Knowledge sharing is the exchange of ideas and experiences through networks of relationships; it is about creating learning processes. On the other hand, information sharing is typically concerned with channeling messages between knowledge producers and target audiences. Networks of knowledge and information sharing are either non-existent or too weak in Liberia to meet the requirements for useful exchange on the environment and climate change. Chapter 9 provides direction to a few regional and international information-sharing networks. It is recommended that stakeholders make best use of these and many more of the networks out there in the world.

From the process of developing this INC, it is concluded that capacities at the systemic, institutional, and individual levels are deficient. To improve and enhance the implementation of the Climate Change Convention in Liberia, capacity building at all levels is required and should be a high priority. At the systemic level, policies, strategies, plans, and programs should be revisited and aligned with emerging issues, particularly in the environment and climate change spheres. Institutional frameworks should be strengthened and made relevant to address the ever-present risks posed by the environment and climate change for social and economic development. The skills and capacities of individuals who are tasked by public and private sector institutions to participate in the implementation of the Climate Change Convention in the country should be built and enhanced.

Putting into practice the recommendations put forward in this INC requires the development and implementation of appropriate climate-change integrated policies and strategies at the sectoral and national levels. It is recommended that Liberia develop and implement a Low-Carbon Development Strategy (LCDS) that is comprehensive, all inclusive, and capable of addressing most of the gaps and challenges that are faced in the implementation of the convention in Liberia. The development of a Liberian LCDS is one of the highest priority projects identified during the validation of this INC, and a project profile has been included in Annex II of this report.

11.9: MOBILIZATION OF TECHNICAL, TECHNOLOGICAL, AND FINANCIAL RESOURCES

Implementation of the Climate Change Convention and its Kyoto Protocol at the national level is technically, technologically, and financially expensive. However, it is also agreed that lack of action is irreversibly more expensive. Through the identification of mitigation and adaptation activities and the development of project cost profiles, the national experts and consultants involved in the development of this INC have estimated the technical, technological and financial requirements to address climate change in Liberia, especially the required capacity-building efforts. These are preliminary estimates from experts with limited knowledge and expertise on designing and conducting economic costing of climate change activities. Better estimates will be forthcoming during the development of full-scale projects.

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ANNEX I

SUMMARY TABLE OF NATIONAL GREENHOUSE GAS INVENTORY

COUNTRY: LIBERIA **INVENTORY YEAR: 2000**

National greenhouse gas (GHG) inventory of anthropogenic emissions by sources and removals by sinks of all greenhouse gases not controlled by the Montreal Protocol and greenhouse gas precursors.

GHG Source and Sink Categories	CO_2 emissions (Gg)	CO_2 removals (Gg)	CH_4 (Gg)	N_2O (Gg)	NO_x (Gg)	CO (Gg)	NMVOCs (Gg)	SO_x (Gg)
Total National Emissions and Removals	**3,571**	**-96,811**	**197.18**	**1**	**1**	**15**	**0**	**0**
1. Energy	**3,571**	**0**	**73**	**1**	**0**	**0**	**0**	**0**
A. Fuel combustion (sectoral approach)	3,571		73	1	0	0	0	0
1. Energy Industries	1,117		0	0	0	0	0	0
2. Manufacturingindustries and construction	105		0	0	0	0	0	0
3. Transport	2,152		1	0	0	0	0	0
4. Other sectors	197		72	1	0	0	0	0
5. Other (please specify)	0		0	0	0	0	0	0
B. Fugitive emissions from fuels	0		0		0	0	0	0
1. Solid fuels			0		0	0	0	0
2. Oil and natural gas			0		0	0	0	0
2. Industrial processes	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
A. Mineral products	0				0	0	0	0
B. Chemical industry	0		0	0	0	0	0	0
C. Metal production	0		0	0	0	0	0	0
D. Other production	0		0	0	0	0	0	0
E. Production of halocarbons and sulfur hexafluoride					0	0	0	0
F. Consumption of halocarbons and sulfur hexafluoride					1		0	0
G. Other (please specify)	0		0			15	0	
3. Solvent and other product use	**0**			**0**				
4. Agriculture			**122**	**0**	**1**	**15**	**0**	**0**
A. Enteric fermentation			117					
B. Manure management			4	0			0	
C. Rice cultivation			0				0	
D. Agricultural soils				0			0	
E. Prescribed burning of savannahs			0	0	0	0	0	
F. Field burning of agricultural residues			1	0	1	15	0	
G. Other (please specify)			0	0	0	0	0	
5. Land-Use Change and Forestry	**0**	**-96,811**	**0**	**0**	**0**	**0**	**0**	**0**
A. Changes in forest and other woody biomass stocks	0 0	17,631				0		
B. Forest and grassland conversion		-114,442	0	0	0			
C. Abandonment of managed lands	0	0						
D. CO_2 emissions and removals from soil	0	0						
E. Other (please specify)		0	0	0	0	0		0
6. Waste			**2.18**	**0**	**0**	0	0	
A. Solid waste disposal on land			2.00		0		0	
B. Wastewater handling			0.18	0	0	0	0	0
C. Waste incineration					0	0	0	0
D. Other (please specify)			0	0	0	0	0	0
7. Other (please specify)	**0**	**0**	**0**	**0**	**0**	**0**	**0**	
Memo items								0
International bunkers	**64**		**0**	**0**	**0**	**0**	**0**	**0**
Aviation	58		0	0	0	0	0	0
Marine	6		0	0	0	0	0	
CO_2 emissions from biomass	**32,994**							

SUMMARY OF KEY CATEGORY ANALYSIS (WITHOUT LULUCF)

Item	Sector number	Sector	Catergories to be assessed in key catergory analysis	Applicable greenhouse gas	Base year 2000 estimate (Gg CO_2 eq)	Current year 2000 estimate (Gg CO_2 eq)	Level assessment	Level assessment %	Cummulative
1	**4.A**	*Agriculture*	CH_4 emissions from enteric fermentation in domestic livestock	CH_4	2,457	2,457	0.306	30.63	30.6
2	**1.A.3**	*Energy*	CO_2 mobile combustion: road vehicles	CO_2	2,152	2,152	0.268	26.83	57.5
3	**1.A.4**	*Energy*	Other sectors CH_4 (non-CO_2) emissions	CH_4	1,512	1,512	0.188	18.85	76.3
4	**1.A.1**	*Energy*	CO_2 emissions from energy industries stationary combustion	CO_2	1,117	1,117	0.139	13.92	90.2
5	**1.A.4**	*Energy*	Other sectors (energy emissions)	CO_2	197	197	0.025	2.46	92.7
6	**1.A.2**	*Energy*	CO_2 emissions from manufacturing industries and construction	CO_2	105	105	0.013	1.31	94.0
7	**4.B**	*Agriculture*	CH_4 emissions from manure management	CH_4	84	84	0.010	1.05	95.0
8	**6.A**	*Waste*	CH_4 emissions from solid waste disposal sites	CH_4	42	42	0.005	0.52	95.6
9	**1.A.3**	*Energy*	CH_4 mobile combustion: road vehicles	CH_4	21	21	0.003	0.26	95.8
10	**A.F**	*Agriculture*	CH_4 emissions from agricultural residue burning	CH_4	21	21	0.003	0.26	96.1
11	**6.B**	*Waste*	CH_4 emissions from wastewater handling	CH_4	4	4	0.000	0.05	96.1
12	**1.A.4**	*Energy*	Other sectors N_2O (non CO_2) emissions	N_2O	310	310	0.000	0.00	96.1
			TOTAL		**8,022**	**8,022**	**0.961**	**96.14%**	

ANNEX II

ADAPTATION AND MITIGATION PROJECT **PROFILES**

ADAPTATION OPTIONS

Project Title: Integrated Crop Management as an Adaptation Measure

Current Situation: At present a huge percentage of farmers are engaged in slash and burn farming practices which are environmentally unfriendly. The vast majority of farmers are not engaged in integrated crop management which would enable them to have a higher yield and enhance food security and livelihood options.

Justification: The need for an integrated farming system is a requirement for the fulfilment of food sufficiency and at the same time provides a considerable forest cover in support of emission reduction to combat climate change.

Objectives: The project objective is to introduce an integrated crop management method/practice to Liberian farmers as an adaptation measure for GHG emission reduction in the agriculture sector.

Timeline: Ten years.

Activities: The following activities will ensure maximum utilization and efficient outputs under an integrated crop management system:

Activity 1. Creating a nursery for indigenous plants.
Activity 2. Planting a variety of crops.
Activity 3. Building capacity in the proper use of fertilizers and agrochemicals.

Input: Training, making available fertilizer and agrochemicals, providing indigenous seeds.

Outcomes: Seeds collected and nursery established, sufficient yields, 1,500 farmers trained in the sustainable used of fertilizers and agrochemicals.

Financial Resources: US$10 million.

Implementation Plan and Partners: Project will be implemented in accordance with the duration of the project and partners will be the MOA, FDA, MIA, EPA, LISGIS, UNEP, UNDP, World Bank, FAO, FFI, and Conservation International (CI).

Monitoring and Evaluation: Monitoring of project activities will commence at the onset of implementation. Monitoring will be comprehensive and will focus on all project activities. However, the following key indicators will be closely monitored as they significantly progress: number of persons involved in the project, methods used, and results

Project Title: Enhancing the Capability of the National Meteorological Service (NMS) of Liberia to Provide User-Tailored Weather and Climate Information, Products, and Services in Support of Poverty Reduction.

Current Situation: There is very limited monitoring and systematic observation of the atmosphere for the provision of weather and climate information and services. Communication and data-processing facilities for meteorological data are inadequate due to the absence of meteorological observation networks. The development, generation, and provision of weather and climate information, products and services are not carried out. There is no public weather service or early warning system. There are no tools or equipment for climate modeling and prediction and weather forecasting. There are inadequately trained human resources. Liberia is not participating in the Global Climate Observing System (GCOS) program of the World Meteorological Organization (WMO), and it does not link to the Global Telecommunication System (GTS). There is no atmospheric research to support scientific assessment of climate change.

Justification: Weather, climate, and water, and especially climate change, have significant impacts on the socioeconomic development of Liberia, particularly in agriculture and food security, health, fisheries, forestry, water resources management, energy, transport, tourism, environment protection, disaster risk-reduction, and climate change adaptation.

Examples include the following:
a) → Agriculture, which contributes about 60% of Liberia's GDP, is highly dependent on rainfall. In the near future the GOL is planning to invest in mechanized farming. Farmers need weather forecasts and advisories to maximize agricultural production.

b) → The public needs weather information for planning day-to-day activities and operations. Currently, Liberians are missing public weather service.

c) → Air transport depends on weather information for safety and economical operations. The anticipated increase in air traffic at the Roberts International Airport (RIA) and at domestic airports will require efficient and sufficient meteorological services.

d) → Liberia is also prone to weather- and climate-related risks that seriously affect the nation and the environment in general. Monitoring and forecasting of these events is necessary for early warning and mitigation. These events are manifestations of climate change. Scientific assessment of climate change is achieved by continuously monitoring and measuring weather and climate parameters.

e) → Other socioeconomic sectors which need weather and climate information for their operations include the construction industry (construction of roads and other structures), environment, water resources management, and energy generation.

Objectives: The specific objective of the project is to strengthen the capability of the NMS to deliver tailored products and services needed by the public, decision makers, and the key weather- and climate-sensitive sectors of the country's economy, including agriculture, health, energy, water resources management, transport, environment, construction, tourism, shipping, etc. This will assist the GOL's Poverty Reduction Strategy (PRS).

Activities: The project activities include the following:

1 → Establish adequate observing networks to monitor hydrometeorological parameters.

2 → Create a robust communication system for data transmission and archiving as well as dissemination of forecasts and sharing of information with sister agencies in other countries, particularly in the West African subregion.

3 → Install a high-speed computing system for data assimilation and numerical weather prediction for early warning.

4 → Equip personnel with appropriate training and build skills and capacities.
5 → Interact closely with users of weather and climate information.

6 → The transboundary nature of severe weather phenomena also requires closer collaboration between meteorological services in the subregion for enhanced data sharing through the GTS of the WMO.

7 → Improve observing/monitoring systems to provide reliable data that produce customized, accurate, and timely forecasts of great value to the all sectors and promote sustainable economic development.

8 → Provide modern meteorological equipment and instruments for the collection of reliable weather and climate data.

9 → Refurbish observation stations affected during the war and set up new ones to increase the network density.

10 → Make efforts to recover some of the substantial amount of good climate data that was lost during the civil war.

11 → Acquire communication, data processing, and weather forecast dissemination facilities.

Timeline: 5 years

Financial Resources: US$ 6 million

Project Title: Capacity Building on Energy and Climate Change.

Current Situation: It is necessary to introduce courses at the University of Liberia (UL) on energy and GHG inventory assessments and assist science students to conduct essential research projects on GHG and energy technologies, especially renewable energy technologies. The Department of Energy, Ministry of Lands, Mines and Energy (MLME), which in the past conducted energy assessment but currently has inadequate trained personnel in the area of climate change analysis and mitigation. With adequate capacity, this unit can conduct national energy assessment and policy development, taking into consideration environmental concerns and GHG emission and mitigation measures.

Justification: There is an urgent need to collect and develop inadequately trained human resources in order to improve the capacities of developing countries to participate in research and systematic observation. This will ensure clear roles and responsibilities of different institutions in integrating inventory data formats in national data collection activities. With adequate capacity, the Energy Department, MLME can conduct national energy assessments and policy development.

Timeframe: The project to build capacity on energy and climate change is estimated to take ten years.

Baseline Scenario: Due to the civil war Liberia experienced a serious brain drain. The lost hydro facilities, the shutdown of the oil refinery, and the pilfering of the Bushrod power generation plant resulted in the displacement of engineers and other trained professionals into other countries or other employment fields. According to the baseline data available to us, there are no energy training program courses being offered anywhere in the country, even at the secondary or tertiary levels.

Expected Emission Reduction: Properly trained people and adequate institutional capacity to develop emission-reduction and awareness can lower emissions to an acceptable level and make Liberia a carbon-neutral environment.

Description and Specification of Targets:

1 → Establishment of degree-granting programs in energy and climate change at the university level.

2 → Development of institutional research capacity for energy and climate change data-collection and management.

3 → Creation of energy and climate change awareness programs and workshops throughout the country.

4 → Provision of advanced training programs for professionals in energy and climate change analysis and mitigation.

Sustainable Development Impacts: This Capacity Building on Energy and Climate Change Project will provide Liberia with the technical and technological capacity to develop sustainably. Appropriate policies and regulations with sustainable indicators will be available and implemented. This will bring Liberia in line with other countries in the struggle against climate change through mitigation and adaptation in the energy sector.

Requested Funding and Support: This program will require concerted and coordinated funding from multi-sectoral sources, including national and foreign governments, international donors, and other stakeholders and players in the energy sector. We estimate a minimum support of US$10 million to sustain the project over the ten-year project period.

Implementation Plan and Partners: Once funding is secure, we anticipate the first phase of implementation of this project to begin in the fourth quarter of 2013. The institution responsible for this project would be the Energy Department of the MLME, in collaboration with the EPA and the UL.

Monitoring and Evaluation: Monitoring and evaluation of the project will be by the donors and the GOL, which will fill in the monitoring and evaluation mission to Liberia and work with the implementing agency. National monitoring and evaluation will be conducted by the UNFCCC Focal Secretariat.

MITIGATION OPTIONS

Project Title: Improving the Efficiency of the Transport System in Liberia

Current Situation: Currently, the transport system is characterized by the importation of numerous old, used vehicles, the majority of which pollute the environment and emit huge quantities of GHGs. Furthermore, there are a limited number of good streets and highways. Roads and highways connecting various parts of the country are generally bad. As a result, highway motor accidents and urban traffic jams are commonplace. The main commercial transportation within the country is road-based—trucks, buses, motorcycles, and automobiles, and sea, air, and rail transport within the country are minimal or non-existent. However, smaller vehicle sizes, coupled with higher average-load factors, would likely bring down energy use per passenger-km. Railroad transport in Liberia is very limited and used only for the shipment of iron ore from the mines to the port and not for passenger and cargo. Farm-to-market roads are largely nonexistent and where they exist they are in deplorable condition. During the rainy season travel around the country is difficult, and some communities are cut off. On the environmental side, particulates emitted from vehicles cause visible air pollution and a number of adverse health effects, with diesel-fueled vehicles emitting 30 to 70 times more particulate than gasoline. In Liberia emission controls have not been implemented or have been minimal, and as a result congestion is increasing and air quality is steadily deteriorating. Other issues include:

- The lack of reliable data describing vehicle fuel economy and vehicle load factors.

- The poor Liberian road infrastructure and poor vehicle maintenance practices.

- The use of older and used vehicles which forces an increase in the use of vehicle fuel.

- The poor quality of the truck fleet in Liberia, which is generally very old, smaller, and less technologically sophisticated than the truck fleet of industrial countries.

Justification: A more efficient transport system will benefit Liberia in so many ways. This includes the economy, health and safety, social welfare, and mitigation of GHG emissions and air pollution. It is a known fact that economic growth and development are linked to good and efficient transportation systems and that social welfare as well as the reduction of accidents and traffic jams require an efficient transport system. Comprehensive transport policies will address the above series of issues, which take into consideration energy use and environmental impacts as well as the popular demand for effective transport.
Timeframe: Development of an efficient transport system in Liberia is a project estimated to take about 10–15 years.

Baseline Scenario: The conflict in Liberia reduced the capacity of the transportation sector. The road network is in a devastated condition with very limited road construction, largely funded by logging companies. Most vehicles in Liberia use low-grade diesel and mixed petroleum and have a high potential to emit large quantities of greenhouse gases. Liberia has only two international airports: RIA, which is located 45 km south of the nation's capital of Monrovia, and the James Spriggs Payne Airport, located in Sinkor, Monrovia, which is also used for domestic flights. There are a few gravel-surfaced airfields. The 490 km of railroads in Liberia were paralyzed by the civil war. Currently, only the Bong Mines rails are functional after being rehabilitated for private and informal rail transport services from Monrovia to the old Bong Mining premises in Lower Bong County. The railway network was not developed to transport passengers within and outside the country but was constructed to transport iron ores from mining sites (Bong and LAMCO mines) to the ports of Monrovia and Buchanan. There are four seaports (Buchanan, Greenville, Harper, and Freeport of Monrovia) which are used for the export of iron ore, cocoa, coffee, and rubber. In effect, three ports (Monrovia, Greenville and Harper) are generally engaged in the shipment of rubber and timbers. The six major rivers in the country are not navigable by boats or large canoes due to the stems and debris found in these rivers, and as a result rivers are not frequently used as means of transportation in Liberia.

Expected Emission Reduction: The Efficient Transport System Project is intended to help reduce GHG emissions and contribute to Liberia becoming a carbon-neutral environment.

Description and Specification of Targets: The targets include roads, airports, and sea and river ports for water transport. The project will address the issues of:

1 → The use of public mass transport modes (bus and rail) for improved energy efficiency.

2 → The use of public freight, sea, and air transport modes where applicable for the energy-efficiency benefits of rail, air, and water transport over road transport.

3 → The use of fuel-efficient vehicles and equipment and clean fuels to reduce air pollution and adverse health effects.

4 → Development of comprehensive transport policies to address the above series of issues, taking into consideration energy use and the environment as well as growing short-term and long-term transport demand.

5 → Planning appropriately to develop an efficient transportation infrastructure that will support and meet the aspirations of the population for increased mobility and convenience in their daily transport.
Requested Funding and Support: The estimated cost of development of the Efficient Transport System Strategy Project is about US$658 million for the total package. Other support requested includes capacity building and technical and technological assistance.

The breakdown of the support categories is as follows:

1 → A program to rehabilitate the roads.

2 → Vehicle registration and licensing of drivers to be decentralized in the counties.

3 → Provision of vehicle GHG-emission measurements, with testing and monitoring stations appropriately equipped in each county as a requirement for licensing and renewals.

4 → Installation of road safety signs throughout the streets and countryside, including speed limits and other emission controls; designation of parking lots both for cities and transport union operations,

and defining clearly the role of the transport unions around the country.

5 → Regulation and monitoring of fuel quality to ensure that clean-burning and standard fuels are imported in the country.

6 → Development of a domestic air-transport system to include at least ten local terminals and refueling facilities for local flights.

7 → Development of a railway network system for cargo and mass transport of passengers for long, cross-country distances.

8 → Development of domestic coastal shipping using the ports of Cape Mount (to be developed), Freeport of Monrovia, Buchanan, Rivercess, Sinoe, Harper, and others for cargo shipping and other economic activities such as the petroleum exploration program and development of a shore base.

9 → Development of sea-transport safety regulations and standards, keeping in mind that using rail, air, and sea makes the roads last longer.

Implementation Plan and Partners: We anticipate that the first phase of implementation of this project will begin in the second quarter of 2013 starting with policy plans and transport infrastructure improvement. The responsible institution for this project would be the Transport Ministry (MOT) and Ministry of Public Works (MPW), in collaboration with the EPA.

Monitoring and Evaluation: Monitoring and evaluation of the project will be done by the GOL through the MOT, MPW, the Liberian Maritime Authority, and the Liberian Civil Aviation Authority. Local communities and donors will fill in the monitoring and evaluation mission to Liberia and will work with the implementing agency. National monitoring and evaluation will be conducted by the UNFCCC Focal Secretariat.

Project Title: Development and Implementation of a Low-Carbon Development Strategy of Liberia.

Current Situation: Liberia submitted its National Adaptation Program of Action (NAPA) in 2007 and is currently finalizing its INC for submission to the UNFCCC in 2012. These reports contain information on the level of GHG emissions, mitigation measures to reduce emissions, projected impacts of climate change, proposed adaptation options to address the impacts, and proposed international cooperation measures. However, Liberia has no climate change policy and no set strategy for the implementation of the Climate Change Convention. There are set institutional structures but they are not adequate as these are functional only during project implementation. There is no domestic funding for a fully fledged, functioning structure.

Justification: The absence of a climate change policy and strategy makes the implementation of the Climate Change Convention in Liberia an ad-hoc process that has no sustainability. The institutional structures in place are not adequate, as these are functional only on an ad-hoc basis without domestic funding and therefore are active only during projects such as the development of the INC. The inadequacy of institutional structures is also the result of the absence of climate change policy, regulations, and strategies. The institutionalization of a policy, regulations, and a strategy will lead to the legal establishment of the appropriate institutional structures mandated by law to operate in the country and will therefore be funded through the domestic budget. As part this mitigation submission to the UNFCCC, Liberia proposes to develop its LCDS to plan and implement a broad range of mitigation activities and emissions pathways, some of which are part of this submission. The process of development and implementation of a Liberian LCDS will open up many new avenues to fully establish appropriate institutional and legal structures for the effective and sustainable implementation of the Climate Change Convention and its Protocol. The presence of a Liberian LCDS will also provide a comprehensive outlook on policies, measures, strategies, and actions at the national level that will facilitate a shift to low-carbon development. The national GHG inventories submitted under the first and second National Communications of Liberia to the UNFCCC will be an important factual information component that will track future progress in moving towards low-carbon development.

Timeframe: The development (18 months) and implementation (66 months) of the Liberian LCDS will take about seven years.

Baseline Scenario: Total national emissions in 2000 were about 3,623 Gg CO_2 equivalent, giving per capita emissions of 13.5 tCO_2e. Liberia is willing to participate in the global effort to reduce its current national emissions and develop and implement policies and strategies to develop sustainably and thus contribute minimally to future global warming.

Expected Emission Reduction: Specific emission reductions will be assessed during the development of the LCDS. During the development of this mitigation document, assessment of the expected emission reduction has not been possible due to time constraints and limited human, technical, and technological capacities. Some targets are proposed in the next paragraph.

Description and Specification of Targets: The proposed targets include revision of GHG emission levels from the forestry sector to uptake levels (source to a sink) and reduction of the year 2000 emissions from the waste management category by 50% by 2030, from animal husbandry and rice cultivation by 50% by 2030, and from the transport sector by 50% by 2030.

Sustainable Development Impacts: The development and implementation of an LCDS in Liberia will provide the country with the technical and technological capacity to develop sustainably. Appropriate policies and regulations with sustainable indicators will be available and implemented.

Requested Funding and Support: The cost of the development of the LCDS is about US$850,000, and this support is requested. Other support requested includes capacity building and technical and technological assistance.

Implementation Plan and Partners: The development of the LCDS is Liberia's highest priority mitigation measure. Its implementation is projected to begin in the early part of 2013 with the availability of the support requested above. The EPA, Ministry of Planning and Economic Affairs, and the Ministry of Finance will lead the coordination and execution of the development of the strategy. Sectoral institutions (finance, agriculture, energy, education, forestry, and environment) will be responsible for leading the development of the sectoral components of the LCDS.

Monitoring and Evaluation: Monitoring and evaluation of the development of the LCDS of Liberia will have national and international components. The donor will fill in the monitoring and evaluation mission to Liberia and will work with the UNFCCC Focal Point to conduct the exercise. National monitoring and evaluation will be conducted by the UNFCCC Focal Secretariat.

Project Title: Promoting the Use of Energy-Efficient Cooking Stoves and Efficient Charcoal-Production Kilns.

Description of the Current Situation of the Energy Sector: Liberia derives its energy from four sources. These are fuel wood, petroleum products, electricity, and renewable energy. According to the 2005 Household Energy Survey (HES), fuel wood accounted for more than 80% of the total energy consumed. The same survey revealed that fuel wood accounted for 97% (95% firewood and 2% charcoal) of the total household energy consumption, petroleum products 1.60% (1.09% kerosene and 0.51% LPG), electricity 0.9%, and renewable biomass 0.4%. This shows the extreme level of pressure on Liberia's forest resource.

Justification of Proposed Project: The dependency on Liberia's forest to meet the cooking fuel needs of the population is very great. The demand has significantly depleted the forest. Besides the issue of the forest, household expenditures on cooking fuel are significant. To help with this problem, 200,000 improved cooking stoves (100,000 each of charcoal and firewood stoves) are targeted to be distributed by 2030. This proposed project intends to train four persons (two for charcoal and two for firewood) per region in fabricating improved cooking stoves. The cost of each improved cooking stove will be L$7 in order to make the stoves more affordable. This scenario will save 452,453.36 tons of wood and 419,486.11 tons of charcoal. The policy will save households a total of L$135,914,230.07 within the timeframe set for the implementation of this policy. This project's benefit in terms of money saved by the people of Liberia by far outweighs the cost of implementing the project. In addition to the monetary saving to households, the stove project will greatly reduce indoor pollution and its related health implications, thus reducing money spent on healthcare. The rate of deforestation and its deleterious effects will also be minimized by this policy.

Project time Frame: 2000–2030

Baseline Scenarios: With the baseline scenario, emissions from the use of fuel wood (firewood and charcoal) are expected to reach 41,510,894 tons of GHG emissions by 2030

Expected Emission Reduction: A total of 9,071,230.50 tons of GHG emission will be saved by 2030 compared to the reference year 2000. The results from this scenario show that major savings in both CO_2 emissions and energy consumption will be realized by simply popularizing the use of improved cooking stoves that will save up to 100,000 TOE fuel wood by

2030. The cumulative savings for wood and charcoal for urban households will be around 850,000 TOE.

Description and Specification: This project aims to produce 200,000 improved cooking stoves (100,000 each of charcoal and firewood stoves), which are targeted to be distributed by 2030. The project intends to train four persons (two for charcoal and two for firewood) per region in making improved cooking stoves. The cost of each improved cooking stoves will be subsidized at L$7 in order to make the stove more affordable. With the implementation of this project, 452,453.36 tons of wood and 419,486.11 tons of charcoal will be saved. A total of 9,071,204.80 tons of GHG emissions will be reduced with the implementation of this policy scenario by 2030. The project also intends to educate the general public on the benefit of using improved cooking stoves through preparing informative leaflets and TV and radio panel discussions.

Requested Funding and Other Support: The implementation of this policy is estimated at US$1.405 million. Other support requested includes capacity building and technical and technological assistance for the implementation of the project.

Implementation: The project will be implemented within five years by the EPA in collaboration with the Ministry of Gender and Development, Rural Renewable Energy Agency and the Ministry of Youth and Sport.

Monitoring and Evaluation: The UNFCCC Focal Secretariat and the Department of Energy will conduct monitoring and evaluation at the national level. External monitoring and evaluation will be based on the measurement, reporting, and verification (MRV) system in place according to COP decisions and procedures.

Project Title: Developing Hydroelectric Power Facilities to Reduce GHG Emissions and Consumption of Petroleum Products for Electric Power Generation

Description of Current Situation of the Electricity Sector: There is currently only one small hydropower plant with the installed capacity of four MW on the Farmington River. It is operated by the Firestone Company. The 64MW Mount Coffee hydropower plant that was serving the capital of Monrovia and its environs and the micro hydro plant (30KW) in Yandehun, Upper Lofa County were both destroyed during the fourteen years of civil war.

Justification of Proposed Project: The project will contribute to mitigating climate change in the energy sector by reducing petroleum product consumption for electric power generation. Hydro is a means of producing cheaper energy, which contributes to Millennium Development Goals (MDGs) and poverty reduction and supports income generation and education and health activities.

Project Time Frame: The project will take five years to install ten-to-fifteen mini and micro hydro projects around the country.

Baseline Scenarios: Liberia is endowed with six principal river basins and numerous small- to medium-sized rivers and streams throughout the country. Many of them have been assessed as having hydropower potential. It is estimated that up to 1000MW of hydropower could be available from the development of these rivers and streams.

Expected Emission Reduction: If we assume a 100MW of total installed capacity of various sizes of mini and micro hydro plants around the country, this project will save the country an equivalent amount of GHG emissions from the use of petroleum products.

Description and Specification: This project aims to develop a total of up to 100MW of installed hydro electric capacity consisting of fifteen or more mini and micro hydro power units around the country. With the implementation of this project, regional electric utilities will be developed to interconnect transmission grids thereby reaching all the targeted communities. The project also intends to create a policy of public-private sector partnership during the process of developing institutional capacity for independent power production for local communities.

Requested Funding and Other Support: The estimated investment for the proposed development of mini and micro hydro projects across the country is US$100 million for the total 100MW installed capacity. Additionally the project will require investment in transmission and distribution and managerial capacity. We estimate this additional cost to be a minimum of US$50 million.

Implementation: The project will be implemented within ten to fifteen years, and implementation will be led by the Department of Energy and the Liberia Electricity Corporation (LEC) in close collaboration with the relevant government agencies and NGOs.

Monitoring and Evaluation: The UNFCCC Focal Secretariat, the Department of Energy, and the LEC will conduct national level monitoring and evaluation. External monitoring and evaluation will be based on the MRV system in place according to COP decisions and procedures.

Project Title: Integrated Waste Management in Liberia

Current Situation: In Liberia waste management has become a serious issue. Over time people began to dispose of their waste in wetlands and drainages and also burn waste, which emits GHG into the atmosphere. This improper disposal of waste continues and contributes to the increase in the concentration of GHG. The following are lacking in Liberia:

- A waste disposal assessment plan.
- An integrated waste management plan.
- A national waste management profile.
- A waste management strategy.
- A waste recycling strategy and implementation.
- Landfill development.
- Capacity for comprehensive composting of waste into natural fertilizer production.

Justification: As climate change is the world's major challenge, it is important to reduce the amount of GHG from the waste sector in Liberia. Integrated waste management measures, when put in place, will reduce the volume of waste that is placed in the streets and other public places. From the standpoint of sustainable developmental, integrated waste management will provide a healthy environment for the people by providing jobs and building capacity and healthy living conditions and livelihoods.

Timeframe: This project will cover a period of six years with the first six months dedicated to creating awareness in order to enhance project implementation.

Baseline Scenario: The improper disposal and burning of waste in the environment is common in peri-urban and rural communities. The absence of incinerators in key public areas contributes to the waste problem. Furthermore, this environmental deterioration has become in Liberia not just a matter of aesthetics or quality of life but a serious issue involving the diminishing of economic productivity, health problems, water quality deterioration, and the acceleration of social dislocation.

Expected Emission Reduction: Over 75% of Liberia's peri-urban towns do not possess adequate and meaningful waste management. The idea of sustainability thus serves as a guide to decisions affecting the management of the urban system. In this light, based upon the project implementation, emissions will be reduced by 75%.

Description and Specification of Target: Municipalities, communities, industries, factories, etc.

Sustainable Development Impacts: The health of the people will be improved, communities will be saved, livelihoods will be improved through job creation and industries, and factories will be able to take care of their employees.

Requested Funding and Support: This project will cost US$200 million with support from donors (Global Environment Facility [GEF], UNEP, UNDP, Least Developed Country [LDC] Fund, etc.) and the GOL.

Implementation Plan and Partners: GEF, UNEP, UNDP, LDC Fund, etc., and GOL.

Monitoring and Evaluation: There will be an intensive monitoring and evaluation of the activities of the project involving funding donors to ensure that the project is carried out and that progress is measured against desired objectives.