wjert, 2022, Vol. 8, Issue 4, 41-74. Case Report ISSN 2454-695X

World Journal of Engineering Research and Technology

WJERT

www.wjert.org SJIF Impact Factor: 5.924

CLIMATE CHANGE AND WATER RESOURCE MANAGEMENT: CASE STUDY OF LIBERIA

***Catherine Kuku Dolo and Prof. Dr. Huseyin Gokcekus**

Near East University Graduate School of Educational Sciences Environmental Education & Management Master Program.

Article Received on 24/01/2022 Article Revised on 14/02/2022 Article Accepted on 06/03/2022

***Corresponding Author**
Catherine Kuku Dolo
Near East University Graduate School of Educational Sciences Environmental Education & Management Master Program.

INTRODUCTION

Background

Liberia is a state with water criticality which is suspected to be a pollution crisis when water scarcity corresponds with low problem-solving strength. In addition, 25% of the Liberia population experiences water scarcity, however, 70% live within a water abundant position, but abundance does not necessarily have excessive water. Relative abundance does not take other measures into account such as water accessibility and availability of sanitation. According to the report which was conducted by UNEP (2003), 1100 million households do not have clean water accessibility and 5 million deaths annually are caused by contaminated water in Liberia. According to (Clement, et al., 2018), Liberia has been experiencing the devastating effect of global warming as a result of geographical location people with low-income levels, lower technological innovation and learning are vulnerable to environmental change as well as overreliance on climate-sensitive renewable natural resources industries including agriculture and climate. Liberia is the country with the most susceptible to climate change for desertification systems, water catchment declining, reducing soil fertility, relying on subsistence agriculture, AIDs prevalent disease, inefficient government policies and rapid population mechanism. Specifically, the country with 70% living in the Caribbean and Pacific areas are working in the agriculture industry and for those people, understanding and confronting climate change is not a concept. However, it is the evaluation of life and death.

According to climate change and water resource management model analysis conducted by (Oberle, et al., 2019), water scarcity increases rising temperature during the second half of the century, affecting semi-arid areas, which is expected to be higher than the world figure. Another discussion revolving around climate change reported that above 1.5ºC is reducing water supply. Evidence suggests that looming changes in the environment have drastic effects on water availability in African countries. Although, the country is not subject to creating greenhouse gas emissions which is the main cause of creating these environmental challenges. Similarly, Africa creates 2% greenhouse gas emissions annually. Thus, understanding the tie between Liberia climate change and water resources provides a chance to address the environmental challenges proactively and provide a systematic framework for sustainable water resources utilised in Liberia (Wezel, et al., 2016).

Earth is the ocean with life-filled, is specific among galaxies planets in a way. Occupying 71% earth surface, ocean life in the galaxy plays a superior role in regulating the global climate. Change has become a norm as the planet "Earth" is circulating through a variety of states where a person's life has flourished, reduced and experienced different calamities. Climate change consists of two parts: intrinsic events including volcanic activities and extrinsic activity such as large meteorite strikes which experience hostile conditions that led to an increase in extinction rates and further navigated ecosystem collapse (Trainer, et al., 2020). There is overwhelming evidence that human activities are the most important driving factor in rapid climate change, similar to past events. Similarly, many climate changes are occurring in the world with dramatic consequences ahead. The concentration level of oxygen is highly influenced by anthropology. Overfishing and eutrophication are the main precedents of climate change which further increase anoxic and hypoxic events which increase the risk of mass mortality among benthic habitats. Generally, Climate change is a global event exhibited specifically by global warming (Dias, et al., 2020). Climate change is exploiting weather ornament, driving water scarcity, contaminating the supply of water, and uncertain water availability. Such consequences may impact water quantity and quality that humans require to survive. Moreover, an increase in evaporation, rise in sea level, uncertain precipitation and lasting drought may have serious intensification to the global water cycle. Climate change intensifies the potential of water resources which makes water, energy and carbon ties were more complicated (Fragnière, et al., 2020).

Water Resource Management

Water resources are an important resource for sustaining the socio-eco environment. However, the management of water resources is becoming challenging as the occurrence of climate change uncertainties. The bulging impact of climate change on the global water cycle can be comprehensively analysed by the total quantity of water decreased and spatiotemporal gene development of precipitation, leading to frequent drought with larger magnitude and flooding. Similarly, the natural global hydrogen cycle is disturbed which led to an increase in unusual evapotranspiration while decreasing the replenishment of soil water, and the recharge of groundwater (Geissen, et al., 2018). Correspondingly, a rise in sea level causes saltwater intrusion and frequent flooding. Special distribution of water quantity affects surface water supply and groundwater in most of the induced sirs like agriculture, hydropower, domestic living, industry and river biotic and abiotic systems, which led to stress water availability. Undoubtedly, water is the basic condition for human survival and is irreplaceable to support the social-economic system. The regions with a high water demand have high water scarcity. Similarly, stressing water quality in developing countries has complicated the process of water resource management. To exploit the concept of water resource management, the Improve Water Resource Management program was established in the 1980s and has gained immense attention over the last decades (Owusu, et al., 2016). Improve water resource management is a process to regulate or circulate water among most demanding sectors such as agriculture and industrial. The process not only takes economic benefit into account but also addresses the water shortage issue with the social and ecological environment. A significant amount of metropolitan areas are utilizing water from rivers which is discharged with 80% waste from upstream located areas. As a result, the wastewater is discharged without recycling or refurbishing or reusing. Reuse with indirect approach was seen in Paris suburbs and London. Developed countries report that 80% of river water originates from wastewater treatment plants. The auto purification and dilution process of the river has made the public influential. During the water shortage crisis, the professional development of alternative water resource management is likely to be the most suitable sustainable water solution (Altenburger, et al., 2015). Planned water resource management has three important elements such as reclaimed water, seawater and stormwater. Treatment with these sources would result in addressing each application for water scarcity problems. Whereas, the process of decision making that municipalities are now facing as they have to create alternative resources of Integrated Water Resource Management on the agreed framework as a part, is very complex. At present, both climate change and water source management alternatives

are one of the most influential topics under the Global Sustainable Development Goals (Grigg, 2016).

Research problem

The relationship between climate change and water resource management, i.e. water scarcity, burning of fossil fuels, deforestation, pollution, human activities, contaminated water, solid waste and effluent treatment plants has not yet been explored, so recent studies were obvious which factor is dominant in the actual ecosystem." Furthermore, other studies are limited to climate change and water treatment practices in developed countries (Fazey, et al., 2018). However, the current study analyses climate change and water resource management in African nations i.e. Liberia which is not specifically addressed in recent studies. Hence, the study aims to assess the impact of climate change and water resource management in Liberia.

Research question

How do government policies impact climate change and water resource management?

What are the consequences of climate change?

How does water resource management affect Liberia?

Objective

- To analyse the effects of government policies on climate change and water resource management.
- To identify the consequence of climate change
- To what extent does water resource management affect Liberia?

Significance of the study

The finding of the study will benefit society, government bodies, and organisations operating in different sectors as Climate change is caused by framing, deforestation and burning of fossil fuels. Knowing the importance of climate change and water resource management, the study will contribute to specific actions toward Sustainable development goals. The study will allow gaining new knowledge in academia, and the consumer from different cultural backgrounds. Similarly, the current study will add value to the existing literature and benefit future researchers as the concept of climate change and water management was unexplored in Liberia. Similarly, the community as a whole will be able to evaluate the significance of climate change and the water cycle. As a result, these beneficiaries will be encouraged to promote global sustainability.

Limitation

The study will focus on two parameters within the African countries (Liberia). The study has a mixed research method so qualitative research may have a small sample size and potential bias in respondent answers. The sample selected for the current study are specifically corporations, government bodies and students who have a piece of certain knowledge in the subject of sustainability. The study will not include other concerned sectors.

Literature Review

Climate Change and Global Warming

(Jang, and Hart, 2015) said that the solar radiation (SR) from the sun is balanced by the thermal radiation (TR) reflecting from the globe; this communicates stability and decides the outside temperature by the globe. The received SR from the sun has self-governing therefore the outgoing TR depends on the surface of earth temperature and the presence of GHGs, which absorb several by the TRS (Antwi-Agyei, et al., 2015). Greenhouse gases (GHG), for example, methane, carbon dioxide, water vapour, nitrous oxides, ozone and chlorofluorocarbons are accountable for being trapped by warmth. For example, water vapour (40 per cent) is responsible for absorption popular by TR from the world, followed by methane (20%), carbon dioxide (30%) and more gases (5%) (Change, 2018).

Consequently, it indicates that responsive TR is mainly absorbed by carbon dioxide and water vapour. Also, the change in the work of art of water vapour caused by human practices are unimportant, consequently, it implying that the GHG shaped by human practices are likely accountable for the heat-trapping (Benjamin, et al., 2015). But, (Mehnert, 2016) and (Ahmad, and Hossain, 2015) argued that the trapping of heat by CO2 is not important and somewhat it is probable that radiations of the sun are accountable for the international hotness rise. Once more, the discussion on whether the SR or Greenhouse gases is accountable for the international hotness recently continues, (Donnelly, et al., 2017) refute the claim that likeliness by SR as the reason for international warming power was not true. He argued that it is probable that the sun could temperate the globe given that the mould of the solar strength increased over the years. Also, the sunspot information does mean that there was a little development by the quantity of sunshine from behind the 1800s to the mid-1900s that specialists estimating that it can have contributed at the largely up to 0.1°C of the 1.0°C (1.8°F) of warm observes as the pre-developed time. But, there has been no important net change by the energy of sun production from the late 1970s to the current (look at the figure

given under), that is while the fastest GW was observed. Moreover, (Bein, et al., 2020) claimed that the scientists rule out the important characteristics of the sun in GW caused by the detail that if the energy of sun production had intensified then it is reasonable to suppose each of the layers of the atmosphere of earth to be warming, that is not the container that has been observed. Relatively, weather balloons and satellite studies explained that much warmer in the lesser environment (troposphere) and cool within the higher environment (stratosphere). This model of differential warming is what is expected is caused by the finding of growing Greenhouse gases heat-trapping.

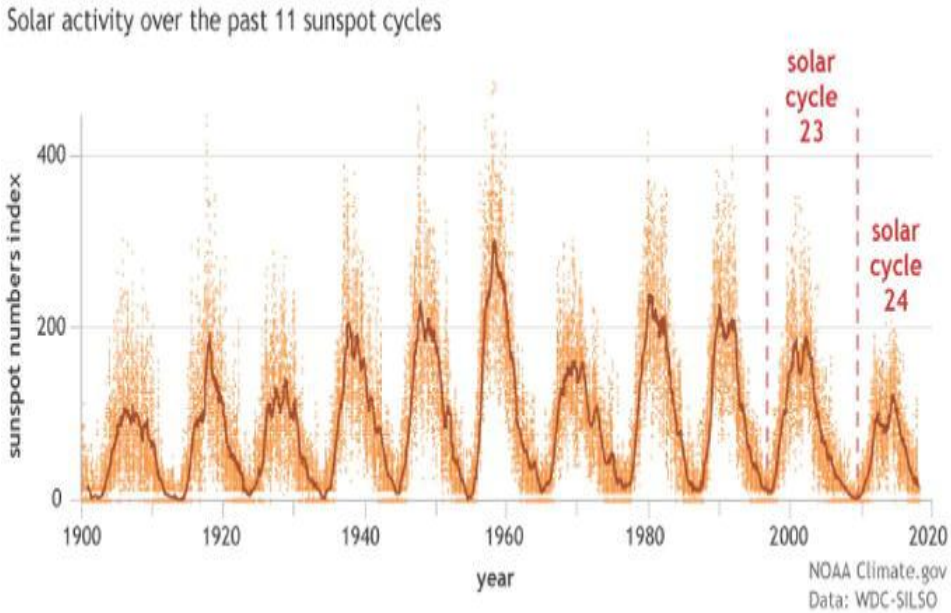


Figure 1.

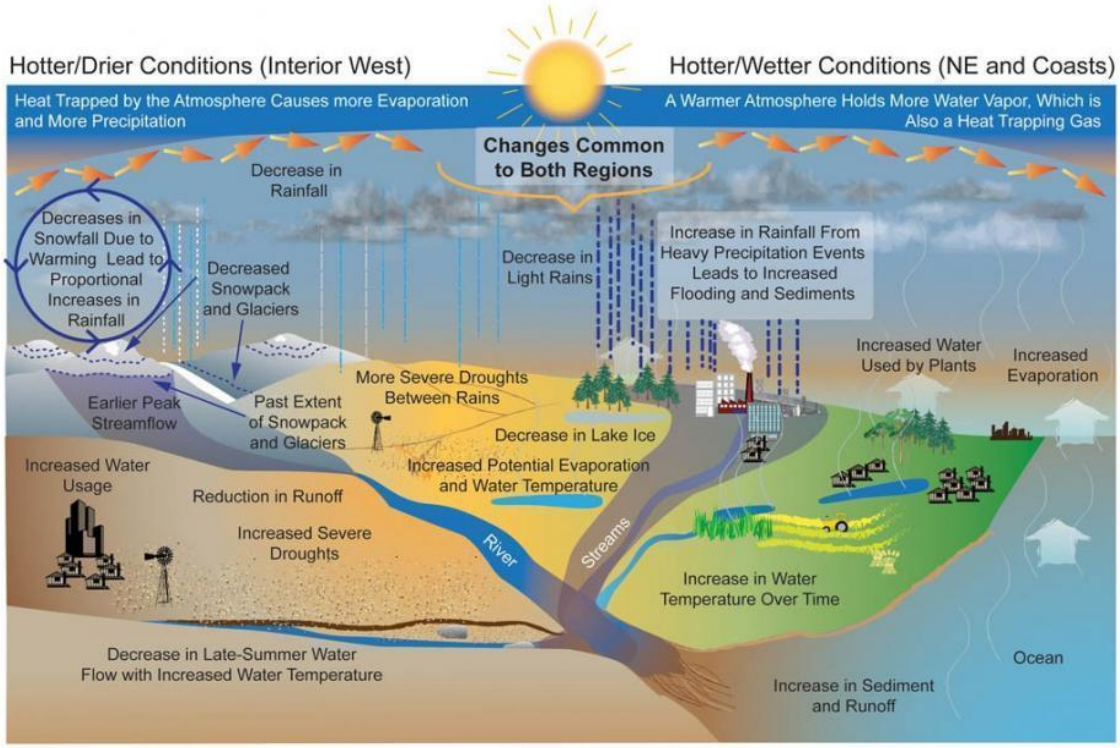
The peak and valley in solar geomagnetic (SG) practice was 1900, based on the figure of sunspots practical on the face of the sun every day (carroty dots). Graph by NOAA Climate.gov, based on data from the WDC-SILSO, Royal Observatory of Belgium. By the boost in the attention of the GHG it would work as a broad blanket within the environment everywhere it would absorb the SR (Leiserowitz, et al., 2015). The oxygen molecule and the carbon molecules within the carbon dioxide undergo shaking like bending, stretching, and this act absorbs the SR. Thereby hindering the reflection of SR by the globe creating the globe surface hotness warmer.

Water Resources and Climate Change (CC)

Besides (Lu, et al., 2019), depending on the area, CC would have broadly incompatible impacts on the water of Europe. High temperatures would commonly increase the

international hydrological cycle. Yearly precipitation trends by Europe mean that northern Europe has turned into 10perecent-40percent wetter above the final century, while southern Europe has become up to 20 per cent drier. Above the last century, yearly stream free has improved in several areas, for example, Eastern Europe, when it has fallen in others, for example, southern Europe. CC can as well noticeably change the variation of the season by river flow. In addition, (Kundzewicz, et al., 2018) claim that high temperatures would press on the limit of snow up in northern Europe and mountainous regions of the mountain. This, in conjunction with minus precipitation decreasing as snow, would find in a high winter run-off in northern European and mountain-feed rivers, for example, the Rhône, the Rhine, the Danube, and the Po. Furthermore, past spring melts would guide a move in mountain flow ranges. As a result of the falling snow pool and reducing glaciers, there would be minus water to recompense for the small flow prices by summer.

(Goyal, and Surampalli, 2018) said that altered by the quantity of rain falling through storms gave proof that the cycle of water is now changing. Over the last 50 years, the quantity of rain falling through many heavy rainfall occasions has boosted for most of the US. This tendency has been most severe in the Midwest, Northeast, and higher Great Plains, anywhere the quantity of rain falling through the mainly strong 1perecent by tempests has improved over 30perecent. Warming heat temperatures create much precipitation to reduce rain relative to snow. Additionally, increasing temperatures reason snow to start melting later in the year. This changes the duration of watercourse flow by rivers which have their source in areas of the mountain. On the other hand, (Mishra, et al., 2018) argued that as temperature increases, animals and people require much water to continue their thriving and health. Several significant activities of economic, like producing energy at raising livestock, power plants, and rising food crops, as well need water. The quantity of water accessible for these can be decreased as warms of Earth and if rivalry for resources of water increased.



Projected changes in the water cycle. Source: USGCRP 2021

Water Quality. The quality of water can suffer because of the increase in rainwater. Such as, in the Midwest and Northeast increasing heavy rainfall actions can cause issues for water transportation, as systems of gutter and water deal undergrowth are overwhelmed by the improved water's volumes. The heavy downpour could boost the quantity of runoff into lakes and rivers, nutrients, washing sediment, trash, animal waste, pollutants, and other materials into supplies of water, creating them unsafe, unusable, or in need by water deal (Morris, et al., 2018).

Developing Countries Cases

According to (Shrestha, and Clement, 2019), the country with climate change experience is indicated by seasonal changes and precipitation of various severity despite being over-dependent on rain-fed agriculture. Africa lives under water stress areas and is using more than 30% of renewable water resources. However, withdrawal over 50% means serious water consequences. For example, (Kochhar, et al., 2018) report that the personal water withdrawal in Nigeria during the 1990s is 30 cubic meters annually. Similarly, the international dialogues carried out on water and climate reported that water scarcity is continuously increasing in relatively dry areas like (sub-Saharan Africa). According to (Ngwa, et al., 2017), Liberia is blessed with water resources extremely, the country with enormous rainfall, rivers, streams,

lakes, water bodies and groundwater reservoirs which are least managed by municipal authority for enabling communities to access clean water. Since, lack of clean water supply in urban and rural areas, economic and social costs increased specifically early mortality which is resulting from waste consumption, environmental pollution and overexploitation of water resources further driving lower productivity. The gap prevalent in the Liberian society is featured by unsustainable measures, lack of learning and innovative ideas, and poor solid waste management thus, bringing the population to large about 65% which depend on groundwater sources including self-supply further creating solid waste and contaminated water as the country is not equipped with climate change and water management policies. Further, the evidence is also supported by the study of (Aladejana, et al., 2020) that climate change like increases in temperature, rising sea levels, and most frequent flooding and droughts, land degradation, desertification in Liberia which is the most affected country with biodiversity. Climate change increased rainfall variation which led to an increase in precipitation by around 15% thereby aggravating coastal lands submersion. However, a study conducted by (Kochhar, et al., 2015) on climate change and water resources in Liberia also supports the evidence that flooding has become a constant phenomenon as a result of the reduction in precipitation thereby areas with Chad and others are constantly being threatened by these adverse weather effects. Rainfall variation is taking place in Liberia and this is continuing to increase. Similarly, droughts are also expected to increase in Liberia as a result of temperature rise. It was reported that many lakes namely Chad and many others are dying with the risk of disappearing. However, the study is not in agreement with another study who claimed that environmental changes tied with climate change are not the similar consequences across the country but it heavily relies upon the industrial nature as industry and agriculture sector are heavily reliant on water and thus utilize more than any other sector in the country. (Fafunwa, et al2017) believed that the supposition somewhat also favoured by the study conducted on climate change in South and North Africa further elaborated that Liberia with tropical climate has two regimes of precipitation like North with lower precipitation and South with high precipitation. The nature of the area led to droughts and desertification in the North and erosion in the South areas. Similarly, a study conducted on climate change Vulnerability analysis further demonstrates that areas in the North experience a higher level of vulnerability than the South. Thus, the pattern of climate change vulnerability also confirms the climate-sensitive agriculture productivity. Similarly, the affirmation is also justified by the fact that the Northern regions of Liberia are more vulnerable to climate change as they have a higher degree of reality than Southern areas.

Climate Change and Water Resource in Liberia, West Africa

According to (Coulibaly, et al., 2018), Liberia with forestry and biodiversity culture, the country is located in West Africa with the two largest forest blocks, estimated to account for half of the rainforest in the country. Liberia is also well-known for global biodiversity as the country with the strongest forest resources ties with low pressure of population and limited access. In addition, technological infrastructure and human activity are among the main characteristics of climate change in Liberia. The assumption is also supported by the activities with climate change where farmers contributed to cutting down trees, excessive use of agrochemicals, poor farming techniques, fossil fuel and coal burning. Integration of these activities has resulted in undesirable environmental change such as excessive greenhouse gas emissions in a culture which leads to low precipitation, Damage soil fertility, and global warming. Subsequently, (Schroth, et al., 2016) opined that unnecessary environmental conditions such as flooding further affect the agricultural productivity of Liberia resulting in malnutrition, hunger and death of communities with other marine life.

On the other hand, various internal and external paths were suggested between anthropogenic impairment consisting of the water cycle and other environmental components such as water, soil and biosphere. Without stressing climate change, water management is one of the most pressing concerns in developing countries. In most cases, the water crisis is traced by state governance. Moreover, climate change and water scarcity are two of the main concerns confronting society today. However, (Sylla, et al., 2016) reported that Nigeria and Norway partnership in 2014 further stressed the importance of improving forest governance by ensuring law enforcement support reducing forest degradation in Liberia. Notwithstanding, the country with forest pressure in commercial logging for local enterprises is transforming cultivation, permanent agriculture, and charcoal production. Climate change brings extreme flooding and droughts, Nigeria is at risk of damage to infrastructure property. The clearing of forest for permanent agriculture; and charcoal production. Where climate change brings with it an increase in the frequency of extreme weather events such as flooding and drought, the risk of damage to property and infrastructure also rises.

METHODOLOGY

Research design

The research philosophy is based on positivism to satisfy the objectives of the study. The research approach is deductive as the study goes from general to specific. Descriptive

methods research locates in the centre of the spectrum as the study incorporates the element quantitative descriptive approach. The study reflected the quantitative study which is based on descriptive nature as it describes the events and patterns of climate change and water resource management under the current study (Wright, et al., 2016). Using descriptive quantitative data, the researcher describes the characteristics of Climate change and water resource management in Liberia.

Data Collection

The study employed longitudinal data to explain the patterns of climate change and water resource management from 1900 to 2020. Data was collected through the Environmental Protection Agency, USAID, World Bank Group, and Green Climate Liberia. The unit analysis where the study was conducted in Liberia where the researcher used different variables such as temperature patterns, heavy rainfall, weather trends in Liberia, safely managed water accessed by households, Liberia specific position in adapting water resource management techniques and collaborated support by countries and environmental agencies in Liberia to explain the trends and patterns of climate change and water resource management.

Instruments

The observational method was used to collect different types of climate patterns and water scarcity studies in Liberia where the behaviour of certain events is observed and recorded. Secondary data was reviewed until the end of December 2020.

Data analyses

The study analysed the data trend over some time with descriptive research statistical capabilities. The data were analysed through various graphs to gauge visual representation. Data were analyzed at different periods to identify the relationship between climate change and water scarcity management and the patterns of similarity and dissimilarity over time (Arafat, et al., 2016).

Ethical Consideration

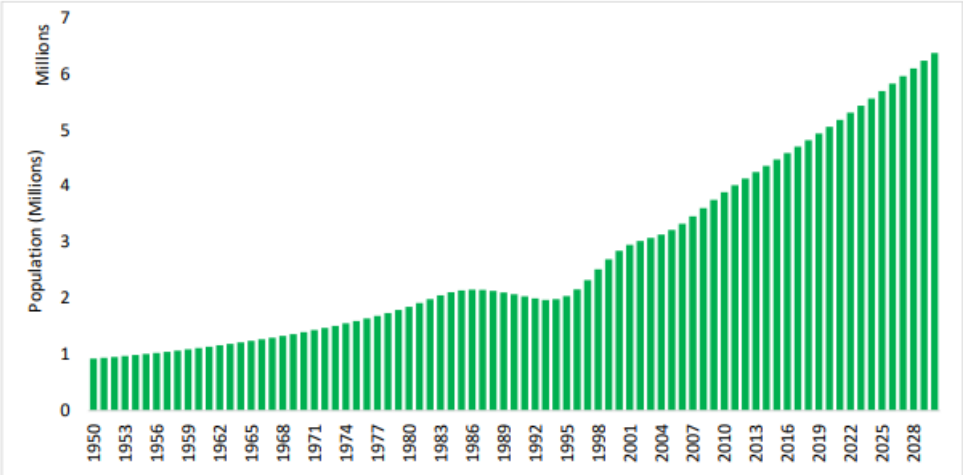
The study based on observation method in the Liberian nation would respect the privacy and psychological well-being of the nature employed. Additionally, a particular account for local cultural values and traditions would be taken. With the multi-dimensional of accessible secondary data, the study ensures replicability of such findings and would provide greater transparency and integrity of research procedure.

RESULTS

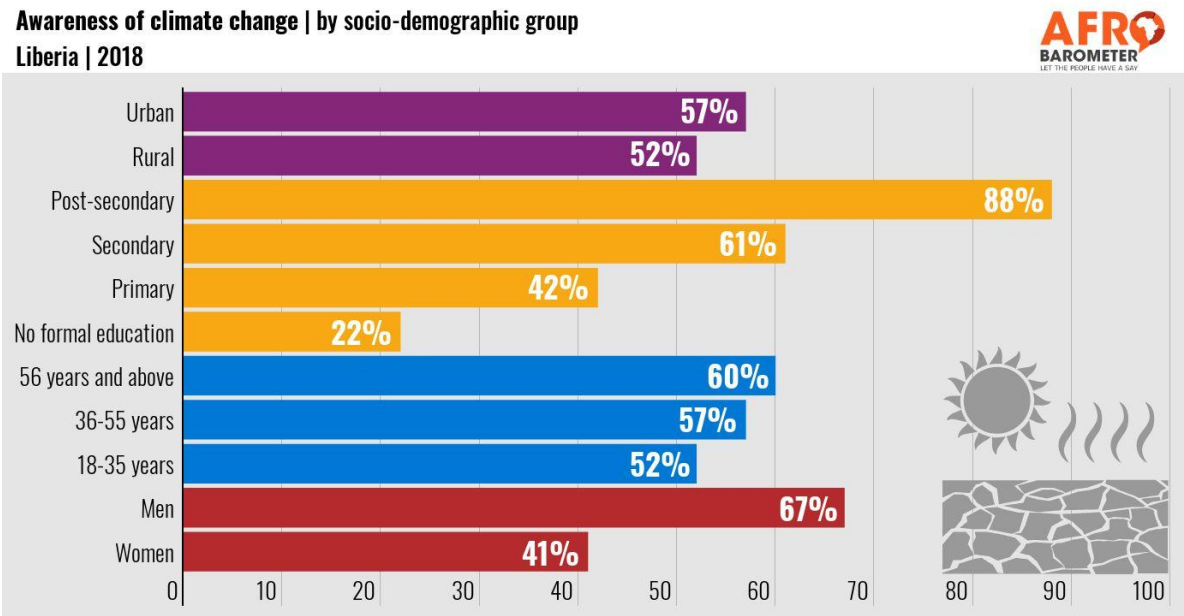
The chapter provides the descriptive statistics of secondary data by observing some trends in climate change and water resource management recently in Liberia. The section contains the discussion of each question as per the study objective. In the descriptive analysis, summarizing data and having an overview vision to results are considered.

Demographic Analysis

Population Trend



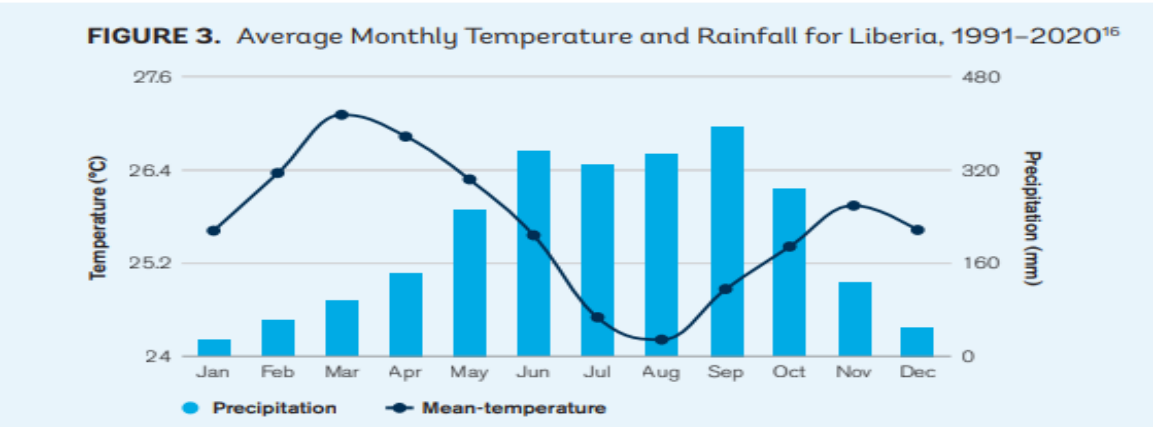
The above graph shows that the Liberian population was 1.02 million during 1962, 2.1 million in 1985, 3.68 million in 2009 and forecasted to be 4.5 million in 2016. According to the National Census, the population of Liberia is expected to increase by 4.3 million and the population to grow by approximately 3%. Similarly, the data depicts that the population is expected to hit 6 million by 2030. The population density of the nation is just about 40 per square km which ranks 180th globally and the country has 16 ethnic groups and foreign minorities where indigenous group comprises 95% of Liberia.



https://afrobarometer.org/fr/publications/ad268-climate-change-making-life-worse-liberia-only-half-citizens-have-heard-it

According to the analysis, the country has a population of around 5 million people with a growth rate of 2.4% in 2020 where 51% of the people live in urban zones and the figure is projected to increase by 6% to 15% in 2030 and 2050. Similarly, Rural livelihoods have also a similar percentage. Most of the people in Liberia are postgraduate such as 88% while the remaining have primary and secondary education. In addition, the age group consisting of 56 years and above are highest among the group criterion. Similarly, males are more than females.

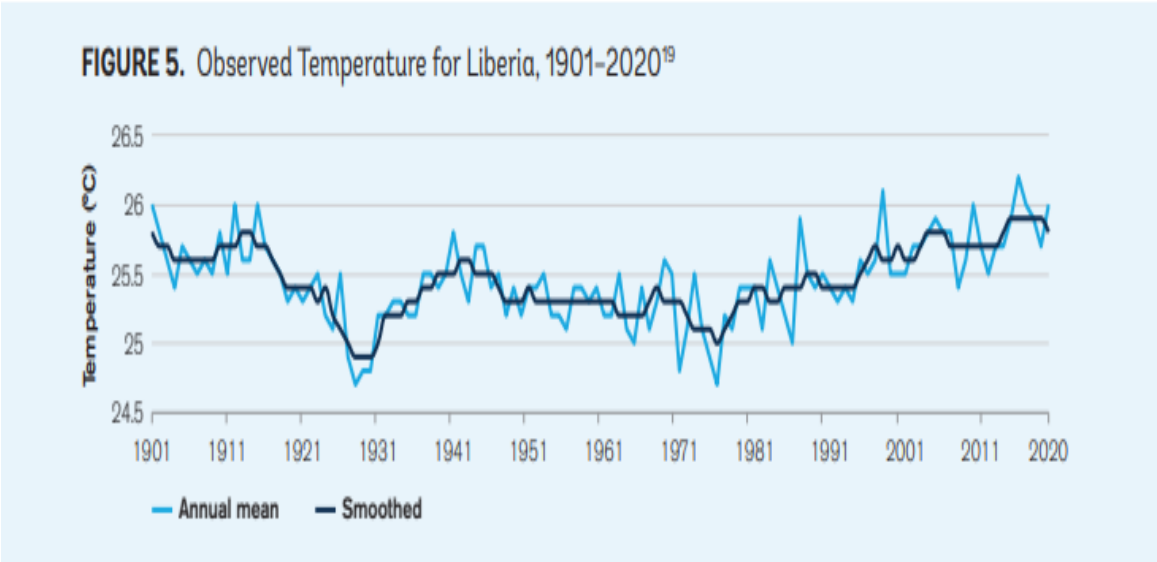
Precipitation and Temperature in Liberia



Source: https://climateknowledgeportal.worldbank.org/sites/default/files/2021-07/15917-WB_Liberia%20Country%20Profile-WEB%20%281%29.pdf

Rainfall occurs throughout the year, with peak rainfall occurring from June to September. The graphical representation shows the spatial variation of the observed average annual precipitation and temperature across Liberia.

Temperature

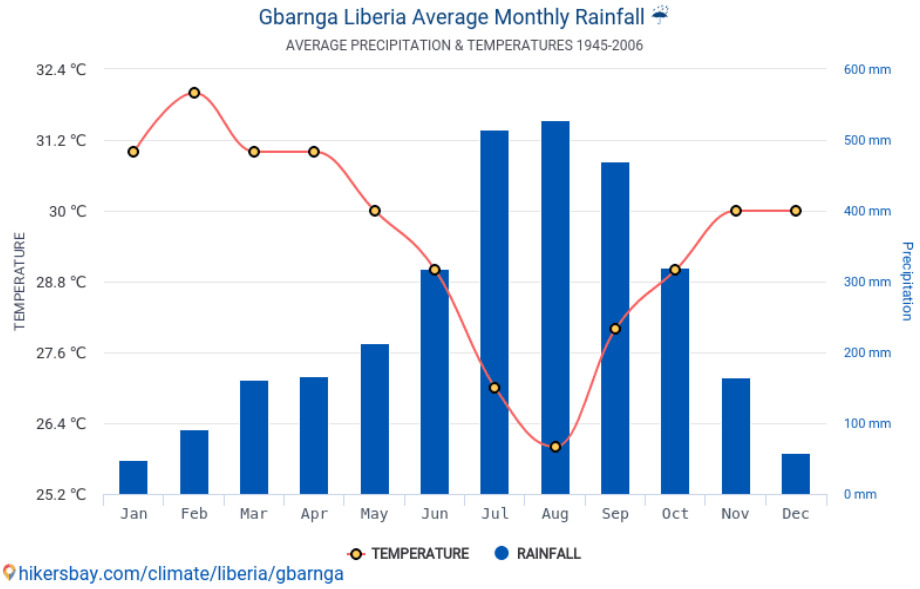


Source: https://climateknowledgeportal.worldbank.org/sites/default/files/2021-07/15917-WB_Liberia%20Country%20Profile-WEB%20%281%29.pdf

The visual observations indicate that the average annual temperature increased 0.8 degrees centigrade between 1931 and 1975 which directed an average rate of 0.18°C per decade. In addition, Observations specified that average annual temperatures greater than before by 0.10 degrees centigrade from 1960-2006, a mean of 0.20 degrees centigrade per decade. In addition, more rapid warming in Liberia's interior than in coastal areas.

Precipitation

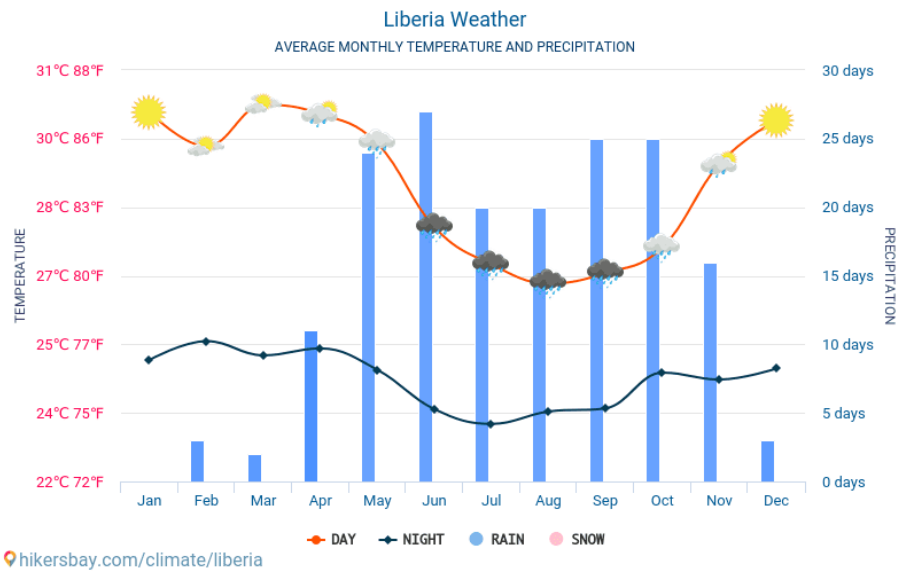
Average annual rainfall in Liberia has reduced since 1960, but, it leftovers unclear consideration regarding long-term trends or rainfall variability for Liberia. However, increased frequency of intense rainfall is expected to grow further which will expected increase sea levels which may also result from additional variability in the coastal zones during heavy precipitation.



Source: https://climateknowledgeportal.worldbank.org/sites/default/files/2021-07/15917-WB_Liberia%20Country%20Profile-WEB%20%281%29.pdf

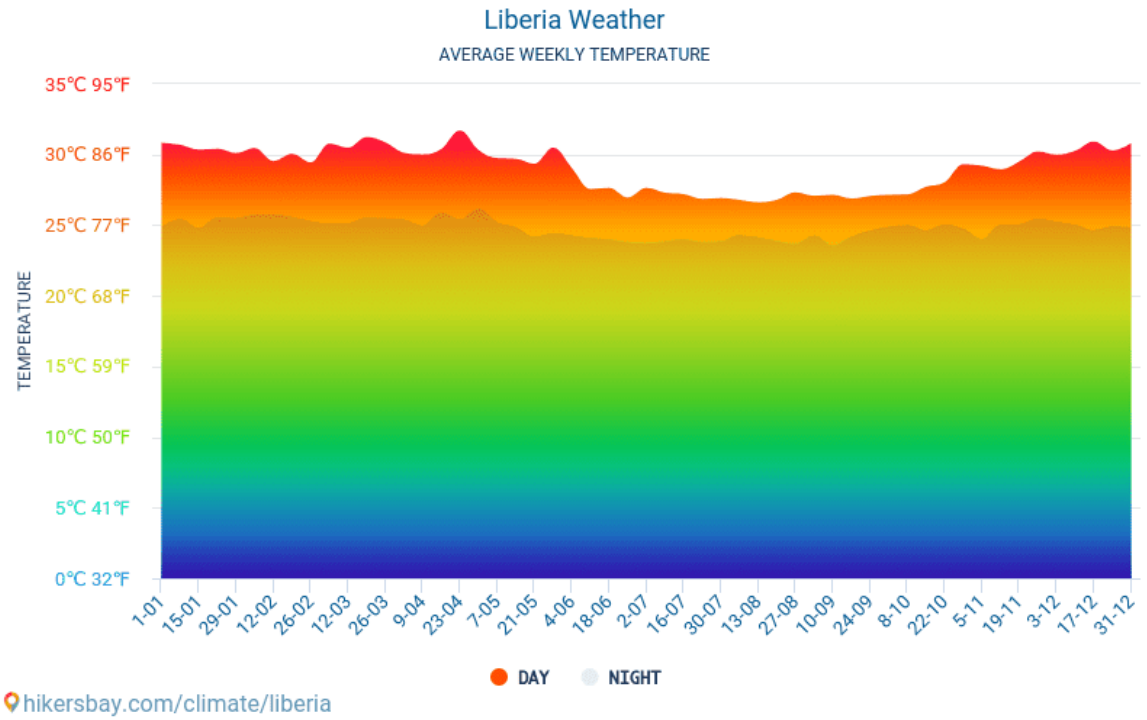
The above graph shows that the temperature is dramatically rising from August and rainfall increased in July, August and September. As per the country of Liberia National Communication states that increasing temperature and heavy rainfall hurt the country water balance particularly for the river of Cavalla, St John and St Paul which creates more vulnerability to agricultural settings because of soil excess and concentrated rain. Extreme precipitation and flooding actions have increased since 1960 during the rainy season.

Weather



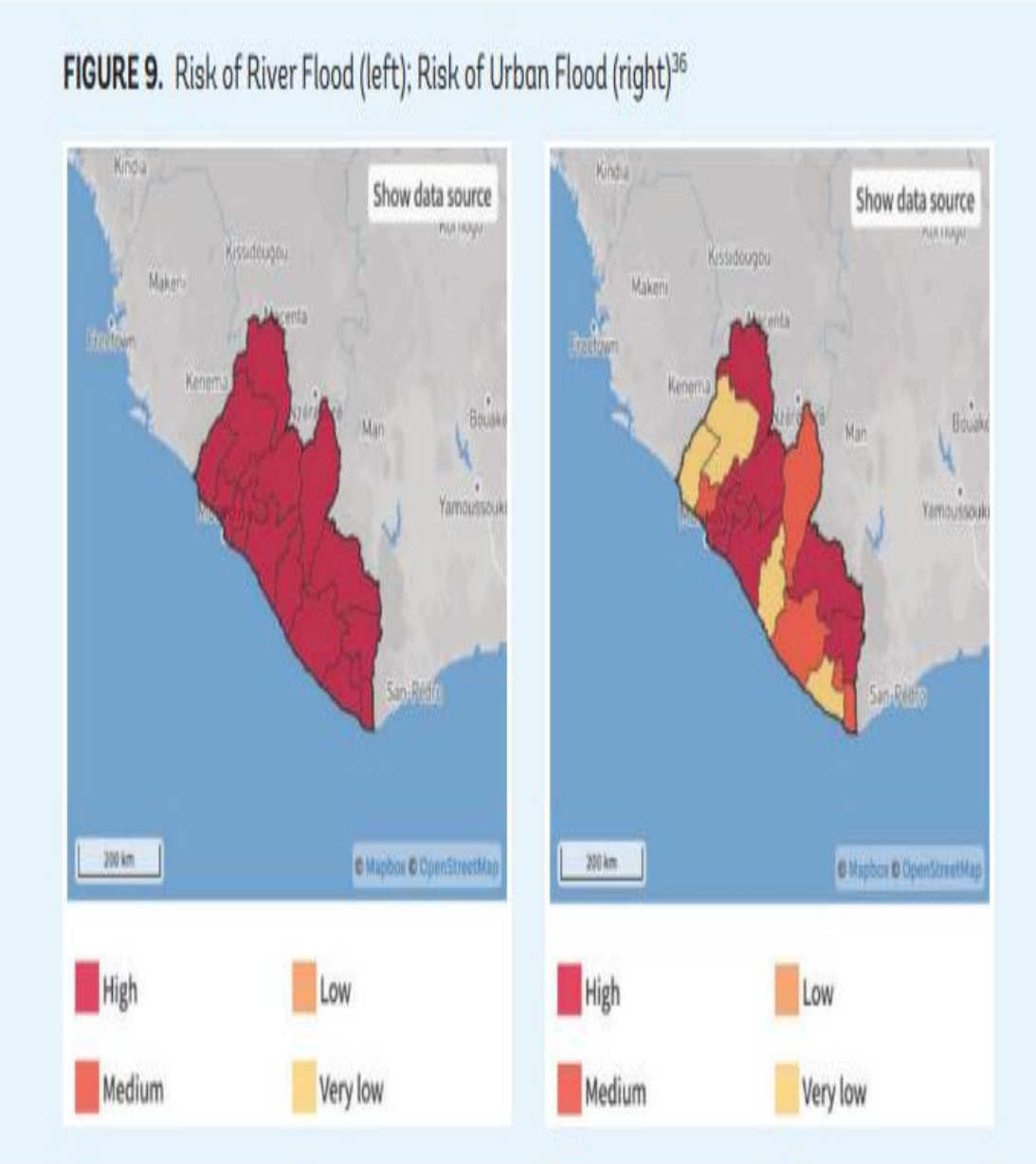
Source: https://climateknowledgeportal.worldbank.org/sites/default/files/2021-07/15917-WB_Liberia%20Country%20Profile-WEB%20%281%29.pdf

The graph shows that Liberia is vulnerable to the effects of climate change variability like heavy rainfall in May, June, September and October. Apart from that, the above figure shows the annual temperature for Liberia is 25.7 degrees centigrade with highlighted monthly temperature which is ranging between 30 degrees centigrade during January to December. However, lack of sufficient data regarding daily temperature trends for all weather patterns, the available data indicates that the average number of hot nights annually grew by 60% from 1960 to 2003. There is also a significant decrease in cold nights which is reduced by 18 days annually. The rate of change has been highlighted in June to September period (Manogaran et al., 2018).



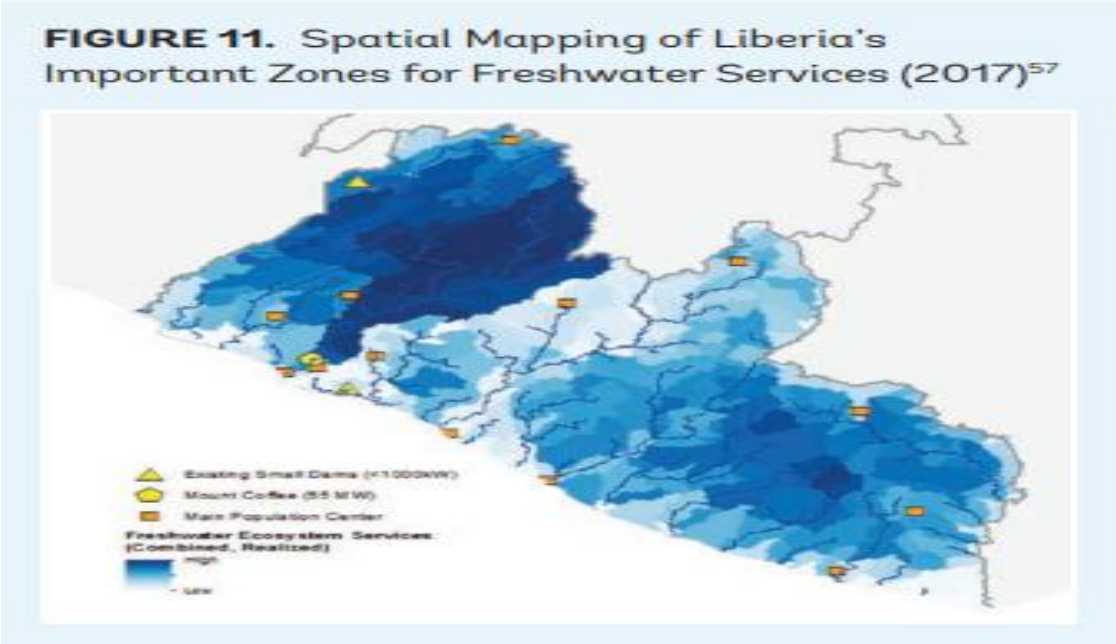
Source: https://climateknowledgeportal.worldbank.org/sites/default/files/2021-07/15917-WB_Liberia%20Country%20Profile-WEB%20%281%29.pdf

The chart shows that the length of Liberia days does not change substantially throughout the year by staying within 44 minutes of twelve hours all over. Liberia shortest day is 21 December with eleven hours and thirty minutes of daylight and the longest day is 20 June with twelve hours and 45 minutes of daylight (Lu et al., 2019).



Source: https://climateknowledgeportal.worldbank.org/sites/default/files/2021-07/15917-WB_Liberia%20Country%20Profile-WEB%20%281%29.pdf

The map shows that the country is experiencing high river flood hazards with the potential risk of damage life-threatening as it is occurring throughout the year (Lu et al., 2019). As shown in the map above, Liberia is highly risky for urban floods and coastal flooding which is affected by the resultant factor of sea level rises. Furthermore, the figure shows that the population densities like Monrovia and coastal zone are overlapping with flood zones of high vulnerability.

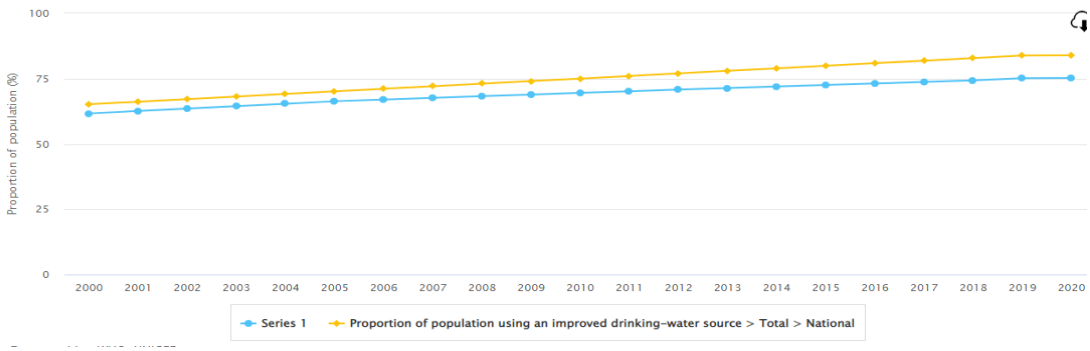


Source: https://climateknowledgeportal.worldbank.org/sites/default/files/2021-07/15917-WB_Liberia%20Country%20Profile-WEB%20%281%29.pdf

The above chart shows that the services of freshwater in Liberia concerning the quantity, quality and flow regulation with wide-ranging population and hydropower dams (Coulibaly et al., 2018).

Water Scarcity and Sanitation Resources

The proportion of the population using safely managed to drink water services in Liberia, progress over time

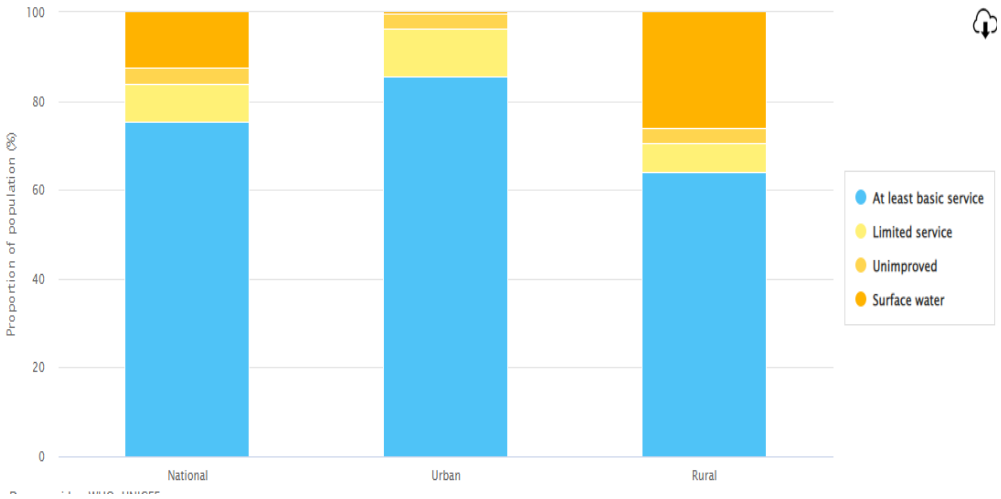


Source: https://www.sdg6data.org/country-or-area/liberia#anchor_6.3.2

The above trend shows that only a small percentage of people access safely managed to drink water services and limited progress was made between 2000 to 2020 by the water sanitation and treatment authority as the gradual increase in population using safely managed drinking water services. In addition, research is in agreement with the result by the statement that

water quality and sanitation in Liberia remains a key challenge faced by the whole community (Coulibaly et al., 2018)

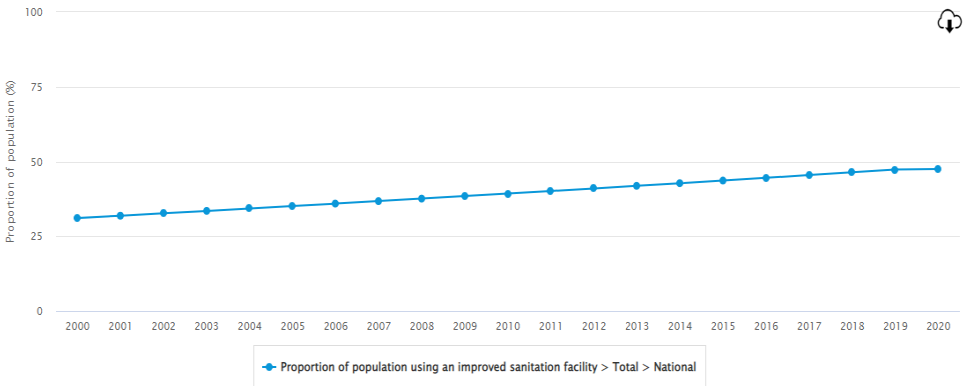
The proportion of the population using safely managed drinking water services in Liberia, by service level and location (2020)



Source: https://www.sdg6data.org/country-or-area/liberia#anchor_6.3.2

The above trend explains that at least the basic requirement of water is being fulfilled in urban areas. However, rural zones have acceptable levels of water resources. In addition, rural have more surface area than urban with an extremely low figure. Limited services are provided in urban is greater than in rural which affect more urbanisation. Hence, seasonal changes in precipitation and rainfall have a significant impact on water balance by degenerating water quality via contamination (Coulibaly et al., 2018).

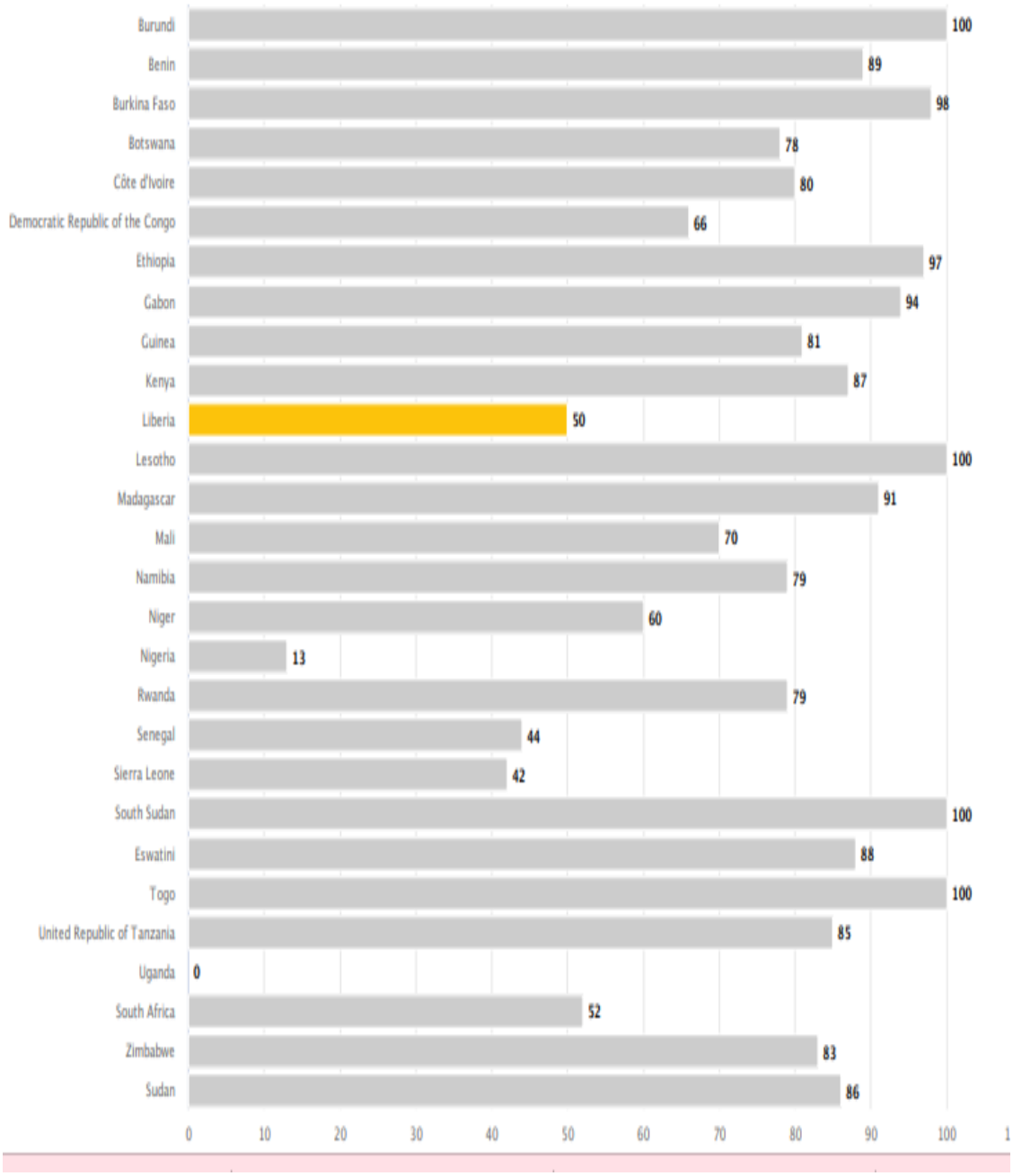
The proportion of the population using safely managed sanitation services in Liberia, progress over time



Source: https://www.sdg6data.org/country-or-area/liberia#anchor_6.3.2

The chart shows that the society of Liberia accessing safely managed sanitation services is also low over time which suggests that water resources are not utilized and managed at a greater potential in the country. The result supported by who finds that the people using an improved sanitation service is general low approximately 40% in 2010 and increase was taken place by just 5% from 1990 (Olatunji et al., 2020).

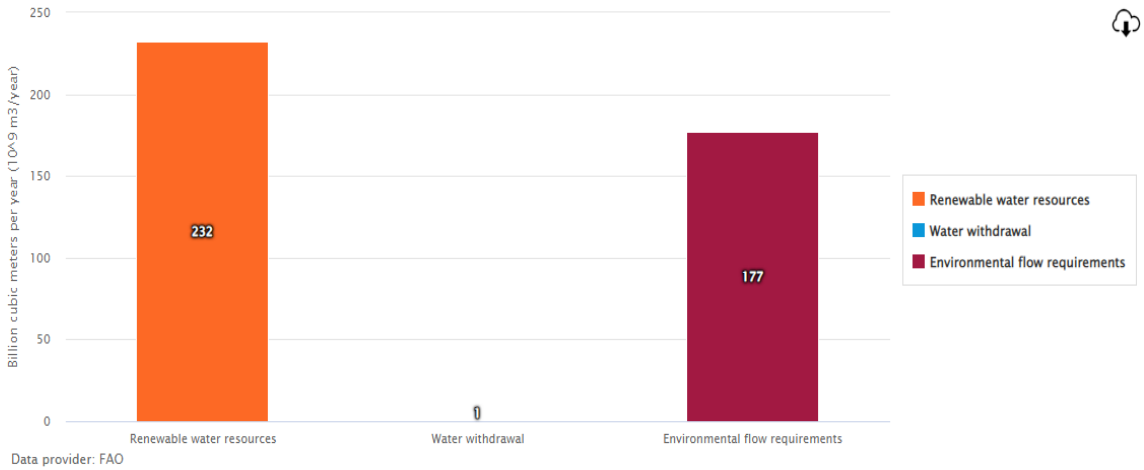
The proportion of bodies of water with good ambient water quality in Liberia (2017), compared to other countries (and areas) in the region



Source: https://www.sdg6data.org/country-or-area/liberia#anchor_6.3.2

The above chart shows that Liberia has the lowest rank of having good ambient water quality after Nigeria and Uganda comparatively to other countries and regions such as Burundi and South Sudan which is outperforming as both areas are experiencing a good trend in accessing good water quality which is supported by (Odikamnoro, et al., 2019) who identified that only 25% of the population could access clean drinking water in 2016 and more than 1 million people are unable to access safe water in 2016.

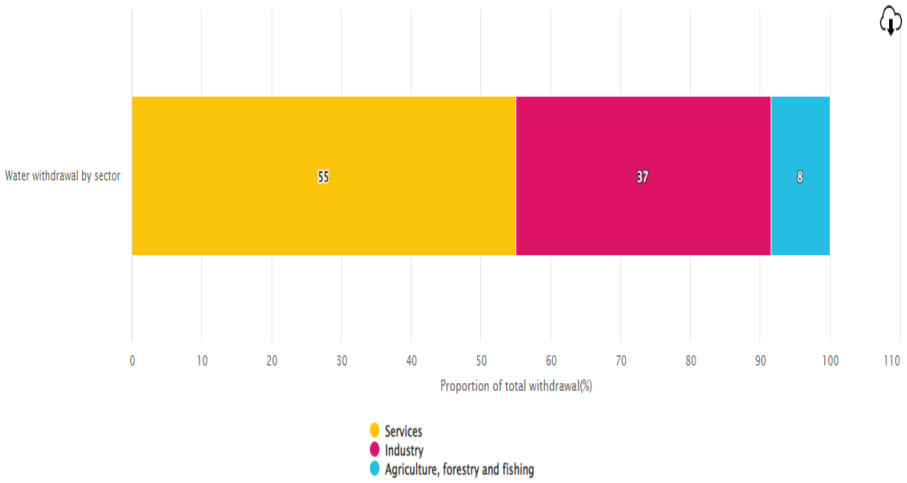
Water resources and withdrawal in Liberia, total and per capita



Source: https://www.sdg6data.org/country-or-area/liberia#anchor

The above graph shows that the total amount of water withdrawal per capital for Liberia was 0 cubic meters annually. However, facts suggest that water withdrawal per capita was 30.28 cubic meters annually in 2018 (Coulibaly et al., 2018) and decrease gradually from 56 cubic meters in 1997 to 30 cubic meters per anum in 2018. Liberia water withdrawal for agriculture was at 0.01 cubic meters per anum in 2018 which was unchanged from the previous two years (Pavičević et al., 2021).

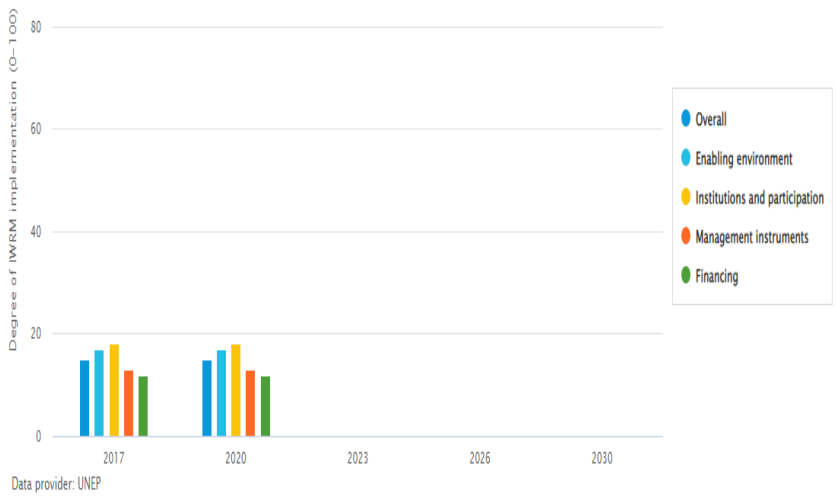
Change in water-use efficiency over time in Liberia, by sector (2000,2005)



Source: https://www.sdg6data.org/country-or-area/liberia#anchor

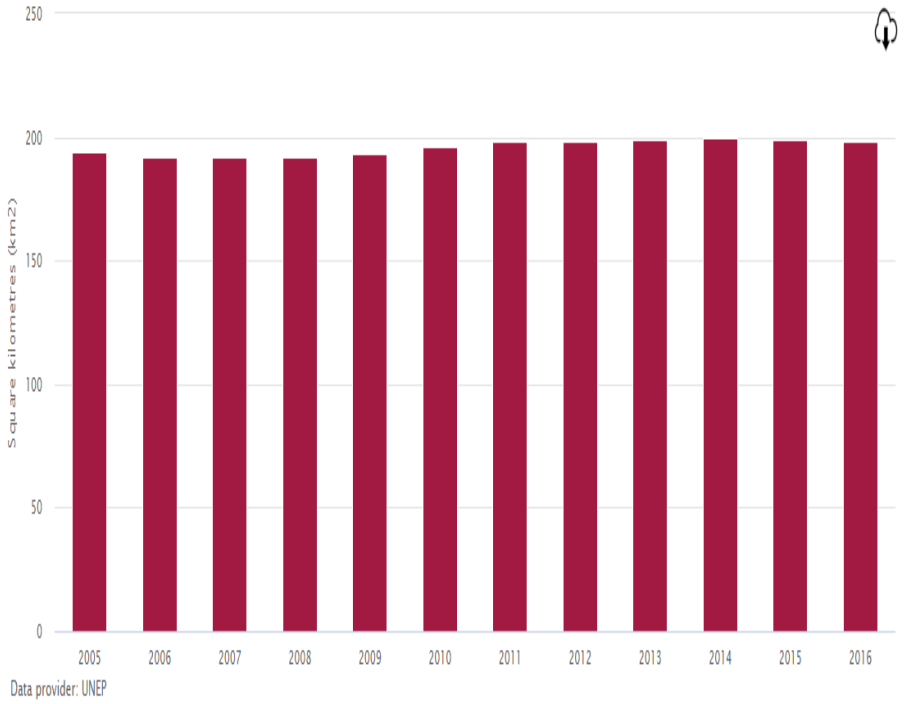
The above graph shows that service sector which is 55 times more water withdrawal than Industry and livestock sector which is among the lowest. The water use efficiency implies that the total volume of water is utilized by the different industries and gross value added from these sectors accordingly. The results are in agreement with (Seedee, 2018) who highlights the importance that the development of the agricultural sector is the priority of the Liberian nation where the agriculture sector has low water withdrawal around 10% relative to industrial and municipal usage. Hence, investment in the agri-food sector would facilitate the likelihood and economic prosperity of Liberia (Coulibaly et al., 2018).

Degree of integrated water resources management implementation (0-100) in Liberia, progress over time, by dimension



Source: https://www.sdg6data.org/country-or-area/liberia#anchor

The above chart shows the very lowest participation in the degree of integrated water resource management implementation on a scale of (0-100) ranging from very low (0-10), low (11-30), medium-low (31-50), medium-high (51-70) high (71-90), very high (91-100)) by four dimensions such as institutional participation, enabling environment, financing and management instruments. The results are very shocking as these parameters are under the range of the "low" category.



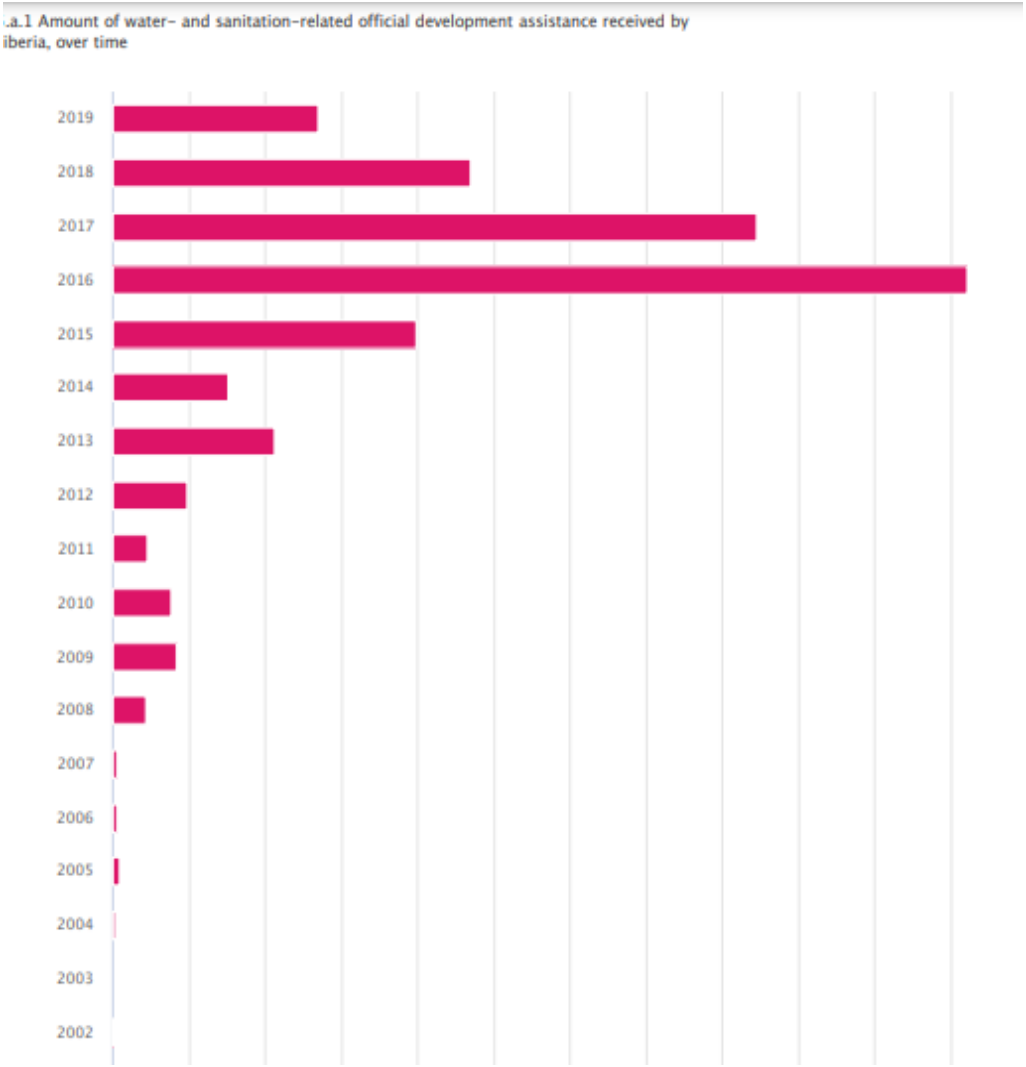
Source: https://www.sdg6data.org/country-or-area/liberia#anchor

The graph depicts the relationship between changes occurring in surface water-covered areas to flood and droughts and connected to climate change (Seedee, 2018). In addition, longitudinally extend rivers and artificial bodies which are as explained.

- Latest 5 year period 2011-2015: 198km^2
- Baseline 192 km square during 2001 to 2005
- Change in the baseline is gaining 50% momentum

International Collaboration

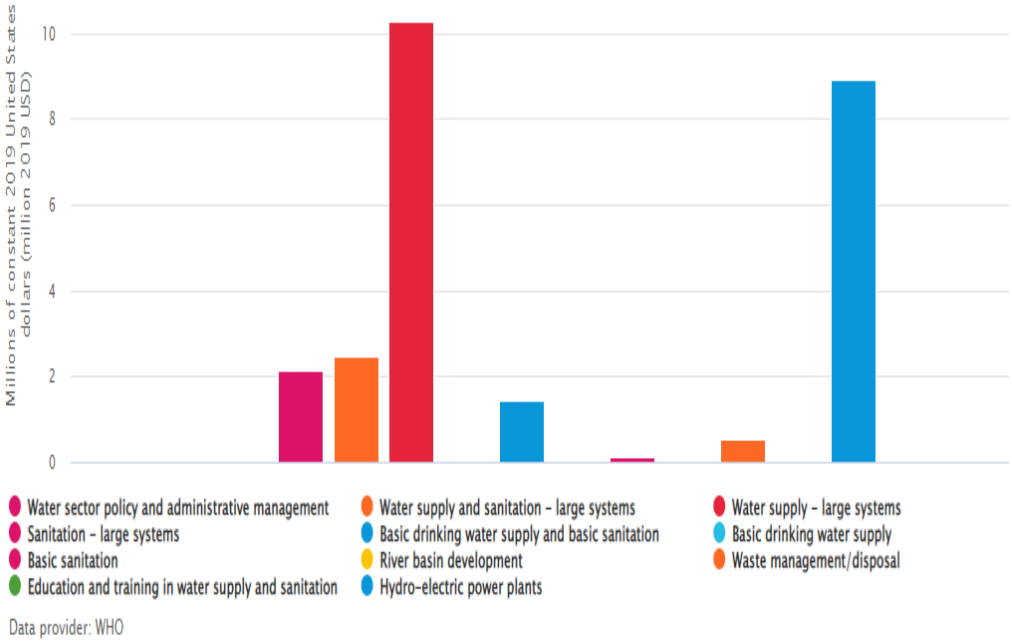
International cooperation and capacity-building



Source: https://www.sdg6data.org/country-or-area/liberia#anchor

The chart depicts that the amount of water and sanitation assistance programs received by the country was highest in the year 2016 and then 2017, 2018 and 2015. Contrarily, receiving those supported programs were lowest during 2019 and 2013. However, the graph further suggests a good trend toward the Liberian support program over a while (Seedee, 2018).

Amount of water- and sanitation-related official development assistance received by Liberia in 2019, by sub-sector

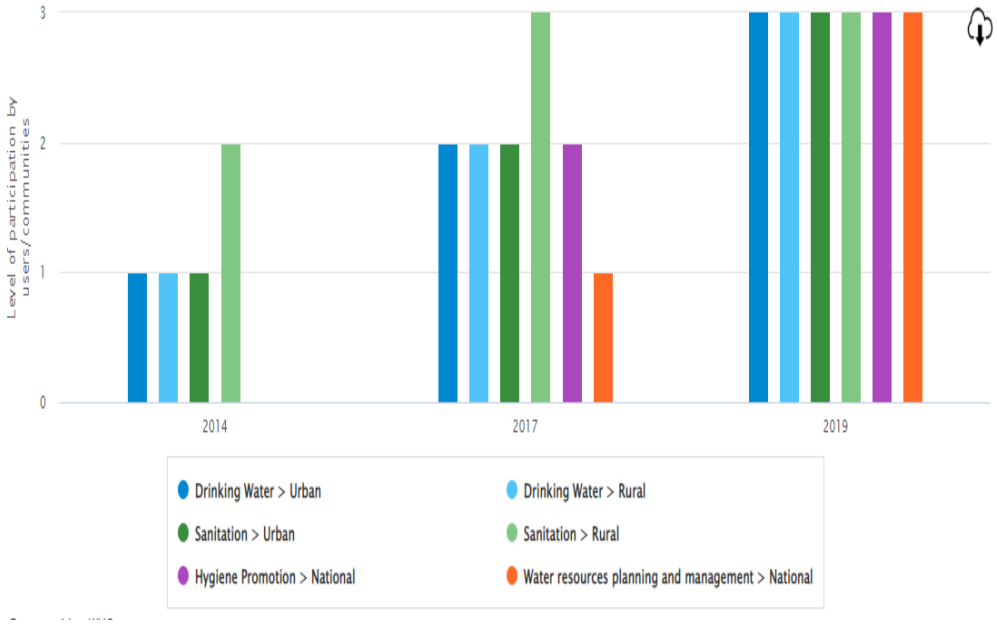


Source: https://www.sdg6data.org/country-or-area/liberia#anchor

The chart shows that the highest sub-sector in water and sanitation assistance programs received by Liberia sub-sectors was water sector policy and administrative management and water supply and sanitation. However, other sectors are lagging in receiving water-related support in 2019. Water and sanitation affiliated development support comprise river basin development, agriculture water resource, hydroelectric power, waste management and disposal, and water resource conservatism (Seedee, 2018).

Community participation

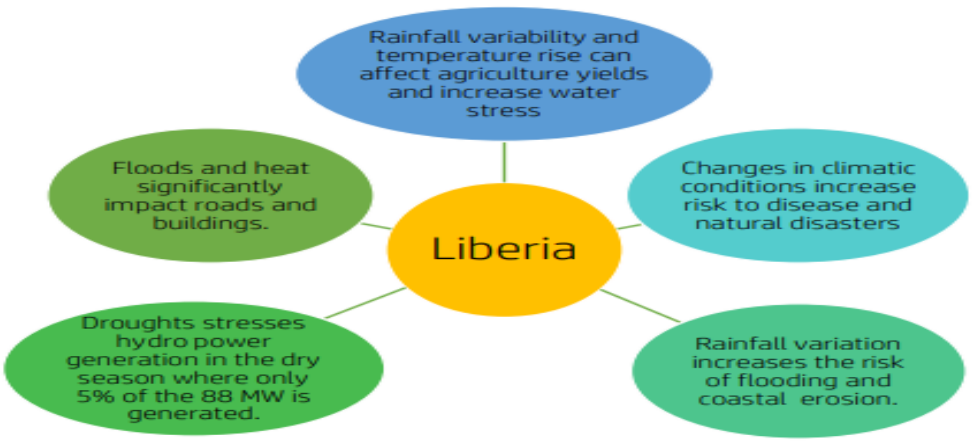
Level of participation by users/communities in Liberia, progress over time, by sub-sector



Source: https://www.sdg6data.org/country-or-area/liberia#anchor

The graph shows the level of participation by communities and sub-sector in Liberia where results depict that the sanitation by rural has the highest participation than sanitation by urban in 2014 and 2017 and then following drinking water where both urban and rural have similar contributions. Similar, hygiene promotion and water resource planning and management nationwide have been taking place since 2015 and contribute most in the nation of Liberia (Coulibaly et al., 2018).

Climate Change in Liberia



(Source: Liberia, 2020)

The figure highlights some of the drastic impacts of climate change in the nation of Liberia. Similar to any other country, the effect of changing climate is estimated to be reflected in Liberia. Being one of the least developed nations of the world, the outcomes which come from climate change are severe due to lack of adequate support and institutional methodology and poverty. The patterns changes in sea rise, precipitation, temperature and water withdrawal by individuals and by sector hurt water balance by reducing water volume and degenerating water quality (Coulibaly et al., 2018). Overflowing in the St. Paul River is estimated to be reduced 0.7-25% by the end of 2021 due to severe temperature and precipitation changes which further impact potential hydropower facilities at the Mount Coffee Plant and water flow for Monrovia which is the largest Municipal power resource in providing electricity. Similarly, water access and sanitation support programs also declined substantially. However, improvements were made in Liberia. Furthermore, environmental degradation, lack of biodiversity, sanitation infrastructure and climate change constitute a serious problem to development efforts that increase vulnerability to nation hazards. There is a strong relationship between rainfall intensity and climate change. Rising sea levels have a significant association with seasonal storms and tidal surges which destroys infrastructure and displace coastal livelihoods (Freije et al., 2021). The current findings are supported by the study (Wright, 2016) who stress the importance of the Falkenmark Water Stress Index and measured water scarcity by taking the availability of renewable freshwater to each person data annually. Liberia is experiencing water scarcity. Despite having surface water, the country is limited on groundwater availability in urban zones which further grow the uncertainty of potential harm to water supply and people health. Water resource management programs across certain management institutions were dispersed, a dedicated ministry for water integration is low. Similarly, the lack of coordination among the entities impedes water resource efficiency efforts. Lack of financing and limited technical support also hinder the nation Integrated Water Resource Management policy (Fragnière et al., 2020).

CONCLUSION

It has been concluded that climate change (CC) is a region of science that has been studied for several years. Climate change in Liberia has a multitude of long term immediate effects on water resource management in African countries. The impacts include flooding, rise in sea level, melting glaciers, droughts, contaminated water in surface and groundwater networks, water evaporation distortion and snow diminution. Integration of these effects may have a devastating effect on ecosystems ranging from health and insecurity and social ecologies like

water scarcity and contaminated water which all have a threat to Liberia. The record of fossils has trained humanity most regarding situations on Earth long previous to their arrival. They currently live in an exclusive period within which their scientific capability has not merely provided them with an accurate age by the globe, therefore of the world itself. Livelihood individuals live on food, food is shaped by growth and a plant of plants depending on climate. Consequently, erratic change (EC) within the climate would set billions of lives at risk. But, it is of paramount importance that they talk about, monitor and ensure that the climate for various areas remains at its natural level. A lot of literature proposes that global warming (GW) caused by the GW gases emitted extremely by the developed companies and automobiles sectors are the reason for EC. GW if unchecked would power the climate of the globe to the aim that globe tipping aim is reaching, everywhere the surviving globe could not maintain some lives in it, changing the route by history proceeding by mass destruction by species within the globe. Due to the probability of paying a greater cost later owing to the easy negligence by period, it is the responsibility of all the international people to be alert regarding it and come jointly to result in successful solutions to moderate the issue that is always going to be better as it takes late. It will be a serious fault to choose not to heed this international immediate call, for it can also break or make their future group.

Climate change and water resource management are perceived to be hot topics for global sustainable development goals which are gaining literature attention throughout the world. Analysed the impact of global climate change on hydrology and water cycle in River catchment in Liberia with focusing on the tie between climate change and water resource management. Further, the author explores the summarized process of water availability and its utilisation in many regions of Liberia.

Recommendation

- The responsibility that the government of Liberia and other role players, including the private sector, must act in water stewardship to attain a sustainable, future low-carbon is accepted in SDGs and. However, this information is still sapient. Most firms are not obtaining the instance of forward-looking companies in their strategies to divert city water, energy, and biodiversity and climate objectives to reduce trade-offs and reduce synergies (Ha, et al., 2015).
- Technology-led climate change revocation methods usually need investment in minimizing emissions from powering infrastructure of water, counting for suppliers of

drinking water, handling of wastewater and tempest water, and pumping water for agriculture and other uses in Liberia. In this context, there are diver water- and sanitation-related revocation approaches that ought to be careful about management and planning procedures in the extraction, treatment and distribution of water (Manogaran, et al., 2018).

- Manufacture of renewable recovery and energy (thus minimizing the demand for fossil fuels)for example Turbines placed along with the water wastewater and supply systems for hydropower cohort (in the context of a combined water capitals management system that could classify whether specific growths are advisable and feasible) in Liberia.
- The utiliser of wastewater can be a sustainable and cost-efficient means of power, nutrients, organic matter and other valuable by-products.20 Biogas from the wastewater status procedure can be taken and donated to carbon-neutral status in Liberia. Also, given the fever of wastewater, heat pumps can be connected in drain pipes to crop power.
- Aquifers include the globe biggest means of new water presented for people utiliser and can be less susceptible than superficial water to the straight influences of climate change. Thus, aquifers signify a key constituent in the revocation of the danger of short-term water lack and cumulative water safety through climate adaptation events for example achieved aquifer renewal. However, storing volume and renewing taxes vary significantly, meaning that measures must be adopted locally in Liberia (Freije, et al., 2017).
- Co-management could improve flexibility to address drought, making it likely to increase a region's overall water-storing volume. Conjunctive water management interferences for example subversive humanizing of deluges for irrigation are sustainable, cost-effective and climbable answers, and maybe particularly pertinent in the developing-country context.28, 29, 30 through rainwater imprisonment is chiefly pertinent in areas with uneven precipitation delivery to revocation the dangers of extreme precipitation run-off and to stock new water in the earth for the dry period in Liberia (Frischknecht, et al., 2016).
- Cross-sectoral devices that an explanation for the understood and clear water promises crossways all shares and heights of civilisation among and within countries – chiefly in the context of sympathetic key hydro-climatic risks – are significant to safeguard that doings are feasible and do not undermine local water safety, especially for vulnerable inhabitants in Liberia (Medina, et al., 2017).

- Utiliser of first warning community and systems engagement can revoke the contact of metropolises to drought and flood risk. A singular challenge is discovering enough interplanetary to handle top flows throughout extreme storm saving and events enough freshwater for utilisation during the dryer eras. This problem calls for answers at diver scales from the domestic level up to the town level. In rural parts, expanding living choices, providing admission to credit, safeguarding land tenancy, refining access to power and farming extension, as well as hydroclimate services, and increasing crop cover computer operator can assist rural communities to be additional hardy to rainfall stressors and tremors in Liberia (Marx, et al., 2018).

REFERENCES

1. Ahmad, N.N.N. and Hossain, D.M., 2015. Climate change and global warming discourses and disclosures in the corporate annual reports: A study on the Malaysian companies. *Procedia-social and behavioural sciences*, *172*: 246-253.
2. Aladejana, J.A., Kalin, R.M., Sentenac, P. and Hassan, I., 2020. Assessing the impact of climate change on groundwater quality of the shallow coastal aquifer of eastern Dahomey basin, southwestern Nigeria. *Water*, *12*(1): 224.
3. Altenburger, R., Ait-Aissa, S., Antczak, P., Backhaus, T., Barceló, D., Seiler, T.B., Brion, F., Busch, W., Chipman, K., de Alda, M.L. and de Aragão Umbuzeiro, G., 2015. Future water quality monitoring—adapting tools to deal with mixtures of pollutants in water resource management. *Science of the total environment*, *512:* 540-551.
4. Antwi-Agyei, P., Dougill, A.J. and Stringer, L.C., 2015. Barriers to climate change adaptation: evidence from northeast Ghana in the context of a systematic literature review. *Climate and Development*, *7*(4): 297-309.
5. Arafat, S.Y., Chowdhury, H.R., Qusar, M.M.A.S. and Hafez, M.A., 2016. Cross-cultural adaptation & psychometric validation of research instruments: A methodological review. *J Behav Health*, *5*(3): 129-36.
6. Bein, T., Karagiannidis, C. and Quintel, M., 2020. Climate change, global warming, and intensive care. *Intensive care medicine*, *46*(3): 485-487.
7. Benjamin, D., Por, H.H. and Budescu, D., 2017. Climate change versus global warming: Who is susceptible to the framing of climate change?. *Environment and Behaviour*, *49*(7): 745-770.
8. Change, P.C., 2018. Global warming of 1.5 C. *World Meteorological Organisation: Geneva, Switzerland*.

9. Clement, M., Mwakalila, S. and Norbert, J., 2018. Implications of Land Use and Climate Change on Water Balance Components in the Sigi Catchment, Tanzania. *Journal of the Geographical Association of Tanzania*, *39*(1): 142-159.
10. Coulibaly, N., Coulibaly, T.J.H., Mpakama, Z. and Savané, I., 2018. The impact of climate change on water resource availability in a transboundary basin in West Africa: The case of Sassandra. *Hydrology*, *5*(1): 12.
11. Dias, F.B., Fiedler, R., Marsland, S.J., Domingues, C.M., Clément, L., Rintoul, S.R., Mcdonagh, E.L., Mata, M.M. and Savita, A., 2020. Ocean heat storage in response to changing ocean circulation processes. *Journal of Climate*, *33*(21): 9065-9082.
12. Donnelly, C., Greuell, W., Andersson, J., Gerten, D., Pisacane, G., Roudier, P. and Ludwig, F., 2017. Impacts of climate change on European hydrology at 1.5, 2 and 3 degrees mean global warming above the preindustrial level. *Climatic Change*, *143*(1): 13-26.
13. Erika, I. and Bala, K., 2017. Sampling and sampling methods. *Biometrics & Biostatistics International Journal*, *5*(6): 00149.
14. Fafunwa, T.S., Mogaji, H.O., Oluwole, A.S., Adeniran, A.A., Fagbenro, M.T., Sam-Wobo, S.O., Bada, B.S. and Ekpo, U.F., 2017. Water Resource, Hygienic Practice, and Soil-Transmitted Helminthiasis in Some Rural Communities of Osun State, Nigeria. *Journal of Water Resource and Protection*, *9*(2): 99-110.
15. Fazey, I., Schäpke, N., Caniglia, G., Patterson, J., Hultman, J., Van Mierlo, B., Säwe, F., Wiek, A., Wittmayer, J., Aldunce, P. and Al Waer, H., 2018. Ten essentials for action-oriented and second order energy transitions, transformations and climate change research. *Energy Research & Social Science*, *40:* 54-70.
16. Fragnière, Y., Pittet, L., Clément, B., Bétrisey, S., Gerber, E., Ronikier, M., Parisod, C. and Kozlowski, G., 2020. Climate change and alpine screes: no future for glacial relict Papaver occidentale (Papaveraceae) in Western Prealps. *Diversity*, *12*(9): 346.
17. Freije, A.M., Hussain, T. and Salman, E.A., 2017. Global warming awareness among the University of Bahrain science students. *Journal of the Association of Arab Universities for Basic and Applied Sciences*, *22:* 9-16.
18. Frischknecht, R., Fantke, P., Tschümperlin, L., Niero, M., Antón, A., Bare, J., Boulay, A.M., Cherubini, F., Hauschild, M.Z., Henderson, A. and Levasseur, A., 2016. Global guidance on environmental life cycle impact assessment indicators: progress and case study. *The International Journal of Life Cycle Assessment*, *21*(3): 429-442.

19. Geissen, V., Mol, H., Klumpp, E., Umlauf, G., Nadal, M., Van der Ploeg, M., Van de Zee, S.E. and Ritsema, C.J., 2015. Emerging pollutants in the environment: a challenge for water resource management. *International soil and water conservation research*, *3*(1): 57-65.
20. Goyal, M.K. and Surampalli, R.Y., 2018. Impact of climate change on water resources in India. *Journal of Environmental Engineering*, *144*(7): 04018054.
21. Grigg, N.S., 2016. *Integrated water resource management: an interdisciplinary approach*. Springer.
22. Ha, N., Feike, T., Back, H., Xiao, H. and Bahrs, E., 2015. The effect of simple nitrogen fertiliser recommendation strategies on product carbon footprint and gross margin of wheat and maize production in the North China Plain. *Journal of environmental management*, *163:* 146-154.
23. Heeringa, S.G., West, B.T. and Berglund, P.A., 2017. *Applied survey data analysis*. Chapman and Hall/CRC.
24. Jang, S.M. and Hart, P.S., 2015. Polarized frames on "climate change" and "global warming" across countries and states: Evidence from Twitter big data. *Global Environmental Change*, *32:* 11-17.
25. Kochhar, K., Pattillo, C., Sun, Y., Suphaphiphat, N., Swiston, A., Tchaidze, R., Clements, B., Fabrizio, S., Flamini, V., Redifer, L. and Finger, H., 2015. Is the Glass Half Empty Or Half Full?. *Is the Glass Half Empty Or Half Full?*, *2015;* (11): 1-44.
26. Kochhar, M.K., Pattillo, M.C.A., Sun, M.Y.M., Suphaphiphat, M.N., Swiston, M.A.J., Tchaidze, M.R., Clements, M.B.J., Fabrizio, M.S., Flamini, V., Redifer, M.L. and Finger, M.H., 2015. *Is the glass half empty or half full?: Issues in managing water challenges and policy instruments*. International Monetary Fund.
27. Kundzewicz, Z.W., Krysanova, V., Benestad, R.E., Hov, Ø., Piniewski, M. and Otto, I.M., 2018. Uncertainty in climate change impacts on water resources. *Environmental Science & Policy*, *79:* 1-8.
28. Leiserowitz, A., Maibach, E., Roser-Renouf, C., Feinberg, G. and Rosenthal, S., 2015. Climate change in the American mind: March 2015. *Yale University and George Mason University, New Haven, CT: Yale Project on Climate Change Communication. Web*.
29. Lu, S., Bai, X., Li, W. and Wang, N., 2019. Impacts of climate change on water resources and grain production. *Technological Forecasting and Social Change*, *143:* 76-84.

30. Manogaran, G., Varatharajan, R. and Priyan, M.K., 2018. Hybrid recommendation system for heart disease diagnosis based on multiple kernel learning with adaptive neuro-fuzzy inference system. *Multimedia tools and applications*, *77*(4): 4379-4399.
31. Marx, A., Kumar, R., Tober, S., Rakovec, O., Wanders, N., Zink, M., Wood, E.F., Pan, M., Sheffield, J. and Samaniego, L., 2018. Climate change alters low flows in Europe under global warming of 1.5, 2, and 3 C. *Hydrology and Earth System Sciences*, *22*(2): 1017-1032.
32. Medina, Á., González-Jartín, J.M. and Sainz, M.J., 2017. Impact of global warming on mycotoxins. *Current Opinion in Food Science*, *18:* 76-81.
33. Mehnert, A., 2016. *Climate change fictions: representations of global warming in American literature*. Springer.
34. Mishra, Y., Nakamura, T., Babel, M.S., Ninsawat, S. and Ochi, S., 2018. Impact of climate change on water resources of the Bheri River Basin, Nepal. *Water*, *10*(2): 220.
35. Morris, J.L., Cottrell, S., Fettig, C.J., DeRose, R.J., Mattor, K.M., Carter, V.A., Clear, J., Clement, J., Hansen, W.D., Hicke, J.A. and Higuera, P.E., 2018. Bark beetles as agents of change in social-ecological systems. *Frontiers in Ecology and the Environment*, *16*(S1): S34-S43.
36. Ngwa, M.C., Wondimagegnehu, A., Okudo, I., Owili, C., Ugochukwu, U., Clement, P., Devaux, I., Pezzoli, L., Ihekweazu, C., Jimme, M.A. and Winch, P., 2020. The multi-sectoral emergency response to a cholera outbreak in internally displaced person camps in Borno state, Nigeria, 2017. *BMJ global health*, *5*(1): e002000.
37. Oberle, B., Bringezu, S., Hatfield-Dodds, S., Hellweg, S., Schandl, H. and Clement, J., 2019. *Global resources outlook: 2019*. International Resource Panel, United Nations Envio.
38. Owusu, P.A., Asumadu-Sarkodie, S. and Ameyo, P., 2016. A review of Ghana's water resource management and the prospect. *Cogent Engineering*, *3*(1): 1164275.
39. Schroth, G., Läderach, P., Martinez-Valle, A.I., Bunn, C. and Jassogne, L., 2016. Vulnerability to climate change of cocoa in West Africa: Patterns, opportunities and limits to adaptation. *Science of the Total Environment*, *556:* 231-241.
40. Seedee, R.W., 2018. *The Impact of Foreign Aid on Extreme Poverty: A Case Study of Liberia's Development Complexities (1980-2018)* (Doctoral dissertation, East Tennessee State University).
41. Shrestha, G. and Clement, F., 2019. Unravelling gendered practices in the public water sector in Nepal. *Water Policy*, *21*(5): 1017-1033.

42. Sylla, M.B., Nikiema, P.M., Gibba, P., Kebe, I. and Klutse, N.A.B., 2016. Climate change over West Africa: Recent trends and future projections. *Adaptation to climate change and variability in rural West Africa*, 25-40.
43. Trainer, V.L., Moore, S.K., Hallegraeff, G., Kudela, R.M., Clement, A., Mardones, J.I. and Cochlan, W.P., 2020. Pelagic harmful algal blooms and climate change: Lessons from nature's experiments with extremes. *Harmful Algae*, *91:* 101591.
44. Wezel, A., Brives, H., Casagrande, M., Clement, C., Dufour, A. and Vandenbroucke, P., 2016. Agroecology territories: places for sustainable agricultural and food systems and biodiversity conservation. *Agroecology and sustainable food systems*, *40*(2): 132-144.
45. Wright, S., O'Brien, B.C., Nimmo, L., Law, M. and Mylopoulos, M., 2016. Research design considerations. *Journal of graduate medical education*, *8*(1): 97-98.