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Climate Change Adaptation and Integrated Water Resource Management in the Water Sector: A case study of Monrovia

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Abstract: *Climate change and the accompanying alterations in natural and human systems constitute the leading research today by scholars, governments, private sector actors, and NGOs. Water has been the source of all known human civilizations remains an indispensable element of life and the attending activities such as food production, industrial activities, energy production, etcetera. This research aimed to examine the impacts of climate change adaptation and integrated water resources management on water use and sustainability in Liberia. A systematic Literature Review of published journal articles was conducted on the subject to determine 1) the effectiveness of the IWRM framework implementation in the water sector of Liberia and 2) to examine the role of institutions, both public and private, in the formulation of adaptation strategies in the water sector in response to the growing impacts of climate change. Results suggest several constraints for IWRM implementation, ranging from the absence of an institutional framework to inadequate governmental support. Since its introduction, Liberia records the least score (15) in IWRM implementation status compared to other nations in West Africa, according to an FAO 2021. Little gains have been made in water resources management for urban settlements since 1995. However, there seems to be little progress in designing a national adaptation plan in the water sector on the future impacts of climate change. This research proffered workable remedies to the crisis in conclusion.*

Key Words: **Climate change, Integrated Water Resources Management, Water pollution, Monrovia, Climate change Adaptation, Climate Change Impact on Water Resources**

1. Introduction

Climate change and the accompanying alterations in natural and human systems constitute the leading research today by scholars, governments, private sector actors, and NGOs. Water has been the source of all known human civilizations remains an indispensable element of life and the attending activities such as food production, industrial activities, energy production, etcetera. As the principal medium through which climate change affects Earth's ecosystems and, therefore, human well-being, water is a critical component of any climate change mitigation plan (Giupponi & Gain, 2017). The shreds of evidence pointing to the direct impact of climate change on water resources remain unclear. However, it is a known fact that rising temperature increases evaporation leading to drought to traditionally dry regions of the globe and melting of glaciers, causing flooding in wetter areas. According to the Intergovernmental Panel on Climate Change (IPCC), an age of fast and accelerating climate change is unavoidable under ideal circumstances for optimizing coordinated worldwide action to decrease additional emissions of greenhouse gases into the atmosphere (Nyamwanza & Kujinga, 2017). The concept of integrated water resources management was introduced in the 20th century to, amongst other things, balance water demand to the many sectors. The Global Water partners, GWPs define integrated water resources management as "the promotion and coordination of development and management of water, land, and associated resources to optimize economic and social welfare equitably while ensuring the long-term viability of critical ecosystems and the environment" (Wang et al., 2019; GWP, 2000). Integrated water resources management as a practical water management approach is today faced with increased complications due to altering the global water cycle due to the exacerbation of the current climate crisis (Ludwig et al., 2014). This paper seeks to examine through Systematic Literature Review of peer-reviewed articles published on climate change adaptation and integrated water resources management in the water sector.

1.1 Problem statement

Water scarcity is considered a global crisis by science believers and doubters as people increasingly face water shortages across the globe. Climate change affects our planet disproportionately. An increase in precipitation in one region can be a drought for other areas. Liberia may be one of the wettest countries in the world (World Bank, 2021), access to safe, clean, and quality water for potable and sanitation use remains a challenge (UNICEF, 2017). The Republic of Liberia has one of the highest rates of water resources per capita in Africa; nonetheless, water quality and sanitation continue to be a serious concern, especially in large metropolitan areas such as the capital city of Monrovia. Integrated Water Resources Management has been most

recommended to address the growing water crisis globally. However, other nations' records show that the IWRM has not effectively addressed water disputes, especially in the developing world. A study by Aidam (2015) found that water pricing, one of the controversial principles of the IWRM, has a negative impact on water resources demand in Ghana.

1.2 Significance of the study

As the crisis of climate change surges, tackling the adverse impacts on almost all human systems becomes a global emergency inevitably. Liberia's position as of the countries with sufficient precipitation rates globally does not guarantee water security for multiple uses. Poor urban drainage infrastructure, ocean intrusion, and the recent growth of semi-industry have undermined safe water availability for portable use. According to the Joint Monitoring Project 2017, fewer than ten percent of Liberians can boast of access to regulated drinking water and sanitation facilities in aggregate (UNICEF, 2017; JMP, 2017). Securing the standard for quality portable for a city like Monrovia with an upward population trend will require adaptation mechanisms that work effectively.

1.3 Limitations and delimitation

Many types of research have been conducted on this topic. However, they have mostly been institutional, with specific targets determined by the donor country or organization funding the research. They have also not combined climate change adaptation and integrated water resources. This paper examines the climate change adaptation and integrated resource management in Monrovia in the drive to guarantee water security for the growing urban population. However, one major limitation of this research is the absence of primary data on water quality testing for consumption. The study relies almost entirely on secondary sources (Literature Review) to analyze the water situation in the study area and make inferences.

2. Literature Review

2.1 Overview of Liberia's water resources

Considered one of the wettest countries globally, Liberia is a small nation located on the west coast of Africa with an estimated population of about 5 million people spread across a landmass of approximately 96,320 km^2. Liberia is one of the wettest nations on the planet, with rivers, jungles, mangroves, and marshes aplenty (UNICEF, 2017). The total annual precipitation in Liberia is quite substantial, almost topping 2,500 millimeters on average (Liberia, 2021). Several significant river systems drain a great portion of the nation in Liberia. These rivers originate in neighboring countries and travel mostly from northeast to northwest. In addition, several small rivers run directly into the sea in the coastal zone ("Hydrogeology of Liberia," 2021). Liberia has six major rivers and a vast stretch of the Atlantic Ocean along the coast. Major rivers in Liberia include St. Paul, Cavalla, St. John, Cestos, Mano, and Lofa River. Liberia boasts of an abundant amount of surface water and groundwater. However, due to the rise in surface water pollution by increased semi-industrial activities, agrochemical runoffs, and regular urban flooding, many citizens rely on groundwater sources like hand-dug wells, self-installed reservoirs for portable sanitation and irrigation purposes.

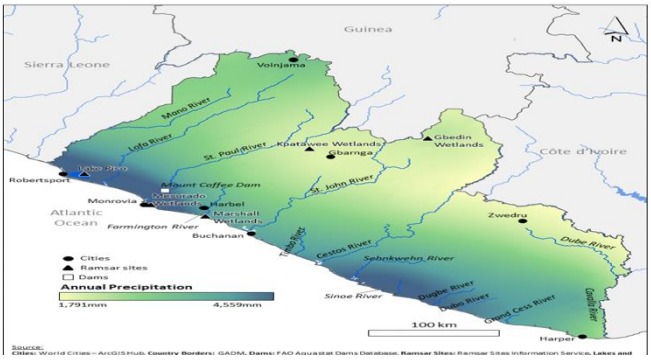

Figure 1 Water Resources Map of Liberia

2.1.1 Surface water resources

Liberia is rich in surface water resources. Liberia has 23 minor coastal drainage regions and 15 large basins that drain water from the northeast to the southwest and into the Atlantic Ocean (Liberia Hydrological Survey, 2016). The six major rivers (Mano, Lofa, St. Paul, St. John, Cestos, and Cavalla) originate in Guinea's Fouta Djallon Mountains. These rivers drain 56% of Liberia, with 11 medium tributaries and several short coastal rivers draining the remainder (EPA Liberia, 2019).

Table 1 Major rivers in Liberia with their properties

Basin	Area (km2)	Annual flow (m3 /sec)
Mano	6,604	251
St. Paul	12,820	512.3
St. John	14,762	
Cavalla	13,726	380
Cestos	10,000	60.3
Lofa	9,194	

2.1.2 Groundwater resources

In addition to Liberia's massive drainage in surface water, there is a significant amount of water stored underneath that complements the fact that Liberia is one of the wettest nations on earth. Except for a small length of uncemented sedimentary aquifers along the northwest coast near Monrovia, just about all of Liberia's groundwater is hard rock (Eastwise British Geological Survey, 2021).

2.2 Integrated Water Resources Management in Liberia

Liberia has ongoing efforts to implement integrated water resources principles to water management. However, like other developing countries, chances of implementation

success still seem blurred. The program faces multiple challenges ranging from the absence of specialized government ministry on water management to a lack of water processing and allocation infrastructure. Though water resources in Liberia seem to be plentiful, it is a rare resource in congested villages and expanding towns like Monrovia, where water bodies have been exploited as dumpsites for trash, according to the UN (Brandolini & Tigani, 2006). The poor urban planning characterizing the city of Monrovia has been a major contributing factor in the deterioration of water quality. The Monrovia City Corporation continues to face challenges of effective waste collection and distribution as stockpiles of waste routinely flood Monrovia's streets. Leakages from these improper waste handling contaminate water sources and exacerbate the health issues in the city. The Integrated Water Resource Management Policy, formulated by the government in 2007, remains the only comprehensive roadmap for achieving efficient water resources management in Liberia. Drakenberg et al., 2014) Drakenberg et al., 2014) However, population growth and urban water pollution continue to pose severe challenges to implementing this policy document. Population expansion, unregulated waste disposal, agricultural, mining, logging, aquaculture, and other commercial activities strain water supplies (LNWRP, 2007). The targets set therein are that to meet current societal demands for water, water-related goods, and services while preserving the ecological function of the country's water resources, the country's water resources will be developed and managed in an integrated manner with land and other natural resources by 2015. The policy, however, made some strides in this direction by improving people's access to safe drinking water. The latest WHO/UNICEF Joint Monitoring Programme (JMP) shows Liberia partly accomplished its WASH MDG targets. The nation fell just 1.5% short of putting the number of people with no access to clean drinking water (from 57 to 76%).

Table 2 IWRM implementation status for West Africa

Country	Score	Score meaning	Intepretation of status
Nigeria (WA)	35	Medium-low	IWRM elements are institutionalized, and implementation is underway
Ghana (WA)	49	Medium-low	IWRM elements are institutionalized, and implementation is underway
Togo (WA)	32	Medium-low	IWRM elements are institutionalized, and implementation is underway
Senegal (WA)	53	Medium—high	Most IWRM elements are being implemented under long-term programmes
Benin (WA)	63	Medium—high	Most IWRM elements are being implemented under long-term programmes
Burkina Faso (WA)	63	Medium—high	Most IWRM elements are being implemented under long-term programmes
Cape Verde (WA)	64	Medium—high	Most IWRM elements are being implemented under long-term programmes
Gambia (WA)	30	Low	Some implementation of IWRM elements has begun
Guinea (WA)	24	Low	Some implementation of IWRM elements has begun
Liberia (WA)	15	Low	Some implementation of IWRM elements has begun
Niger (WA)	50	Medium-low	IWRM elements are institutionalized, and implementation is underway
Mali (WA)	53	Medium—high	Most IWRM elements are being implemented under long-term programmes
Sierra Leone (WA)	19	Low	Some implementation of IWRM elements has begun
Côte D'Ivoire (WA)	32	Medium-low	IWRM elements are institutionalized, and implementation is underway

The table above shows that Liberia is scoring the least (15) on the implementation status of the IWRM principles compared to other West African nations

2.3 The link between the climate crisis and water resources

Climate change has the potential to have a significant influence on the global water cycle by altering precipitation and evaporation patterns, which has the potential to have a detrimental impact on both the quality and amount of water available (Ludwig et al., 2014; (Ludwig et al., 2009; Bates et al., 2008). People living in almost all parts of the world are already faced with one or two forms of water scarcity (quantity or quality). Studying the link between climate variability and water resources, including groundwater sources across nine (9) aquifers in Africa, Carvalho et al. (2018) employed a convenient method for terrestrial climate impact analysis, The Gravity Recovery and Climate

Experiment (GRACE). It found that the combined effect of El Niño Southern Oscillation (ENSO) and the Atlantic MultiDecadal Oscillation (AMO) could generate significant alterations in recharge to the aquifers and groundwater storage, particularly in the Sahel.

2.4 Limitations of current climate prediction models

Almost all invented models on assessing climate change impact on water resources have proven to have significant limitations primarily due to the uncertainties in future climate variability. Considering what drives water quality changes in the Selenga Basin, Maisy et al. (2017) used the large-scale water resources model Water GAP3 to compute loadings of conservative substances (total dissolved solids) and non-conservative substances (fecal coliform bacteria and biological oxygen demand) in a three-dimensionally straightforward way, as well as in in-stream focus to gain an insight into the state of water quality under current and future scenario conditions. They discovered that domestic and industrial sectors are the most significant contributors to water quality. This result only explains the limitation of the available GCMs to estimate the impacts of climate change on water resources acutely. Today, Integrated Water Resources Management (IWRM) remains the world's leading approach globally in tackling and addressing inter and cross-sectoral demand for water resources in the water sector. However, one of the most challenging difficulties for achieving the goals of the IWRM program is the evaluation of climate change effects on the quantity and quality of water resources, as well as the socioeconomic areas that are impacted by water resources in general (Fischer, M et al., 2014). IWRM programs fail due to inadequacy to project climate change's impact on future water vulnerability. This uncertainty is attributed to the variability in future climatic conditions, and forecasts may often fail to address these variations' water resource implications.

2.5 Current efforts in addressing the crisis globally

Using the IPAT formula method to reckon the scenario of measuring the depth of advantages to expect from water demand-side management actions linked with energy efficacy options in North Africa, Quéfélec & Allal (2019) found that the concept of water demand management can offer a more incredible adaptation option that benefits not only water saving but sustainable energy management as well. Water demand management is increasingly becoming a viable option in the water sector of many countries in combating the current trend of water crisis created by climate change. Residents of the Colorado area in the US are currently working on incorporating water demand management strategies into the Colorado River Basin to increase water demand across the region (Colorado Water Conservation Board, 2021).

3. Methodology

3.1 Study Area

Monrovia is situated along the coast, on the peninsula of Mesurado, between the Atlantic Ocean and the Mesurado River, the mouth of which provides a vast natural port. Monrovia has a tropical monsoon climate, according to the Köppen climate classification (Am). It is the wettest capital city globally, with an average annual rainfall of 4,624 millimeters (182.0 in). The yearly temperature of Monrovia averages relatively around 26.5 degrees Celsius. The elevation is low due to the coastal situation of the area. The height is less than 10m above sea level, making it the most vulnerable to extreme climate events like flooding. Two of Liberia's major rivers (Cestos and St. Paul rivers) flow across the capital city of Monrovia, constantly flooding wetland areas. Socioeconomic issues like high rates of severe poverty, joblessness (56.6 percent in Greater Monrovia), dense population, and underdeveloped infrastructure exacerbate the susceptibility of broad segments of the people to climatic effects (Climate Resilience- Liberia, World Bank, 2019).

3.2 Methodology

The research used a Systematic Literature Review (SLR) to examine expert published materials on adaptation to climate change in the water sector. The paper utilized sources like Google Scholar, ScienceDirect, JSTOR, and SpringerLink to gather and review these publications on climate change adaptation and Integrated Water Resources Management in the water sector. In addition, contacts were made with resourceful informants in the water sector to verify the reliability of published materials.

4. Results and Discussions

Climate change is unarguably altering the water cycle, and the impacts are disproportionate across regions and sectors. In addition to mitigation, adaptation offers humanity a greater chance of averting the future hash implications of extreme climate events. Integrated Water Resources Management has been a significant step toward effective water management since the 1980s. Though Liberia's climate indicates a high precipitation rate, it is like any nation susceptible to the harsh impacts of climate variability. Water resources are mainly most vulnerable to climate effects. Monrovia's low elevation and poor urban structural planning increase the areas' vulnerability to climate variations. Socioeconomic issues like high rates of severe poverty, joblessness (56.6 percent in Greater Monrovia), dense population, and underdeveloped infrastructure exacerbate the susceptibility of broad segments of the people to climatic effects (Climate Resilience- Liberia, World Bank, 2019). In Liberia, environmental destruction, climate change, lack of infrastructure, and loss of biodiversity and ecosystem services impede development and poverty reduction

initiatives, increasing the susceptibility and risk of disasters (Drakenberg et al., 2014).

4.1 Current efforts in increasing water security

In addition to the LIWRMP, the government of Liberia formulated a Water and Sanitation policy in 2009 to ensure a sectoral guide approach to water and sanitation improvements in the country. The primary goal of this legislation was to buttress ongoing efforts by the Liberia Integrated Water Resources Management Policy (2007) in tackling the issues of sustainable water management and distribution in Liberia. The Water, Sanitation and Hygiene, WASH initiative has been one working tool the government of Liberia has been using to tackle water and sanitation challenges. These policies, however, have made some strides in this direction by improving people's access to safe drinking water. The latest WHO/UNICEF Joint Monitoring Programme (JMP) shows Liberia partly accomplished its WASH MDG targets.

The nation fell just 1.5% short of putting the number of people with no access to clean drinking water (from 57 to 76%).

Table 3 Major laws on water governance in Liberia

Law	Year	Objective
Integrated Water Resources Management (IWRM) Policy	2007	Establishes framework for implementing IWRM. Organized around transboundary and national river basin units as well as sub-national and local administrative boundaries.
Environment Protection and Management Law (EPML)	2002	Empowers the Liberia Environmental Protection Agency to establish water quality standards, water quality monitoring procedures, and the regulation of effluent discharge in consultation with related ministries.
Public Health Law of Liberia	1976	Prohibits discharge of sewage, agricultural, or industrial wastes into Liberian waters without permission. Empowers County Health Administrations to take legal action against polluters when they endanger public health.

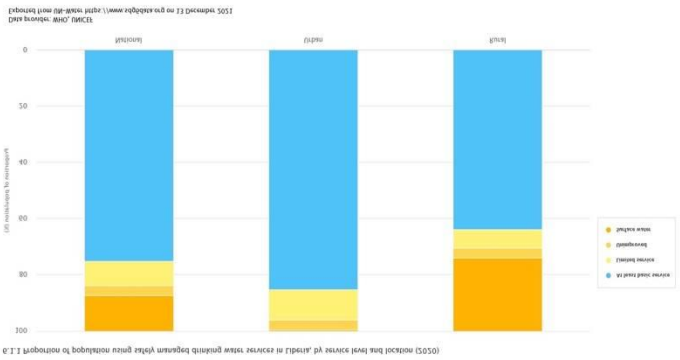

Figure 3 Proportion of Population with access to safe drinking water; Copyright UNEP & WHO, 2020

4.2 Challenges facing integrated water resources management in Liberia

Water security is determined by its availability in quantity and quality to the varying users or sectors to which it is demanded. The IWRM strategy faces a similar problem with implementation in Liberia like it does in most parts of the developing world. The absence of specialized governmental ministry to manage and coordinate water resources remains a significant obstacle in fully implementing the IWRM principles. The World Bank has advocated the establishment of a specialized ministry of water resources and sanitation to centralize sector activity, financing allocations, and capability under a single organization (The World Bank, 2019). Responsibilities are spread across different ministries and agencies, with none taking full responsibility. Integrating local water management approaches into the IWRM framework has failed as donor funding determines the strategy to be used. The NWRSB serves a critical role in coordinating water management initiatives, but it lacks the people and financial resources required. The national IWRM policy identifies 'brain drain' as one of the sector's primary challenges. Collectively, the ministries receive less than 1% of the national budget (National Water Sanitation and Hygiene, 2012). The sector's over-reliance on donor support is one key factor underpinning failure. Climate change adaptation strategies in the water sector remain non-existent.

5. Conclusion and Recommendation

5.1 Conclusion

The shreds of evidence pointing to the direct impact of climate change on water resources remain unclear. However, it is a known fact that rising temperature increases evaporation leading to drought to traditionally dry regions of the globe and melting of glaciers, causing flooding in wetter areas. According to the Intergovernmental Panel on Climate Change (IPCC), an age of fast and accelerating climate change is unavoidable under ideal circumstances for optimizing coordinated worldwide action to decrease additional

emissions of greenhouse gases into the atmosphere (Nyamwanza & Kujinga, 2017). The research analyzed climate change adaptation and Integrated Water Resources Management to deal with the growing global water crisis. While it remains the most recommended solution to water management globally, Integrated Water Resources Management continues to lag in achieving its purpose for water resources management in the third world. While it has recorded gains in improving urban access to safe drinking water by more than 30%, this paper found that Liberia records the least score on the African continent in the implementation status report of the IWRM reported by the FAO 2019. The absence of specialized governmental ministry to manage and coordinate water resources remains a significant obstacle in fully implementing the IWRM principles. The World Bank has advocated the establishment of a specialized ministry of water resources and sanitation to centralize sector activity, financing allocations, and capability under a single organization (The World Bank, 2019). Responsibilities are spread across different ministries and agencies, with none taking full responsibility. Integrating local water management approaches into the IWRM framework has failed as donor funding determines the strategy to be used. The NWRSB serves a critical role in coordinating water management initiatives, but it lacks the people and financial resources required. The national IWRM policy identifies 'brain drain' as one of the sector's primary challenges. Collectively, the ministries receive less than 1% of the national budget (National Water Sanitation and Hygiene, 2012). The sector's over-reliance on donor support is one key factor underpinning failure. Climate change adaptation strategies in the water sector remain non-existent.

5.2 Recommendations

Water is undisputedly the essential element of life. Water security is determined by its availability in quantity and quality to the varying users or sectors to which it is demanded. Climate change is projected to have dire implications for Monrovia due to its low elevation (>10m), high precipitation (approximately 2500mm annually), and unplanned city structure. Water resources are primarily under siege as climate change poses increasing threats. In addition to mitigation, climate change adaptation offers better chances at averting potential negative impacts. These adaptation measures must be proactive in building local resilience to the possible effects of climate variability. To this end, the research recommended the following:

1. The creation of a specialized ministry for water resource management (World Bank, 2021)
2. Reduce donor dependency by introducing and adopting locally designed cost-effective water management approaches
3. Increase budgetary allocation to the water sector to enhance quality provision to households
4. Introduce water education in schools across the country to increase awareness
5. Integrate local knowledge in IWRM programs

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