Climate Change Adaptation and Integrated Water Resource Management in the Water Sector in Liberia: Review Study

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Abstract: Climate-related adaptation effects include dearth and overflow resistance, which are changes that may result in a decline in the availability and quality. Given that certain effects of climate change are irreversible, adaptation is the prudent course of action. Climate change is a global problem in the modern and contemporary world, and its consequences on the environment and water resources are significant. The adaptation to climate change and integrated water resource management in the water industry were the subjects of this research project, which also included an evaluation and secondary analysis of the existing studies on adaptation to climate change and integrated water resource management in the water industry. What has evolved is our understanding and application of a comprehensive set of water management solutions that comply to contemporary regulations and concepts. While the study focused on the most critical issues affecting the country's water management system, integrated water resource management (IWRM) plan, and efforts to adapt to climate change in the water sector, it also examined seminal research publications from the perspective of sub-regional activities on integrated water resource management, climate change adaptation, and the water sector in a few western African nations, specifically. It analyses shortcomings and proposes realistic solutions for the long-term adaptation of the water industry to climate change.

Keywords: Climate adaptation: It is a term that refers to activities that mitigate the adverse effects of climate change while focusing on prospective future possibilities. It entails adopting policies and behaviours to observe or expected climate changes.

Integrated Water Resource Management: The integrated water resources management plan assists in the sustainable and balanced management and development of water and related resources while taking social, economic, and environmental considerations into account. It takes into account the numerous diverse and competing stakeholder groups, the industries that consume and misuse water, and environmental issues.

Liberia: Liberia is a country located in West Africa on the African continent's coast. Liberia is bounded on the south by the Atlantic Ocean and on the north by Guinea, Côte d'Ivoire, and Sierra Leone. Liberia, a former US colony, did not gain ultimate independence from the US until 1862.

Introduction

Background

Climate change has a substantial impact on the availability and safety of drinking water. Droughts, flooding, and other forms of water pollution affect a large number of people worldwide. Although climate change has had far-reaching and pervasive effects on livelihoods, attitudes regarding water management must shift in order to properly adjust tothe impacts and challenges of climate change. Engineers working in the water sector are well aware of the influence of climate change on water resource management.

Climate change is predicted to have such an influence on hydrological systems that new ways will be necessary to better protect investments, with adaptation playing a critical part in this endeavour. The water sector's adaptation to

climate change and integrated water resource management are separated into two primary components. Part I examines the theoretical and methodological foundations of climate systems, as well as the adaptation and management choices available to the water sector in response to climate change and variability. Part II contains case studies on climate change adaptation from around the world on a variety of subjects.

Global climate change has increased by an average of 0.5 degrees Celsius over the last century, in part due to human-caused greenhouse gas emissions. Climate models suggest that unless significant measures to curb emissions are done, the Earth will warm an additional 1.4 to 5.8 degrees Celsius during the next century. These changes will have a large destabilizing effect on the hydrological cycle, increasing precipitation and streamflow variability and intensifying extreme hydrological events.

Engineers and specialists in the water sector must adapt to climate change. Existing commitments to reduce greenhouse gas emissions are insufficient to halt climate change, demanding adaptation.

Liberia is one of the wettest countries on Earth, with rivers, jungles, mangroves, and marshes aplenty. It does, however, lack the required infrastructure and services to ensure that everyone has access to safe drinking water. Sanitation is inadequate, with the vast majority of rural populations lacking access to appropriate toilets and latrines and having to defecate in public. According to the Joint Monitoring Programme, more than 42% of Liberia's population defecates openly in 2017. (JMP 2017). According to the JMP 2017, quality drinking water and sanitation facilities are accessible to below 10% of the Liberian population. All of this is a result of climate change and inefficient water resource management.

Effective water resource management is crucial for economic resuscitation because it facilitates energy generation, agricultural irrigation, and flood control, all of which improve living conditions and provide jobs and economic growth. Simultaneously, providing water and sanitation services contributes to a healthier and wealthier society, directly benefiting women's and children's health.

Problem Statement

Africa will account for more than half of global population growth between now and 2050. As Africa's water needs increase to sustain population growth and development across the continent, and as pollution levels rise, the goal of implementing effective water resource management remains a priority.

In Liberia, obstacles to effective water resource management include massive poverty, a dearth of water control facilities, and, perhaps most critically, climate change. This constraint is critical in view of Liberia's significant rainfall variability, which has been increased by climatic changes. Political uncertainty in the country is a serious impediment, as successful water resource management requires powerful political will and lengthy efforts to develop effective institutional and legal frameworks.

Additionally, there is a limited budget for the water sector, — especially for the governance of water planning and improvement; infrastructural resource capacity gap that exists at all stages; continuous and firmly ingrained gender disparities; and the private sector's and other non-state actors' marginal roles in water-related decision-making processes.

Integrating water resources management (IWRM) helps meet not only water security objectives, but also those for sustainable agriculture and energy production, resilient and sustainable towns and communities, and health and gender equality.

Water is the primary method by which climate change affects the Ecological environment and, thus, human life and well-being. Water-related implications from climate change are already being felt in the form of more frequent and extreme flooding and drought. Steadily increasing average temperatures and changes in rainfall and temperature extremes are expected to have an effect on water availability via shifts in precipitation patterns, soil humidity, glacier and ice/snow melt, and river and groundwater flow; these factors are also expected to contribute to further deterioration of water quality. The poor, who are particularly vulnerable, are also likely to bear a significant share of the burden.

Recognize and successfully responding to this gives opportunities for growth. Appropriate adaptation strategies rely on established land and water management practices to increase future climate change resilience, hence increasing water security. To adapt, fresh technology and integrated solutions of appropriate size are necessary.

Aim of the study

The purpose of this study is to enlighten water professionals, managers, and policymakers on climate change, its impacts, and strategies for adaptation. It makes recommendations and demonstrates how water management may and should reduce vulnerability to future climate change-related system changes.

Additionally, this effort will examine the susceptibility of the water sector to climate change impacts and adaptation options, as well as integrated water resource management. Adaptation measures can take the shape of targeted supply- and demand-side activities, as well as broader measures such as safety net programs, in the water sector. We have identified numerous adaptation strategies, including small-scale irrigation systems, rangeland management, Multiple Use Systems/Services (MUS), and social protection, and will assess their effectiveness in enhancing and/or strengthening local coping capacity.

Limitation of the study

In spite of the fact that the study is primarily concerned with how the effects of climate change, its impactsand strategies for adaptation, its scope is limited to only Liberia and its issues. As a result, the information acquired and considered was relevant to Liberia. A focus on climate change has been established for this study.

Methodology for review research

The adaptation to climate change and integrated water resource management in the water industry are the subjects of this research project, which will include a review and secondary analysis of the international literature on adaptation to climatic change and integrated water resource management in the water industry. The most important issues affecting the country's water management system, the country's integrated water resource management (IWRM) plan, and the country's attempts to adapt to climate change in the water sector were highlighted.

This study examines seminal research publications from the sub-region on integrated water resource management, climate change adaptation, and the water sector in a few western African nations, with a particular emphasis on Nigeria. It identifies inadequacies and makes practical solutions for the water industry's long-term climate change adaptation.

Literature Review

Freshwater is a finite, precious, and fragile resource. Freshwater stress and scarcity are posing a significant threat to economic growth, social cohesion, and political stability in a number of countries as a result of climate change's effect on water supplies.

Climate change should therefore be incorporated into development planning and rule-based governance at all levels and sectors throughout the country, particularly in relation to water resources and greenhouse gas emissions. Water management improvements in collaboration with other sectors including energy, agriculture, industry, tourism, transportation, housing, and waste management. To slow climate change in the short term, adaptation strategies must be developed and implemented.

Climate change adaptation and integrated water resource management are two of the challenges confronting the water sector (Fulco Ludwig & Erik Slobbe, October 2014). This article compares and contrasts essential aspects of climate change adaptation and IWRM. The primary distinction between the two is that IWRM is more concerned with current and historical issues, whereas adaptation is more concerned with the (long-term) future. This research emphasizes the inherent difficulties associated with adapting to climate change, as well as the considerable uncertainty associated with future projections.

Vertical integration for climate change adaptation in the water industry: Lessons from Africa and India's decentralization. (With additional contributions from Gina Ziervogel, Adelina Mensah, and others). Vertical integration, which involves the establishment of strategic ties between national and subnational levels, is being touted as a critical component of climate change adaptation. Decentralization has served a similar goal for decades by redistributing authority and responsibility within an organization. Based on four case studies in semi-arid Africa and India, this article argues that vertical integration for climate change adaptation should incorporate lessons learned from decentralization in terms of natural resource management, notably in the water sector. The research focuses on two critical characteristics of adaptation to climate change: participation and flexibility.

Innovation and adaptation to climate change in Africa's water industry (Linus Nyimul, May 2021) Climate change is expected to have a devastating effect on Africa, with water being one of the most vulnerable sectors. The advancements in this field are being marketed as a means of resolving the problem. Linus Nyimul examined the extent to which the water sector's susceptibility to climate change encourages these innovations by analyzing data on water-related climate change adaption technological advancements.

Recognize Nigeria's institutional constraints in adapting to the effects of climate change on water resources (Sola Ojo, Henry Mensah, et al, 2020). The purpose of this research is to examine the establishment of institutional obstacles to adaptation to the effects of climate change on Nigeria's water resources. The data for this study were gathered through in-depth interviews with institutional leaders in the domains of water resources management and emergency management, as well as a review of secondary literature in databases such as Google Scholar, Scopus, and Web of Science.

The findings indicate that inadequacies in hydrological data management, a lack of public and decision-maker awareness about climate change adaptation, financial constraints, a lack of political will to pass critical bills into law, and an insufficient institutional and legal framework are the primary institutional barriers to climate change adaptation in Nigeria. To ensure long-term water resource management, it is necessary to build an institutional and legislative framework, information management procedures, public awareness, and participatory water resource management.

Nigeria's water resources development and utilization: An evaluation of the integrated water resources management technique (Ben U. Ngene, Christiana O. Nwafo, et al, 2021). The goal of this research is to assess the current state and restrictions of water resource management in Nigeria, as well as the potential benefits of implementing anintegrated water management plan for the country's socio-economic growth. As public support for integrated water resources management (IWRM) grows, it is critical to assess if it is feasible in Nigeria, particularly given the country's vast natural resources and the fact that numerous Nigerian states face water scarcity.

This study studies the literature on the implementation of integrated water resources management (IWRM) throughout the world, with a particular emphasis on poor nations in Africa, and draws parallels between their experiences and the country's IWRM potential. The article discusses the benefits of IWRM adoption in Nigeria, as well as the dangers that must be avoided when implementing IWRM. One of the impediments to sustainable water resource management in the country is a lack of efficient water governance, which has had a negative impact on the quality of water legislation and institutional structures.

According to the conclusions of this study, the slow development of IWRM implementation in Nigeria is due to a lack of clarity in the country's IWRM implementation framework. According to the research findings, an iterative approach to IWRM implementation is recommended since it is adaptable and can be tailored to Nigeria's unique water concerns.

In the context of climate change, Lagos, Nigeria's megacity, faces water resource concerns (Mohammed SanusiShiru, Saleem Salman, et al, 2020). This study explores the water resources and environmental difficulties that the Nigerian megacity of Lagos faces in light of climate change. Lagos' population has grown at an alarming rate as a result of its role as a commercial hub, leading to recurring water and environmental calamity.

Water issues were addressed in this study by a combination of field observation, sample analysis, and in-depth interviews. Climate observations were integrated with estimates from a general circulation model (GCM) and groundwater data to assess water concerns associated with climate change.

According to a new study, the city of Lagos's lack of adequate water delivery infrastructure has forced a large proportion of its people to rely on groundwater, resulting in groundwater overdraft. Saltwater intrusion and subsidence have occurred as a result of overexploitation of groundwater. In wells near a dump, elevated quantities of heavy metals were observed.

Study Area

Major source of water

Liberia receives an average of 2700 millimetres of rain every year, with average monthly rainfall ranging between 150 millimetres and 350 millimetres (150 millimetres to 350 millimetres each month) throughout the rainy season (May to October) (Ndehedehe et al., 2016) Liberia is traversed by six major rivers, which account for almost two-thirds of the country (UNEP, 2004). Sierra Leone and Côte d'Ivoire share the Mano, Cestos, and Cavalla basins, whereas Saint Paul, Lofa Saint John, and basins are shared by Guinea (USAID, 2008). The country's principal rivers travel northeast to southwest due to the terrain, finally emptying into the Atlantic Ocean.

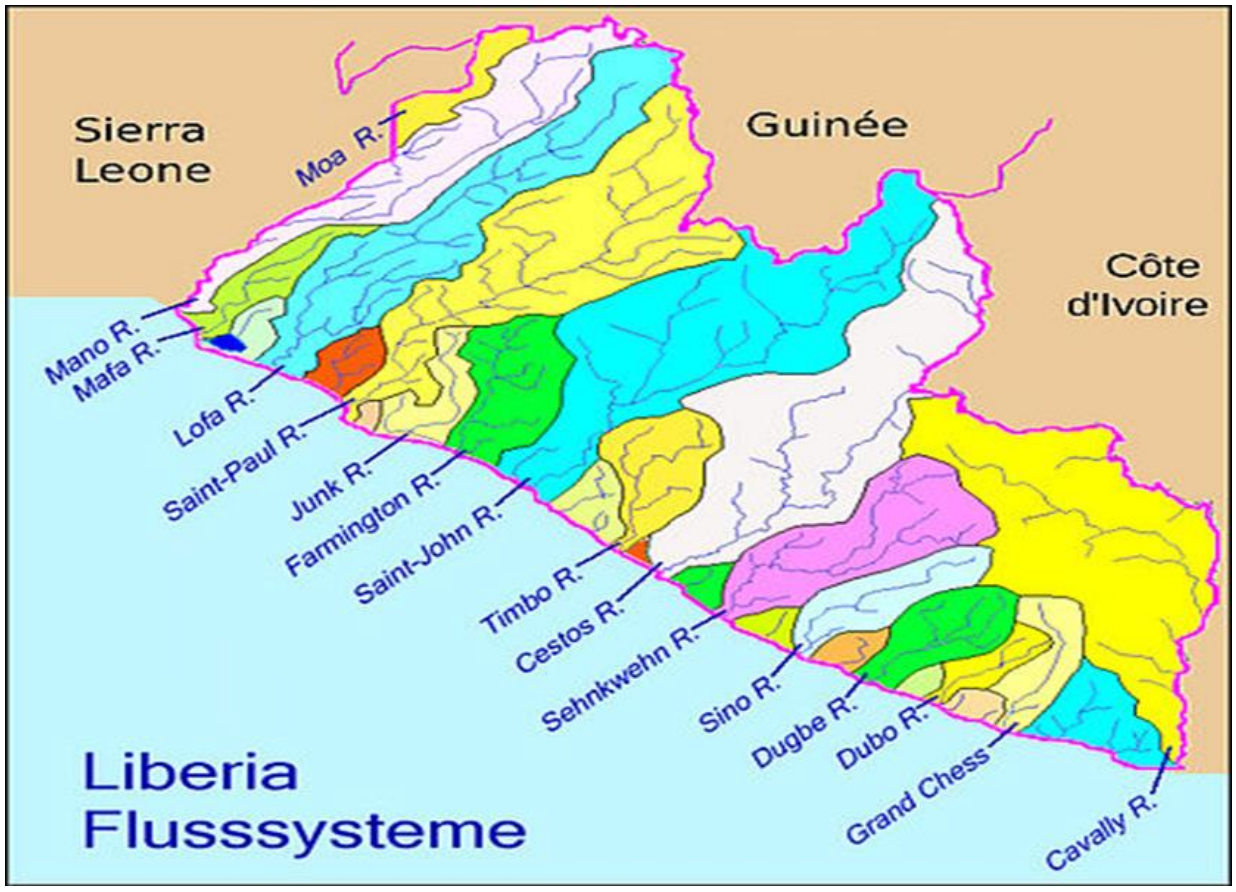


Figure: A map of Liberia with major rivers (google image)

While freshwater is not scarce in Liberia, it is a vital resource for both people and the economy. Both rural and urban communities rely significantly on groundwater resources; just 62% of Liberians have access to protected water sources (MPEA, 2013), the majority of which are shallow, uncontrolled wells or boreholes with hand pumps. Certain communities acquire their water from surface sources such as springs or rain harvesting (UNDP, 2006). According to (UNDP, 2006), Kakata, Gbarnga, Monrovia, and Voinjama were among the 11 cities in Liberia with piped water. The majority of water sources, as well as Monrovia's 53 largest, were reliant on the collection and treatment of surface water (UNEP, 2004), with the reliance on four groundwater sources (USAID, 2008).

Precipitation in the study area

Precipitation amount and distribution will shift across the region, with major volatility projected in Liberia in particular, according to current predictions. Precipitation at a national aggregate level is anticipated to stay largely stable until the 2090s under a high-emission scenario, despite significant inter-annual variability. Despite the instability, the southern regions of the country are predicted to have a drop in the amount of rain that falls during the dry season by mid-century.

Liberia's irregular rainfall patterns are likely to wreak havoc on the country's shoreline, forestry, and agricultural sectors. This has the potential to cause floods in low-lying locations. According to Liberia's First National Communication (2013), rising temperatures and widespread changes in rainfall are disrupting the country's water balance, particularly in the Cavalla, St. John, and St. Paul River Basins, and complicating agriculture due to soil runoff and heavy rain.

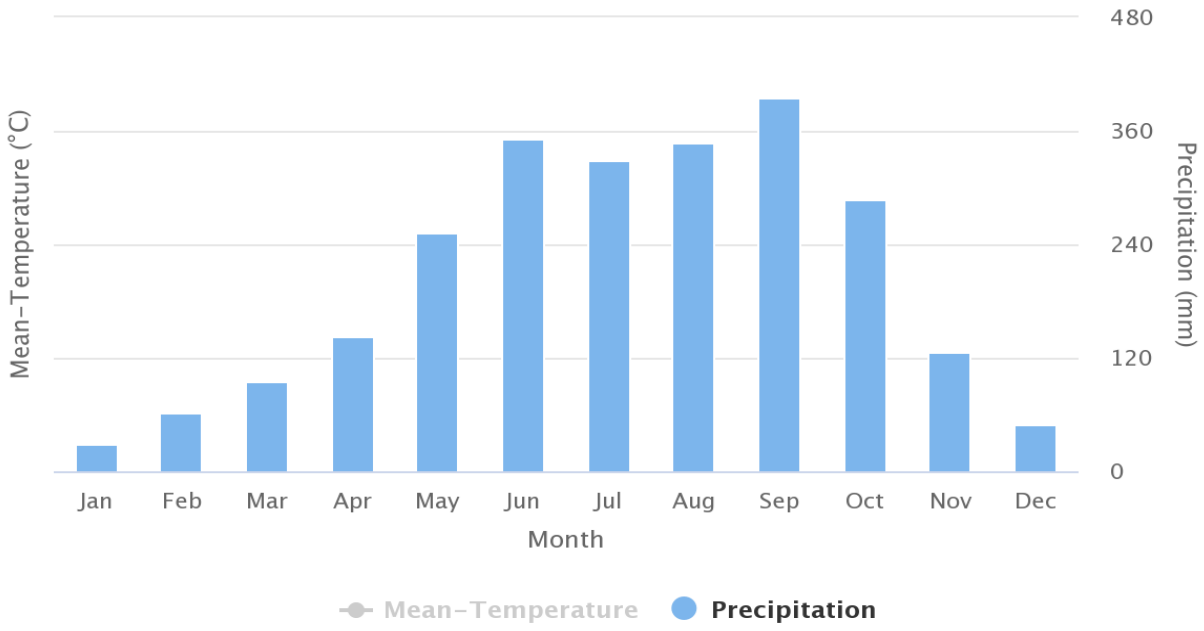


Figure: World Bank Data

Temperature in the study area

Climate change is expected to increase temperatures and deplete Liberia's water supply; some places may face flooding as a result of increased rainfall intensity, coastal erosion, and sea-level rise. The West African Region, as well as Liberia, are very vulnerable to expected climatic trends such as rising temperatures, increased precipitation variability, and the possibility of more severe rainfall events. 22 Projections indicate that monthly temperatures will climb by 3.2°C in the 2080s, and by more than 4.8°C by the end of the century if emissions continue to rise.

While the average annual temperature in the country is predicted to rise, warming rates in the northern interior are expected to be higher and faster than in the coastal zones. Under a high-emission scenario, 'hot' days are expected to occur in 24–65 percent of all days by mid-century and in 29–90 percent of all days by the end of the century. The greatest fast increase will occur in July, August, and September, however, the 'hot season' will likely begin earlier and remain longer. By the mid- and late-century, hot evenings are anticipated to account for 37–89 percent and 49–95 percent, respectively, of all nights. 23 Temperature rise is anticipated to accelerate through the end of the century under all emission scenarios. Increased and intense heat will have a detrimental effect on human and animal health, agriculture, and ecosystems.

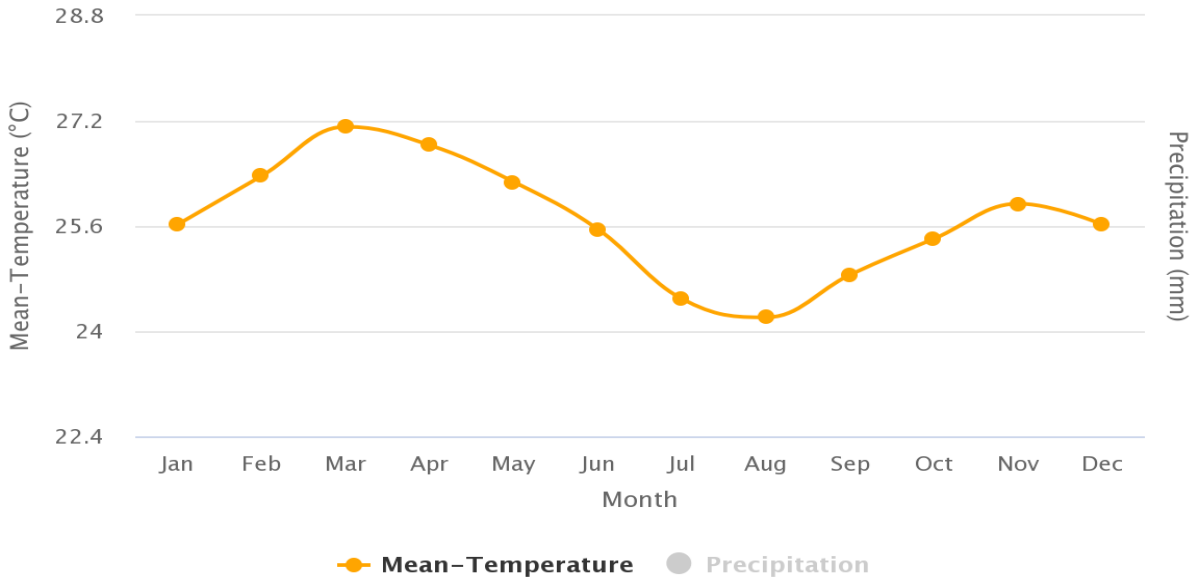


Figure: World Bank Data

Integrated Water Resource Management (IWRM)

Liberia has an abundance of water resources, but good management and planning are critical for attaining national priorities and objectives and preventing conflicts between competing users. This issue is exacerbated by a plethora of administrative, technological, and political obstacles, not the least of which is the country's dire economic state following 14 years of civil conflict.

Liberia's water governance is fragmented, with little cooperation between the various institutions. The absence of a comprehensive framework for managing water resources is one of the primary causes of serious water problems. The water's quality is said to be deteriorating. The National Integrated Water Resources Management Policy, which includes a series of high-level political decisions about how water resources will be managed, priorities will be established, and relevant agencies will be mandated, is the first step toward developing a framework for water resource management in Liberia.

To achieve sound water governance, Integrated Water Resources Management Policy must constitutionally be founded on water resource management principles. It is a component of the enabling environment that promotes the effectiveness of government and private sector programs and actions.

Key Issues in Water Management in Liberia

Population expansion, unregulated rubbish disposal, agricultural operations, mining, logging, aquaculture, and other industrial activities all place a strain on available water. Concerns about deteriorating water quality from upstream to downstream are spreading, and industrialized regions exacerbate the situation.

Water quality degradation is a health hazard since adequate water supply and sewerage infrastructure are missing and household water is typically acquired directly from surface water bodies. Lagoons, estuaries, deltas, and mangrove habitats are examples of coastal ecosystems with great and critical productivity that must be safeguarded, not least because they provide a significant portion of fish protein.

The MDGs are being harmed by the 'explosion' of urban populations caused by people shifting from rural to urban areas, a lack of human capacity for resource management, and other factors. The following are the primary issues that must be addressed in order to comply with the Integrated Water Resources Management standard:

a. **Urban population growth:** The population of the majority of Liberian cities is growing exponentially, putting a burden on social amenities like proper water supply and sanitation. Population growth frequently places a major demand on water supplies. Addressing this propensity is a critical aspect of water resource management.

b. **Inadequate human resource capabilities:** Water resource management is harmed by a scarcity of suitably trained water resource practitioners, exacerbated by the 'brain drain' occurring in third-world nations such as Liberia. There are few training opportunities.

c. **Unrestricted waste disposal:**Disposing of rubbish in an indiscriminate manner creates significant challenges for water resource management. The majority of these wastes contribute significantly to pollution and clog drainage systems.

d. **A number of ministries and institutions are in charge of water-related tasks**

Water resource development status for diverse activities (aquaculture, logging, mining, agricultural, and activities in other economic sectors)

e. **Human interference with mangrove ecosystems, coastal lagoon, estuarine, and delta**

Integrated Water Resource Management (IWRM) Policy in Liberia

The Integrated Water Resources Management Policy advocates a new integrated approach to water resource management that is both sustainable and practicable. This new strategy is based on a constant awareness of both the social and economic worth of water. As a result, water resource development should prioritize maximizing Liberia's net benefit.

Despite the fact that the state is ultimately responsible for water resources, the policy's objective is to foster a sense of public ownership by mobilizing citizens' resources to assist in the management, protection, and conservation of this natural resource. The policy is intended to be a comprehensive document that must be acknowledged by all stakeholders and incorporated into all public and private activities and operations. The policy is broadly classified into two types;

1. **Utilization of water resources:** Covers the policy objectives, guiding concepts, and methods for the production and utilization of water for a variety of purposes to human consumption [domestic water supply], food security [agricultural], industry, and non-revenue water uses such as hydropower, recreation, non-revenue water (fire hydrants and trucks), and ecosystem preservation.

2. **Water resources management**: The management framework is addressed, which includes policy objectives, concepts, and strategies for monitoring, assessing, allocating, and conserving natural resources. The Ministry of Lands, Mines, and Energy will be responsible for all water resource management, regulation, and coordination.

Liberia has one of the highest precipitation rates in the world (4,000 to 5000 mm/year), with a total renewable water supply of 232 kilometres per year and a capital supply of 71,000 kilometres per year. Total water withdrawals were predicted to be 106.8 million m3 in 2000, with agriculture accounting for 57%, households accounting for 28%, and industry accounting for 15%. A published report from the United Nations Food and Agriculture Organization (FAO) was provided in 2005.

Climate Change Adaptation in the water sector in Liberia

Greater temperatures, increased annual precipitation, and an increased frequency of severe rain events are all consequences of Liberia's climatic variability and change. The adverse effects of climate change jeopardize the country's socio-economic progress. Liberia's incapacity to adapt to climate change is partly attributable to the negative consequences of the 1989–2003 civil conflict.

Since the conflict, the administration has worked with a range of foreign and domestic institutions and organizations to better understand and address the country's climate change challenges. Among the other conditions are data about the country's immediate and long-term climate change consequences and vulnerabilities, as well as the financial, technological, and human resources necessary to prioritize adaptation and successfully implement adaptation plans and strategies.

Seasonal precipitation changes and rising temperatures will have a detrimental effect on the water balance, reducing overall water levels and/or degrading water quality. By the 2020s, precipitation and temperature changes are expected to decrease runoff in the catchment basin St. Paul River by 0.7–25%, affecting both potential hydropower generation at the Mount Coffee project and Monrovia's water supply. Water and sanitation systems were significantly affected during the civil conflict, although significant progress has been made in the last decade.

In rural areas, the bulk of the water is obtained from shallow wells, the levels of which fluctuate with rainfall, particularly during the dry season (December–April). While nearly three-quarters of the population has improved access to drinking water, only 7% of rural households and 29% of city people have improved access to sanitary facilities.

Severe precipitation is likely to have a detrimental effect on metropolitan water infrastructure, as higher water volumes overwhelm sewage systems and water treatment plants. This could result in increased runoff into rivers and lakes, contaminating them with sediment, nutrients, pollutants, trash, and animal waste, rendering them unusable, dangerous, or requiring treatment, and increasing the expense of water purification to provide communities with potable water.

Climate Change Vulnerability in Liberia

Climate change will be a significant hindrance to Liberia's development ambitions as the climate changes. Agriculture has climate-related challenges such as seasonal variations in rainfall patterns and an increase in rainfall during critical periods of the growing season, which can result in decreased agricultural yields.

Liberia's government has devised a number of policy frameworks aimed at revitalizing agricultural activities in order to contribute to equitable and sustainable economic development and growth, as well as food and nutrition security and employment.

One of the project's objectives was to encourage farmers to adopt technologies that would increase their productivity while also enabling them to withstand the negative effects of climate change. As a result of the project's success, eight rural disadvantaged agriculture-dependent communities in two counties have enhanced their resistance to climate change while decreasing their vulnerability to its effects.

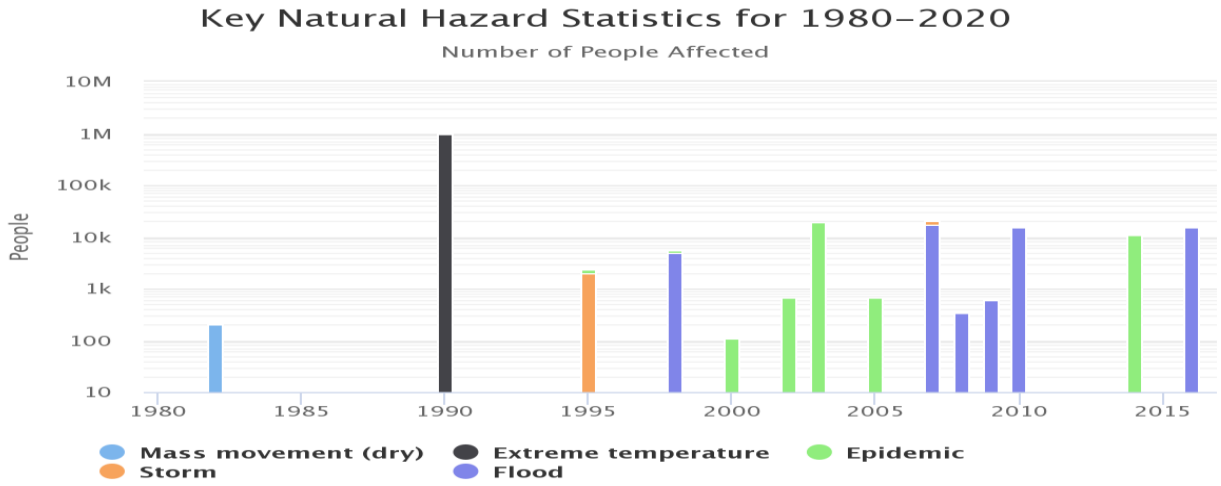
Natural disasters and hydro-meteorological issues put Liberia's infrastructure at risk. Extreme weather events such as severe rain and drought are expected to become more frequent in West Africa as a result of climate change. While Liberia is susceptible to an increase in flooding nevertheless, not in the case of drought in the movement of people in neighbouring nations is likely to become a new source of concern in the near future.

Rainfall extremes, storm surges, sea-level rise, and increasing erosion all jeopardize urban and rural infrastructure. Additionally, heavily populated coastal regions would be subject to frequent flooding, increasing coastline erosion, and sea-level rise as a result of rising sea levels. This is almost certain to result in significant financial losses, as well as damage to agricultural areas and infrastructure, as well as human fatalities.

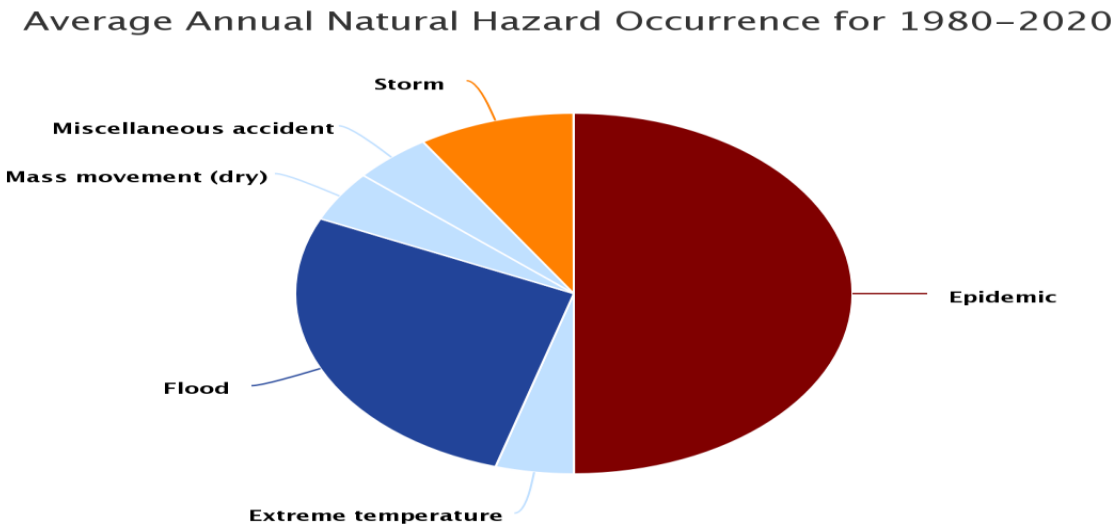
Climate change is expected to exacerbate the frequency and severity of natural disasters in Liberia by resulting in more extreme temperatures and rainfall patterns, as well as rising temperatures and extended heatwaves. The country's vulnerability is exacerbated by its high poverty rate and substantial reliance on 'climate change vulnerable' industries like as agriculture, fisheries, mining, and forestry, which are all vulnerable to climate chang

Data source: Climate change Knowledge Portal (World Bank)

Global climate change, according to the current scientific consensus, has a huge impact on disaster management efforts and poses a significant threat to governments and humanitarian organizations' ability to meet the world's most vulnerable populations' growing demands. Due to the objectives of catastrophic risk management, it is



necessary to provide information that is succinct, simple to comprehend, and credible. If the data presented here serve as a guide for your thinking, you may have a greater knowledge of the frequency, effect, and incidence of natural disasters. Obtainable from the following sources: (PDF)



Data source: Climate change Knowledge Portal (World Bank)

To comprehend a country's historical susceptibility, it is necessary to examine both natural disasters and previous climatic conditions in relation to development contexts. This tool enables you to investigate a range of natural disasters, historical climate conditions, socioeconomic data, and development trends. To obtain a more comprehensive picture of historically sensitive locations, select the Development Context, a Natural Hazard, and a Climate Condition, and then flick the toggle left or right to overlay horizontally.

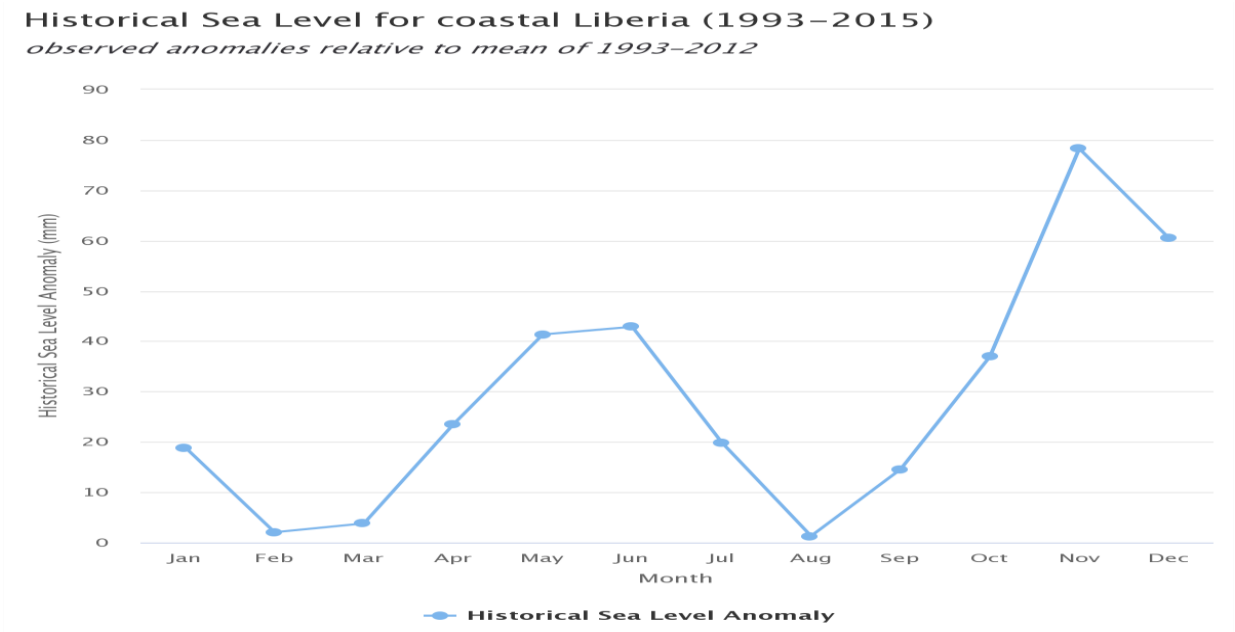
Sea Level Rise in Liberia

The planet's steady warming is directly contributing to global mean sea-level rise in two ways: (1) melting mountain glaciers and polar ice sheets increases the amount of water entering the ocean; and (2) warmer ocean water causes it

to expand, increasing the volume of water entering the ocean. Since 1880, the global mean sea level has risen by around 210–240 millimetres (mm), with the last two and a half decades accounting for almost a third of the rise. At the moment, the annual growth rate is 3 millimetres. Regional variations are caused by natural variability in regional winds and ocean currents and can occur over time intervals ranging from days to months or even decades. Along with global factors, local factors such as ground uplift (e.g., continued rebound from Ice Age glacier weight), changes in water tables due to water extraction or other water management practices, and even the effects of local erosion can all have a significant effect on the ground's stability.

The physical shoreline, as well as the coastal ecosystems that support it, are being strained by rising sea levels. Freshwater aquifers, which supply drinking water to cities and farms while also supporting natural ecosystems and animals, are particularly vulnerable to saltwater intrusion. Sea level will continue to rise for an extended period of time as global temperatures rise, owing to the large lag between reaching equilibrium and rising sea level. Future carbon dioxide emissions and global warming will be critical factors in determining the magnitude of the rise, and the rate ofrising may become increasingly dependent on glaciers and ice sheet melting. The gradual warming of the planet is directly contributing to global mean sea-level rise in two ways: (1) melting mountain glaciers and polar ice sheets increase the amount of water entering the ocean; and (2) warming the ocean water causes it to expand, increasing the volume of water entering the ocean. Since 1880, the global mean sea level has increased by around 210–240 millimetres (mm), with roughly a third of the increase occurring in the last two and a half decades. Annual growth is at approximately 3 millimetres. Regional variations exist as a result of natural variation in regional winds and ocean currents across time intervals ranging from days to months or even decades. Local factors such as ground uplift (e.g., continued rebound from Ice Age glacier weight), changes in water tables as a result of water extraction or other water management practices, and even the effects of local erosion can all have a significant effect on the ground's stability, in addition to global factors.

As a result of rising sea levels, both the physical shoreline and the coastal ecosystems that support it are under stress. Saltwater intrusions have the ability to wreak havoc on freshwater aquifers, which provide drinking water for communities and agriculture while also supporting natural ecosystems and wildlife. Due to the significant time lag between attaining equilibrium and rising sea levels, sea levels will continue to increase for an extended period as global temperatures rise. Future carbon dioxide emissions and global warming will be critical factors in determining the increase's magnitude, and the rate of growth may become increasingly dependent on the rate of glacier and ice sheet melting.



Data source: Climate change Knowledge Portal (World Bank

Conclusion and Recommendations

Conclusion

Climate change is a serious issue that is wreaking havoc on Liberia's water business, as this study demonstrated. As a result of this overall trend, minimum and maximum temperatures are increasing faster than global models anticipate, and wetter regimes are developing, most notably in the Guinea savanna. Nonetheless, there is a high level of vulnerability. Physical activity is high in low-income neighbourhoods, income is low, and physical activity is high, among other factors.

Infrastructure is either non-existent or rapidly deteriorating. As a result, the country's adaptability must be emphasized. If the measures proposed here are adopted, the country's vulnerability to climate change will be significantly reduced. Of course, all of these must be implemented in accordance with established policy procedures. The government's priority now is to guarantee that the current effort to establish a Climate Policy is completed as swiftly as possible and that the policy is implemented. The good news is that long-term success is inversely proportional to adaptability. Currently, the country is in severe need of economic development.

Recommendation

Transaction costs: The two types of charges that are most prominent are information costs and adjustment costs. The first refers to data collection costs, while the second refers to the costs associated with replacing long-lived capital in the water industry in order to adapt to climate change.

Coordination and government efforts. Despite the fact that public decision-makers are responsible for removing the aforementioned hurdles, they face similar impediments such as a lack of competence or financial resources. Additionally, the majority of options for water-related adaptation need extensive coordination at several levels of government.

Good Behaviour toward adaptation. All behavioural abnormalities are highlighted that lead person to make irrational decisions without analysing all relevant evidence and that occur at inopportune times. Social norms and cultural influences have also been shown to have a minimal effect on adaptation-related decision-making.
Certainty: Given its expanding trend, which includes future population increase, technical and economic improvements, and future climate change, it is one of the most significant impediments to water sector adaptation.

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