CLIMATE RISK COUNTRY PROFILE

LIBERIA

WORLD BANK GROUP

Graphic Design: Circle Graphics, Inc., Reisterstown, MD.

ACKNOWLEDGEMENTS

This profile is part of a series of Climate Risk Country Profiles developed by Climate Change Group of the World Bank Group (WBG). The country profiles aim to present a high-level assessment of the climate risks faced by countries, including rapid-onset events and slow-onset changes in climate conditions, many of which are already underway, as well as summarize relevant information on policy and planning efforts at the country level.

The country profile series are designed to be a reference source for development practitioners to better integrate detailed climate data, physical climate risks and need for resilience in development planning and policy making.

This effort is managed and led by MacKenzie Dove (Technical Lead, CCKP, WBG), Pascal Saura (Task Team Lead, CCKP, WBG) and Megumi Sato (Climate Change Specialist, WBG).

This profile was written by Sam Geldin (Climate Change Consultant, CCKP, WBG).

Unless otherwise noted, data is sourced from the WBG's Climate Change Knowledge Portal (CCKP), the WBG's designated platform for climate data. Climate, climate change and climate-related data and information on CCKP represents the latest available data and analysis based on the latest Intergovernmental Panel on Climate Change (IPCC) reports and datasets. The team is grateful for all comments received from climate and development specialists, as well as climate research scientists and institutions for their advice and guidance on the use of climate related datasets.

CONTENTS

FOREWORD

Climate change is a major risk to good development outcomes and presents an existential threat to the World Bank Group's (WBG) twin goals of ending extreme poverty and promoting shared prosperity in a sustainable way. The WBG is thus committed to supporting client countries to invest in a low-carbon and climate-resilient future.

Our approach is outlined in the *WBG Climate Change Action Plan (CCAP) 2021–2025*, which focuses on helping countries integrate climate into their development agendas, with the goal to combine mitigation and adaptation with economic growth and poverty reduction. Guided by the *CCAP*, the WBG prioritizes climate action across five key systems: energy; agriculture, food, water, and land; cities; transport; and manufacturing. Only through transforming these systems can we begin to address climate change, achieve a resilient and low-carbon future, and support natural capital and biodiversity, while achieving development goals.

A key element of this strategy relies on the capacity to systematically incorporate and manage climate risks in development operations. We are thus investing in processes and tools that allow us to inform lending with climate data.

The Climate Change Knowledge Portal (CCKP) is an online 'one-stop-shop' for foundational climate data at the global, regional, and country levels. CCKP provides inputs to the WBG's Climate and Disaster Risk Screening Tool, which contributes to assessing short- and long-term climate and disaster risks in operations as well as national or sectoral planning processes.

Supplementing this effort, the *Climate Risk Country Profile* you are about to read is a signature product of CCKP which supports a better understanding of the impacts of physical climate risks. Guided by the Climate Risk Country Profile, WBG, key external partners, and development practitioners may conduct initial assessments of climate risks and opportunities that will eventually inform upstream country diagnostics, policy dialogue, and strategic planning for developing countries.

It is my hope that these efforts will spur the prioritization of long-term risk management and deepen the WBG's commitment to integrate adaptation planning into strategic country engagements and lending operations.

Jennifer J. Sara
Global Director
Climate Change Group (CCG)
The World Bank Group (WBG)

KEY MESSAGES

- **Observed Climate:** Liberia is one of the wettest countries in the world and features consistently warm temperatures year-round. Its rainiest months (June-Sept) and drier months (Dec-Apr) vary by county, depending on both the timing and intensity of the Intertropical Convergence Zone (ITCZ) and monsoon conditions.
- **Observed Temperature:** Between 1971 and 2020, Liberia's mean temperature increased by 0.13°C per decade.
    - **Central and southern plateau regions** observed the greatest changes over this period during the winter months.
- **Projected Temperature:** Under SSP3-7.0, Liberia's mean temperatures nationwide are homogeneously projected to increase from the 1995–2014 reference period by an anomaly of 0.67°C (0.38°C, 1.09°C) over 2020–2039 and 1.36°C (0.86°C, 2.10°C) over 2040–2059.
- **Extreme Heat Risk:** By midcentury, Liberia is likely to experience higher minimum and maximum temperatures. By end-of-century, it is likely to experience hotter apparent conditions due to high atmospheric moisture content. The following key metrics for temperature illustrate these risks under the SSP3-7.0 scenario for the period of 2040–2059, compared to the historical reference period of 1995–2014.
    - Number of Hot Days, T-max >30°C: The number of hot days with a maximum temperature >30°C are expected to increase 102.39 (59.22, 148.47) days nationally by 2040–2059 under SSP3-7.0, amounting to a median of 226.76 (169.43, 273.09) days per year. Liberia's food and agriculture as well as water and sanitation sectors should monitor this increase.
        - **Coastal areas** experienced the greatest increases by midcentury during spring months while **interior areas** experienced the greatest increases during fall months.
    - Number of Tropical Nights, T-min >26°C: By midcentury, the number of tropical nights with a minimum temperature >26°C, a high threshold, is projected to increase 11.98 (3.77, 33.32) nights from the reference period, during which virtually no tropical nights occurred at the national level. The combination of increased high heat days and tropical nights disproportionately concern: the elderly, pregnant women, children and newborns, people with chronic illnesses and disabilities, outdoor workers, low-wage earners, and people living in areas with poorly equipped and ill-prepared health services.
        - **Counties along the coast** are projected to experience the greatest increases during spring months by midcentury.
    - Warm Spell Duration Index: This annualized index indicates the number days with consecutive daily maximum temperatures greater than the 90th percentile of daily maximum temperature calculated over a five-day window annually. Warm spell anomalies, measured in number of days annually, are projected to dramatically increase 125.26 (35.37, 265.97) days by midcentury. This shift reflects a longer-term change in daily maximum temperatures, which especially impact the most populous areas.
        - **Coastal counties** are projected to experience the greatest increases in warm spells by midcentury.
- **Observed Precipitation:** Over the 50-year period of 1971–2020, some of Liberia's counties experienced significant increases in precipitation per decade while others experienced decreases. It is unclear if this trend portends major long-term increases in annual cumulative precipitation beyond natural variability. Over this period:
    - **Counties in southern Liberia** were significantly drier during winter months.
    - **Counties in central and northern Liberia** were significantly drier during spring months.
    - **Coastal counties** were significantly wetter in summer and fall months.
- **Projected Precipitation:** Projected precipitation patterns under SSP3-7.0 reflect potentially more intense wet and dry monsoon seasons with regionally-specific timing, however there is still a wide range of uncertainty.

Precipitation decreases from the reference period at the national level by an anomaly of –18.41 mm (–376.92 mm, 230.00 mm) annually to 2,279.45 mm (1,749.19 mm, 2,735.86 mm) by midcentury, but exhibits divergent regional and seasonal differences.

  - **The southern and central coasts** are expected to experience the greatest annual decreases in precipitation, mostly during winter months.
  - **The northern coast and central and southern interior** are expected to experience the least annual change in precipitation.

- **Precipitation Risk:** By midcentury, Liberia is likely to experience an overall increase in annual precipitation intensity with regional and seasonal trends corresponding to projected precipitation volumes for the period of 2040–2059 under SSP3-7.0.
  - Average Largest 5-Day Precipitation: Increases in the average highest precipitation amount over a 5-day period, which rise 16.28 mm (–71.64 mm, 64.93 mm) nationwide from the reference period to 171.41 mm (128.58 mm, 248.68 mm) by midcentury, pose risks for flood management and do not always coincide with months experiencing the largest anomalies in total projected precipitation volumes.
    - **The northern coast** is expected to experience the largest increases in average largest 5-day precipitation by midcentury, especially during the summer months.
- **Extreme Precipitation Occurrence:** By midcentury, Liberia is likely to more frequently experience extreme precipitation intensities. These conditions pose risks for food security, flood-related safety, disease ranges, biodiversity, and living conditions.
  - **Counties further north and inland** will be at least 2 times more likely by midcentury under SSP3-7.0 to experience events with 25-year, 50-year, and 100-year historical return periods that produce the largest 1-day precipitation volumes.
- **Climate-Related Hazards:**
  - Sea level rise and coastal inundation will increasingly threaten Liberia's extensive **coastal zones and urban areas**.
  - The frequency of intense floods and droughts nationwide will likely become more common in the future.

For more information, see key documents linked at the end of this profile.

COUNTRY OVERVIEW

Liberia is a relatively small country with a land area of 111,350 km², situated in the center of the Upper Guinea Rainforest Region along the West Coast of Africa. It is subdivided into 15 counties between 4°N–9°N latitude and has a predominantly tropical monsoon climate, with four distinct topo-geographical regions (**see Figures 1a–b)**. These are the: 1) coastal belt, a low-lying plain on the Atlantic Ocean comprised of mangroves, tidal creeks, and shallow lagoons up to 40 km wide and 0–30 meters (m) above sea level; 2) rolling hills, a transitional zone between 60–150 m comprised of hills, valleys, and fast-moving waterways; 3) plateau, the largest zone in area comprising most of Liberia's interior between 200–300 m above sea level, characterized by dense forest cover and a sharp change in elevation from the rolling hills; and 4) northern highlands, mountain ridges located near the Guinean border above 300 m altitude, which include the Wologisi Range in Lofa, Gbarpolu, and Bong Counties (up to 1,440 m high), and the Nimba Range in northern Nimba County (up to 1,385 m high on Liberia's side of the border).[1]

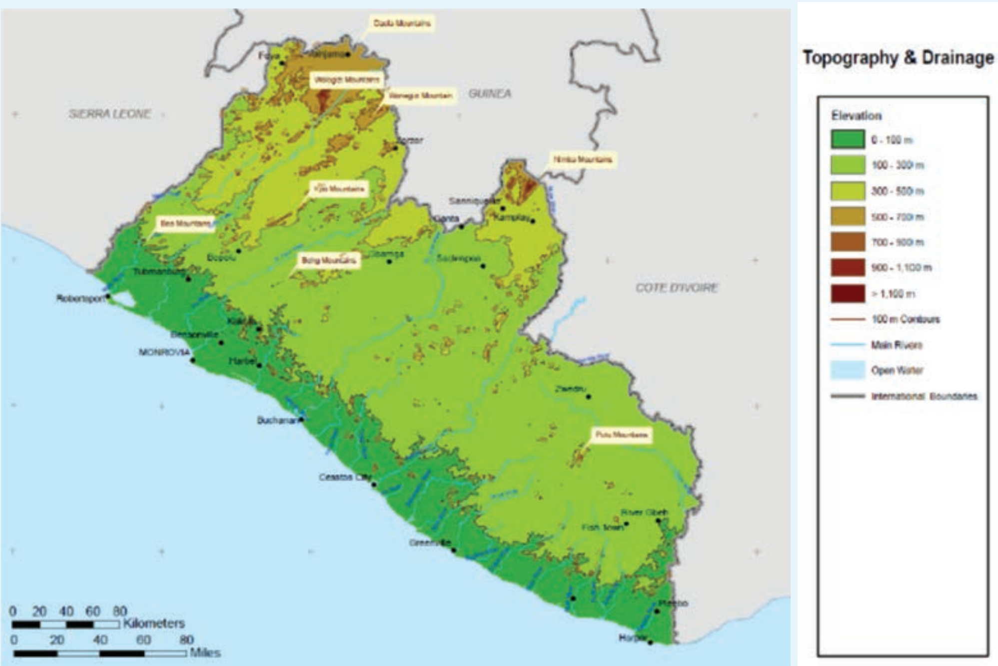
FIGURE 1A. Subnational Units (Counties) of Liberia[2]

Each county's topo-geographic region is listed in **Table 2**.

[1] Spatial extents for the four topographic regions in this profile – which do not specify elevations between 30–60 m and 150–200 m – are approximate due to the different terminology and sets of elevation ranges referenced in various sources.

[2] Neugarten, R., Alam, M., Martinez, N.A., Honzak, M., Juhn, D., Larsen, T., Moull, K., Rodriguez, A.M., Wright, T., Walsh, L. and Donovan, J. (2017). Natural capital mapping and accounting in Liberia—understanding the contribution of biodiversity and ecosystem services to Liberia's sustainable development. Conservation International. URL: https://www.researchgate.net/publication/321304662_Natural_Capital_Mapping_and_Accounting_in_Liberia_Understanding_the_contribution_of_biodiversity_and_ecosystem_services_to_Liberia's_sustainable_development

FIGURE 1B. Topography and Drainage of Liberia[3]



Note that the coastal belt follows the shoreline closely, while the rolling hills region (60–150 m) consists of a relatively narrow segment of land spanning across the transitional dark green-light green boundary in the map above, delineating 100 m above sea level. The northern highlands consist of the yellow (300–500 m), orange (500–700 m), and red zones (>700 m). The plateau region comprises the majority of the light green zones (100–300 m).

Liberia has made significant economic and development progress since the end of its civil war in 2003, however the country's situation remains fragile due to its high levels of poverty with limited access to basic services such as water, sanitation, and energy (**see Table 1**).[4] According to the World Bank's DataBank, Liberia has a population of 5.3 million people as of 2022 with a current population growth rate of 2.1%. Approximately 53% of the population currently lives in urban areas, growing at a rate of 3.0% per year and the majority of whom reside in slums. Liberia is classified as a low-income nation with a 2022 Gross Domestic Product (GDP in $US) of $4.00 billion and a volatile but positive GDP growth rate of 4.8%. The agriculture sector, inclusive of fishing and forestry, notably accounts for 36.2% of GDP and a high proportion of employed labor compared to other countries. By comparison, in 2022, the industry sector (including mining, construction, electricity, water and gas) contributed 21.4% of GDP, while services comprised 37.2% of GDP. Its major exports include: rubber, timber, cocoa, coffee, and minerals such as iron ore and diamonds. Other activities are centered around subsistence farming (raising livestock and cultivating rice, cassava, bananas) and harvesting and processing commodities such as palm oil.[5] But as **Table 1** shows, more than half of Liberia's population live below the national poverty line, with 23.3% additionally vulnerable to enduring multidimensional poverty. Measured monetarily, 44.4% of the 2020 population

---

3 USAID. (2013). Liberia climate change assessment. URL: https://pdf.usaid.gov/pdf_docs/PA00KDJM.pdf

4 USAID (2017). Liberia: Climate change risk profile. URL: https://www.climatelinks.org/sites/default/files/asset/document/2017_USAID%20ATLAS_Climate%20Risk%20Profile_Liberia.pdf

5 Environmental Protection Agency (2021). Second National Communication to the UNFCCC. URL: https://unfccc.int/sites/default/files/resource/SNC.pdf

was living below a threshold of $1.90 a day purchasing power parity (PPP).[6] Overall, Liberia ranks low on the Human Development Index (179 out of 191), considering factors such as life expectancy, education, and income per capita.[7] The country's economic dependence on natural resources and high levels of poverty make it particularly sensitive to adverse climate change impacts.

Liberia submitted its Nationally-Determined Contribution (NDC) to the UNFCCC in 2016, which it updated in 2021, and its Second National Communication to the UNFCCC (SNC) in 2021. The revised NDC unconditionally commits to reducing greenhouse gas emissions by 10% below the business-as-usual level by 2030 and coordinates its cross-sector mitigation and adaptation targets with the U.N. Sustainable Development Goals (SDGs). The SNC identified five priority adaptation sectors – agriculture, forestry, coastal zones, fisheries, and health – which align with the 2018 National Policy and Response Strategy on Climate Change (NPRSCC) to complement or scale up subnational actions, as well as the 2020–2030 National Adaptation Plan (NAP) framework that guides NAP development and implementation over the ten-year period indicated. High reliance on climate-sensitive activities renders Liberia vulnerable to climate variability and change, expected to manifest in higher temperatures, more extreme weather events such as heavy rains, and rising sea levels.

TABLE 1. Key Development Indicators[8]

Key Demographic Indicators	Most Recent Value	Global Rank
Population Density (people per sq km, 2021)	53.92	149 (out of 216)
Life Expectancy (for total population in years, 2021)	60.75	189 (out of 209)
Fertility Rate (total births per woman, 2021)	4.09	29 (out of 210)
Dependency Ratio (dependents per 100 working-age people, 2022)	78.03	28 (out of 217)
Key Economic and Social Development Indicators	**Most Recent Value**	**Global Rank**
GDP per Capita (in current $US, 2022)	$754.53	175 (out of 185)
% Population Below National Poverty Line (2020)[9]	50.9%	13 (out of 100)
Unemployment Rate (% of total labor force, 2022)	3.63%	137 (out of 183)
% Employed in Agriculture (2021)	40.65%	36 (out of 185)
% Employed in Industry (2021)	8.07%	176 (out of 185)
% Employed in Services (2021)	51.29%	118 (out of 185)
% Population with Access to Electricity (2021)	29.85%	205 (out of 215)
% Population Using at Least Basic Sanitation Services (2022)	22.52%	180 (out of 191)

Data for each indicator's most recently measured year is ranked compared to all countries and entities globally in the far-right column, as tracked by the World Bank's Data Bank. Global ranking for the population below the national poverty line only includes countries classified as developing by UNDP.

6 UNDP (2022). Global Multidimensional Poverty Index 2022. URL: https://hdr.undp.org/system/files/documents/hdp-document/2022mpireportenpdf.pdf

7 UNDP (2022). Human Development Report 2021/2022. URL: https://hdr.undp.org/system/files/documents/global-report-document/hdr2021-22pdf_1.pdf

8 World Bank (2023). DataBank – World Development Indicators. URL: https://databank.worldbank.org/source/world-development-indicators

9 UNDP (2022). Global Multidimensional Poverty Index 2022. URL: https://hdr.undp.org/system/files/documents/hdp-document/2022mpireportenpdf.pdf

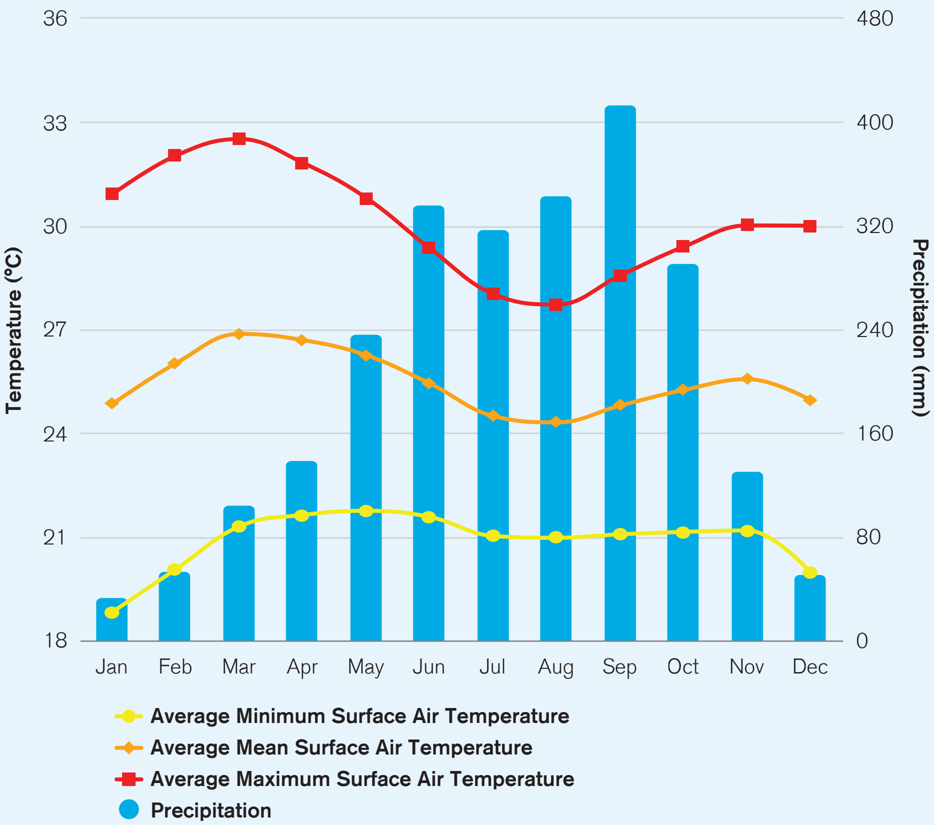
Data Overview

The data presented are from the World Bank Group's Climate Change Knowledge Portal (CCKP).[10] Historical, observed data is derived from the Climatic Research Unit, University of East Anglia (CRU), CRU TS version 4.07 gridded dataset (data available 1901–2022) and ERA5 reanalysis collection from ECMWF (1950–2020).

Climate Overview

Liberia is one of the wettest countries in the world and features consistently warm temperatures year-round, but its rainiest months (June-Sept) and drier months (Dec-Apr) vary by county, depending on both the timing and intensity of the Intertropical Convergence Zone (ITCZ) and monsoon conditions. Over the current climatology (1991–2020, **see Figure 2**), Liberia experienced a mean annual

FIGURE 2. Observed Monthly Climatology of Liberia's Temperature and Precipitation, 1991–2020



Note wider temperature range in winter months, narrower temperature range in summer months, and small dip in precipitation between June and September peaks.

[10] World Bank Climate Change Knowledge Portal (2023). Liberia Climatology. URL: https://climateknowledgeportal.worldbank.org/country/liberia/climate-data-historical

temperature of 25.45°C. During the 1991–2020 period, the warmest month of March ranged from a minimum of 21.30°C to a maximum of 32.51°C, while the coolest month of August ranged from a minimum of 20.97°C to a maximum of 27.72°C. As opposed to the summer months (June–July–Aug), when there is nearly complete cloud cover, winter months have minimal cloud cover, resulting in relatively wider temperature spreads. The average temperature for winter dry season months (Dec–Jan–Feb) ranged from a minimum of 21.59°C in Maryland County and 16.92°C in Lofa County to an average maximum temperature of 30.31°C and 30.60°C, respectively. Whereas, during the wet summer months, the average temperature ranged from a minimum of 20.48°C in Lofa County and 21.99°C in Maryland County to an average maximum temperature of 28.78°C in Lofa County and 27.40°C in Maryland County.

While observed temperatures in Liberia are relatively homogeneous across counties and seasons, observed precipitation patterns are not. In southern Liberia (below 6°N latitude),[11] moist, southwesterly winds from the Atlantic Ocean deliver precipitation throughout the year, with annual totals slowly decreasing as one moves inland from the coast – 2,227.15 mm in coastal Maryland to 2,012.64 mm in Grand Gedeh, as detailed in **Table 2**. For this reason, Maryland County has the wettest monthly minimum in January (64.28 mm), receiving more than twice Montserrado County's rainfall for this month (27.36 mm), despite the latter county having Liberia's wettest annual totals (3,136.38 mm). As the ITCZ moves northward in the transitional month of May, thunderstorm activity interacts with the monsoon flow from the ocean, producing heavy rainfall by June. The ITCZ's continued trajectory north causes rainfall to decline slightly in Liberia's southern counties during July and August, a phenomenon referred to as the "middle dries".[12] However, this pattern reverses when the ITCZ shifts south again during August and September, resulting in the heaviest monthly precipitation in northern and central Liberia and the second monthly rainfall peak in southern Liberia. As **Table 2** illustrates, June is the wettest for Maryland, Grand Kru, and River Gee Counties; September is the wettest for inland Grand Gedeh and more northerly Sinoe County; and every county except Grand Gedeh has an August "middle dry." The wettest fully inland county is Gbarpolu, which receives 2,650.32 mm of rainfall annually, 453.02 mm during its peak month of September. Monthly rainfall then gradually declines during October and November. The onset of the winter dry season, felt most strongly in northern Liberia, occurs when northeasterly trade winds – dry, dusty Harmattan winds from the Sahara Desert and Sahel region – create warmer daytime temperatures and cooler nighttime temperatures. Relative humidity during this period falls to 60%–90%, compared to 90%–100% during the rainy season, which returns again by the end of spring.[13]

---

[11] Counties located in southern Liberia, also listed in **Table 2**, include: Sinoe, Grand Gedeh, River Gee, Grand Kru, and Maryland.

[12] USAID (2013). Liberia Climate change assessment. URL: https://pdf.usaid.gov/pdf_docs/PA00KDJM.pdf

[13] Environmental Protection Agency (2021). Second National Communication to the UNFCCC. URL: https://unfccc.int/sites/default/files/resource/SNC.pdf

TABLE 2. Observed Precipitation Trends for 1991–2020 Climatology in Liberia's Three Regions

Topo-Geographic Region and County	Observed Warmest (Top) and Coolest (Bottom) Months by Mean Temp.	Duration of Wet and Dry Seasons	Observed Wettest and Driest Months per Season	Observed Annual Precip.
Plateau				
Grand Gedeh (south)	Mar: 26.91°C (21.65°C, 32.23°C)	W: May–Oct	W1: June (284.62 mm) W2: Sept (339.36 mm)	**2,012.64 mm**
	Aug: 24.20°C (21.05°C, 27.38°C)	D: Nov–Apr	D1: July (195.89 mm) **D2: Jan (35.46 mm)**	
Rolling Hills and Plateau				
River Gee (south)	Mar: 26.86°C (22.14°C, 31.67°C)	W: May–Oct	W1: June (311.85 mm) W2: Sept (285.61 mm)	2,073.55 mm
	Aug: 24.07°C (21.32°C, 26.89°C)	D: Nov–Apr	D1: Aug (161.31 mm) D2: Jan (50.92 mm)	
Coastal Belt and Rolling Hills				
Maryland (south)	**Mar: 26.95°C** (22.53°C, 31.45°C)	W: May–Oct	W1: June (350.30 mm) W2: Sept (268.19 mm)	2,227.15 mm
	Aug: 24.21°C (21.70°C, 26.80°C)	D: Dec–Apr	D1: Aug (155.16 mm) D2: Jan (64.28 mm)	
Grand Kru (south)	Mar: 26.88°C (22.28°C, 31.50°C)	W: May–Oct	W1: June (349.48 mm) W2: Sept (312.83 mm)	2,321.06 mm
	Aug: 24.17°C (21.53°C, 26.88°C)	D: Dec–Apr	D1: Aug (199.62 mm) D2: Jan (61.14 mm)	
Coastal Belt, Rolling Hills, and Plateau				
Sinoe (south)	Mar: 26.77°C (21.81°C, 31.81°C)	W: May–Oct	W1: June (346.87 mm) **W2: Sept (384.51 mm)**	**2,396.11 mm**
	Aug: 24.13°C (21.16°C, 27.17°C)	D: Nov–Apr	D1: Aug (271.19 mm) D2: Jan (47.01 mm)	
Coastal Belt, Rolling Hills, and Plateau				
Rivercess (central)	Mar: 26.99°C (21.72°C, 32.33°C)	W: June–Oct	W: Sept (453.17 mm)	2,587.72 mm
	Aug: 24.30°C (21.06°C, 27.61°C)	D: Nov–Apr	D: Jan (36.20 mm)	
Grand Bassa (central)	Mar: 27.02°C (21.56°C, 32.52°C)	W: June–Oct	W: Sept (510.15 mm)	2,813.48 mm
	Aug: 24.32°C (20.93°C, 27.78°C)	D: Nov–Apr	D: Jan (32.42 mm)	
Coastal Belt and Rolling Hills				
Margibi (north)	Mar: 27.23°C (21.65°C, 32.90°C)	W: June–Oct	W: Sept (547.81 mm)	3,003.58 mm
	Aug: 24.49°C (21.03°C, 28.03°C)	D: Nov–Apr	D: Jan (29.70 mm)	
Montserrado (north)	Mar: 27.45°C (21.93°C, 33.03°C)	W: June–Oct	**W: Sept (568.98 mm)**	**3,136.38 mm**
	Aug: 24.65°C (21.27°C, 28.13°C)	D: Nov–Apr	D: Jan (27.36 mm)	

(*continues*)

TABLE 2. Observed Precipitation Trends for 1991–2020 Climatology in Liberia's Three Regions (*Continued*)

Topo-Geographic Region and County	Observed Warmest (Top) and Coolest (Bottom) Months by Mean Temp.	Duration of Wet and Dry Seasons	Observed Wettest and Driest Months per Season	Observed Annual Precip.
Bomi (north)	Mar: 27.55°C (21.95°C, 33.24°C)	W: June–Oct	W: Sept (558.23 mm)	3,118.72 mm
	Aug: 24.77°C (21.38°C, 28.26°C)	D: Nov–Apr	D: Jan (24.96 mm)	
Coastal Belt, Rolling Hills, and Plateau				
Grand Cape Mount (north)	**Mar: 27.67°C** (21.82°C, 33.54°C)	W: June–Oct	W: Aug (540.14 mm)	3,006.15 mm
	Aug: 24.92°C (21.54°C, 28.32°C)	D: Nov-Apr	**D: Jan (20.05 mm)**	
Northern Highlands and Plateau				
Nimba (central)	Mar: 26.75°C (20.90°C, 32.67°C)	W: June–Oct	W: Sept (372.53 mm)	**2,076.82 mm**
	Jan: 24.18°C (17.29°C, 31.14°C)	D: Nov–Apr	D: Jan (24.83 mm)	
Bong (north)	Mar: 26.81°C (20.90°C, 32.78°C)	W: June–Oct	W: Sept (445.36 mm)	2,503.80 mm
	Aug: 24.34°C (20.73°C, 28.02°C)	D: Nov–Apr	D: Jan (28.96 mm)	
Gparpolu (north)	Mar: 26.85°C (20.70°C, 33.05°C)	W: June–Oct	W: Sept (453.02 mm)	2,650.32 mm
	Jan: 24.39°C (17.97°C, 30.84°C)	D: Nov–Apr	D: Jan (25.12 mm)	
Lofa (north)	Apr: 26.24°C (20.52°C, 32.02°C)	W: June–Oct	W: Sept (397.47 mm)	2,417.05 mm
	Jan: 23.22°C (16.01°C, 30.51°C)	D: Nov–Apr	D: Jan (23.90 mm)	

Counties in southern Liberia (green) experience two monthly wet season peaks (June and Sept) and two "middle dry" months (July and Aug) that vary in their timing and intensity. Counties in central Liberia (light blue) and northern Liberia (dark blue) experience only one wet season precipitation peak (Sept). Bolded values highlight heaviest precipitation amounts for each region annually and monthly during winter and summer. For the column listing mean monthly temperatures, the minimum (left) and maximum (right) temperatures are shown in parentheses. Precipitation regimes indicate wettest (W1, W2) and driest (D1, D2) months, both further interpreted in the text.

Temperature

Between 1971 and 2020, Liberia's average mean temperature increased by 0.13°C per decade, however the greatest changes were observed during the winter months in the central and southern Plateau region. During winter months nationally, the observed minimum temperature increased 0.17°C per decade and the observed maximum temperature increased 0.16°C per decade between 1971–2020. But during winter months in Nimba County (central Liberia, interior) for the same period, the mean temperature increased 0.26°C per decade, minimum temperature increased 0.30°C per decade, and maximum temperature increased 0.36°C per decade. Minimum temperatures also exhibited less variability per decade during this season. Otherwise, observed increases were relatively uniform geographically, with the lowest mean annual temperature increase along the coast (0.10°C per decade in Bomi County).[14] Mean, minimum, and maximum temperatures nationwide increased significantly and at a much faster rate between 1991 and 2020, compared to 1971–2020. At the national level between 1991 and 2020, Liberia's mean temperature rose 0.27°C per decade, minimum temperature rose 0.26°C per decade, and maximum temperature rose 0.41°C per decade. Notably, both single-day monthly maximum of maximum temperatures and monthly minimum of minimum temperatures, measured annually, increased significantly at the countrywide level. Between 1971 and 2020, the minimum of minimum rose by 0.38°C per decade and the maximum of maximum rose by 0.24°C per decade. For the most recent 1991–2020 climatology, the maximum of maximum rate of increase per decade was three times higher. This observed trend corresponds with more intense maximum of daily maximum temperature events and fewer extreme minimum of daily minimum events occurring towards present day (see **Figures 3a–b**). While variability can be seen in the graphs below, note the clear trend of change shown.

FIGURE 3A. Observed Change in Event Intensity of Maximum of Daily Maximum Temperature, 1951–2020

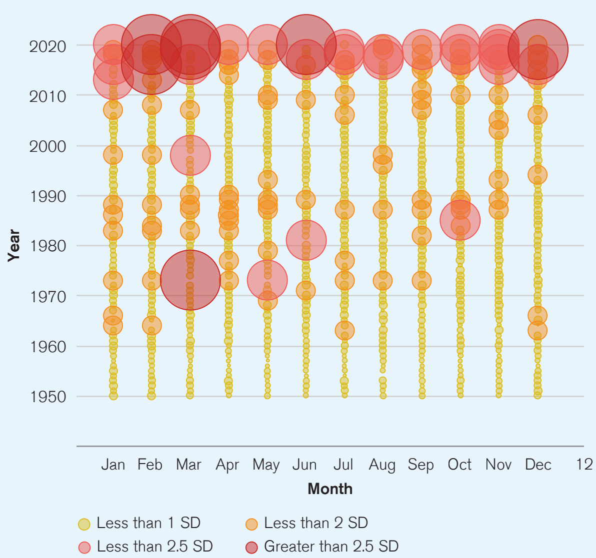
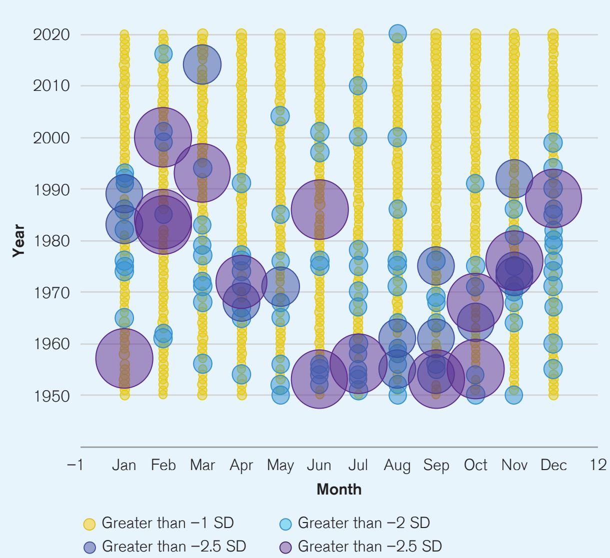


FIGURE 3B. Observed Change in Event Intensity of Minimum of Daily Minimum Temperature, 1951–2020



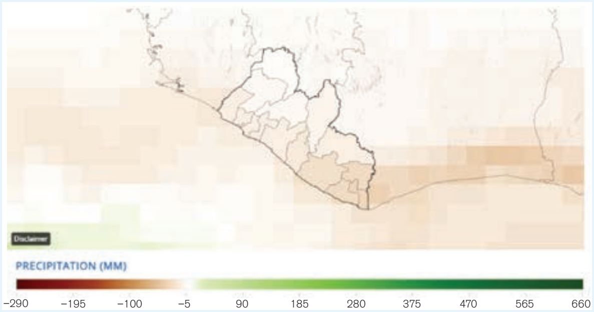
Note the shift after 1990 in number and change (measured by standard deviation from monthly mean of current climatology) of observed events beyond one standard deviation from the climatology's mean values.

[14] Maximum temperature increases were not significant in northern Liberia during spring and summer months.

Precipitation

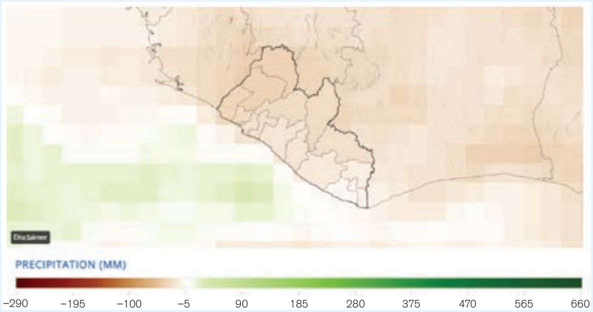
Over the 50-year period of 1971–2020, some of Liberia's counties experienced significant increases in precipitation per decade while others experienced decreases. When viewed at the national level only, observed precipitation trends during this period were not significant, but at the subnational level, precipitation trends varied significantly. During the 1971–2020 climatology (**see Figures 4a–d**), coastal Montserrado County observed an increase of 51.09 mm precipitation per decade, while inland Lofa County observed a decrease of 72.39 mm per decade. Winter months were significantly drier further south. Maryland County observed a decrease of –35.87 mm precipitation per decade during these months. Meanwhile, spring months were significantly drier in central and northern counties such as Lofa, which observed a decrease of –35.49 mm per decade during these months. Additionally, the coasts were significantly wetter in summer and fall months. For example, Montserrado County observed an increase of +75.61 mm per decade during summer months and Grand Kru County observed an increase of +40.10 mm per decade during fall months. Spatial and seasonal patterns during this period therefore suggest more expansive and prolonged dry monsoon seasons and wetter, wet monsoon seasons along the coast.

FIGURE 4A. Winter (Dec–Jan–Feb) Observed Seasonal Precipitation Trend Per Decade, 1971–2020



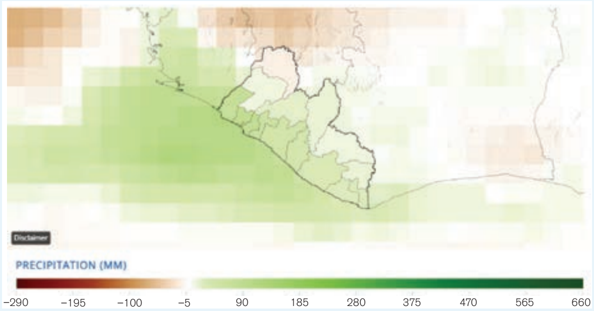
Southeasternmost counties experienced the greatest drying per decade in winter months.

FIGURE 4B. Spring (Mar–Apr–May) Observed Seasonal Precipitation Trend per Decade, 1971–2020)



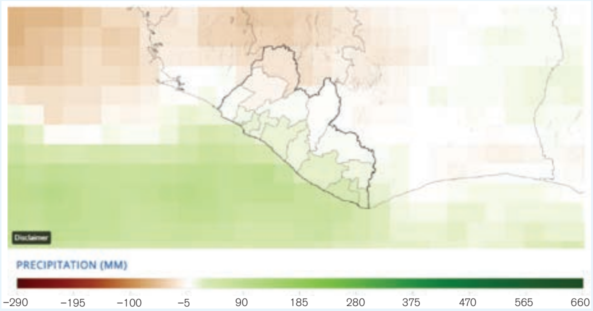
Northernmost counties experienced the greatest drying per decade during spring months, farthest away from the ITCZ.

FIGURE 4C. Summer (June–July–Aug) Observed Seasonal Precipitation Trend per Decade, 1971–2020



In summer, the coastal regions that are typically wettest experienced significantly wetter conditions per decade.

FIGURE 4D. Fall (Sept–Oct–Nov) Observed Seasonal Precipitation Trend per Decade, 1971–2020



In fall months, the period during which the ITCZ shifts south, the southern coast experienced wetter conditions and the far north interior experienced drier conditions per decade.

Data Overview

Modeled climate data is derived from CMIP6, the Coupled Model Intercomparison Project, Phase 6. The CMIP efforts are overseen by the World Climate Research Program, which supports the coordination for the production of global and regional climate model compilations that advance scientific understanding of the multi-scale dynamic interactions between the natural and social systems affecting climate. CMIP6 is the foundational data used to present global climate change projections presented in the Sixth Assessment Report (AR6) of the Intergovernmental Panel on Climate Change (IPCC). CMIP6 relies on the Shared Socioeconomic Pathways (SSPs), which represent possible societal development and policy scenarios for meeting designated radiative forcing (W/m^2) by the end of the century. Scenarios are used to represent the climate response to different plausible future societal development storylines and associated contrasting emission pathways to outline how future emissions and land use changes translate into responses in the climate system. Model-based, climate projection data is derived from the Coupled Model Inter-comparison Project-Phase 6 (CMIP6). CMIP is a standard framework for the analysis of coupled atmosphere-ocean general circulation models (GCMs) providing projections of future temperature and precipitation according to designated scenarios. CMIP6 projections are shown through five shared socioeconomic pathway (SSP) scenarios defined by their total radiative forcing (a cumulative measure of GHG emissions from all sources) pathway and level by 2100. These represent possible future greenhouse gas concentration trajectories adopted by the IPCC.

The following assessment explores projected climate conditions and changes under multiple scenarios[15] for the near (the 2030s; 2020–2039) and medium term (2050s; 2040–2059) using data presented at a 0.25° × 0.25° (25 km × 25 km) resolution.[16] This risk profile focuses primarily on SSP3-7.0. Other SSPs are highlighted where appropriate given different trends and outlooks that should be noted. Projections for extreme precipitation events use data presented at a 1.00° × 1.00° (100 km × 100 km) resolution.[17]

Temperature

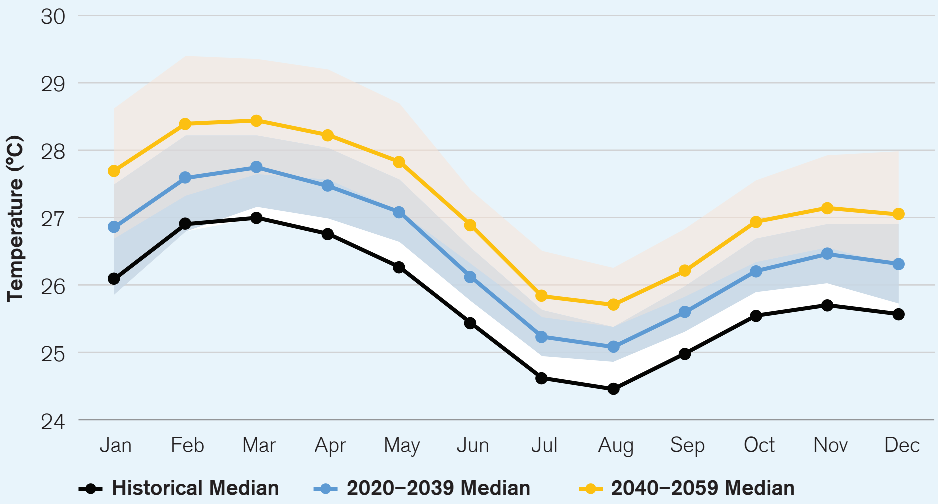
Under SSP3-7.0, Liberia's temperatures are homogeneously projected to increase further (see Figure 5). Mean temperature nationwide increases from the historical reference period of 1995–2014 to 26.45°C (25.97°C, 10th percentile, 26.93°C, 90th percentile) for the period 2020–2039, and to 27.16°C (26.52°C, 27.93°C) for the period 2040–2059. Projected mean, minimum, and maximum temperature anomalies vary minimally geographically and seasonally except during the winter months. Minimum temperature nationwide increases from the historical reference period to 23.00°C (22.60°C, 23.45°C) for the 2020–2039 period, and 23.72°C (23.19°C, 24.42°C) for 2040–2059. Maximum temperature increases to 29.84°C (29.29°C, 30.54°C)

[15] SSP3-7.0 represents a higher emissions scenario and is considered a more realistic worst-case scenario in which warming reaches ~3.5–4°C by 2100. When considering 'risk' it is most prudent to use higher scenarios in order to not dangerously under-estimate potential changes and risk conditions.

[16] World Bank Climate Change Knowledge Portal (2023). Liberia Climate Projections. URL: https://climateknowledgeportal.worldbank.org/country/liberia/climate-data-projections

[17] World Bank Climate Change Knowledge Portal (2023). Liberia Extreme Events. URL: https://climateknowledgeportal.worldbank.org/country/liberia/extremes

FIGURE 5. Projected Climatology of Mean Temperature Countrywide for 2020–2039 and 2040–2059 (Ref. Period 1995–2014) Under SSP3-7.0



Shaded areas indicate 10th and 90th percentiles. The projected climatology of mean temperature countrywide for each month (2040–2059 period) increases roughly two times more than the projected climatology for 2020–2039 above the reference period.

for the 2020–2039 period and to 30.49°C (29.78°C, 31.61°C) for 2040–2059. Projected maximum and minimum temperature changes under SSP1-2.6 and SSP2-4.5 are slightly lower than SSP3-7.0.[18] Under SSP3-7.0 during winter months, mean temperature increases 1.80°C (0.81°C, 2.60°C) from the reference period in the northern highlands of Lofa and 1.27°C (0.86°C, 2.24°C) along the southern coast of River Gee.

Liberia is projected to experience a moderate shift to hotter conditions by midcentury. Hot days with a maximum temperature >30°C are expected to increase along the coast during spring months and in the interior during fall months by the period 2040–2059 under SSP3-7.0 **(see Table 3)**. For example, the number of hot days above this temperature threshold increase by an anomaly of 118.04 (77.56, 169.67) days annually in Montserrado County over this period, with an increase of 41.05 (27.64, 51.17) days during spring months. A comparable increase occurs in Grand Bassa on the central coast. Atmospheric moisture content does not make the number of days surpassing the Heat Index >35°C increase dramatically for the 2040–2059 climatology. In Montserrado, which recorded one of the greatest annual increases, high heat days by midcentury only rose to 26.57 (1.63, 103.58) with a wide range of uncertainty from the reference period, mostly during spring months. However, a significant increase of high heat days occurs under SSP3-7.0 by the end of the century, especially along the northern coast (see Annex for further detail).

Heat-related risks can be compounded when considering both day temperature conditions and night temperature conditions. The number of tropical nights with a minimum temperature >20°C (see **Table 3**) increases in Lofa County by 30.83 (22.66, 48.64) nights annually for 2040–2059, mostly during winter months. On nights temperatures

[18] Under SSP1-2.6, minimum temperature nationwide increases to 23.31°C (22.83°C, 23.88°C) and under SSP2-4.5, increases to 23.56°C (23.08°C, 24.10°C) by 2040–2059. Under SSP1-2.6, maximum temperature increases nationwide to 30.18°C (29.67°C, 30.85°C), and under SSP2-4.5, increases to 30.38°C (29.81°C, 31.07°C) by 2040–2059.

TABLE 3. Highest Projected County Anomalies for 2020–2039 and 2040–2059 (Ref. Period 1995–2014) Under SSP3-7.0

County	2020–2039					2040–2059				
	Annual	Winter (DJF)	Spring (MAM)	Summer (JJA)	Fall (SON)	Annual	Winter (DJF)	Spring (MAM)	Summer (JJA)	Fall (SON)
Hot Days (No. Days T-max >30°C)										
Grand Bassa (coast)	**66.05** (13.42, 110.19)	18.26 (0.40, 36.89)	**26.85** (10.70, 37.23)	3.77 (0.30, 8.47)	13.91 (4.22, 29.48)	117.12 (73.24, 170.43)	34.38 (19.54, 51.75)	40.43 (27.54, 51.44)	10.77 (3.48, 19.77)	31.46 (14.84, 52.81)
Montserrado (coast)	62.85 (19.78, 105.47)	19.01 (0.39, 37.04)	24.81 (12.46, 37.04)	3.28 (0.47, 8.25)	15.05 (4.68, 28.95)	**118.04** (77.56, 169.67)	36.15 (23.02, 52.90)	**41.05** (27.64, 51.17)	10.13 (3.81, 18.96)	32.56 (17.54, 52.05)
Tropical Nights (No. Nights T-min >20°C)										
Gbarpolu (interior)	7.39 (3.60, 16.73)	5.14 (2.51, 13.06)	0.07 (–0.03, 0.41)	0.77 (0.15, 1.94)	0.71 (0.14, 1.58)	12.10 (7.24, 23.57)	9.33 (5.30, 18.64)	0.11 (0.00, 0.53)	0.84 (0.24, 2.40)	0.86 (0.33, 1.67)
Lofa (interior)	**20.52** (11.67, 34.60)	**10.50** (4.50, 22.70)	0.26 (–0.03, 0.97)	2.99 (1.08, 5.43)	5.45 (2.39, 8.00)	**30.83** (22.66, 48.64)	**19.11** (0.10, 34.49)	0.37 (0.00, 1.24)	3.59 (0.06, 6.84)	6.66 (0.00, 9.05)
Tropical Nights (No. Nights T-min >26°C)										
Grand Kru (coast)	**12.01** (4.55, 28.05)	3.73 (1.01, 10.79)	**6.90** (2.92, 13.46)	0.64 (0.18, 1.74)	0.35 (0.08, 1.21)	40.14 (19.56, 90.01)	13.17 (5.12, 30.11)	21.39 (10.65, 36.11)	4.11 (1.26, 12.34)	3.05 (0.56, 10.98)
Montserrado (coast)	7.25 (1.67, 22.38)	1.47 (0.06, 8.68)	4.97 (1.60, 12.78)	0.22 (0.00, 1.16)	0.05 (0.00, 0.77)	**41.83** (10.02, 89.11)	12.90 (0.81, 32.75)	**22.46** (8.32, 44.96)	3.30 (0.35, 8.63)	2.67 (0.06, 9.55)

10th percentile and 90th percentile values shown in parentheses. Bolded values highlight the highest seasonal and annual anomalies. The smallest anomalies (<5 days or nights) from the reference period are shaded gray while the largest anomalies (>50 days or nights) from the reference period are shaded orange. Note that the greatest anomalies for tropical nights with minimum temperatures >20°C occur in the interior counties, while the greatest anomalies for tropical nights with minimum temperatures >26°C and for hot days occur in coastal counties. See text for interpretation.

do not go below 20°C, the human body reaches a biophysiological threshold where it cannot adequately cool down to achieve restorative sleep. In counties along the coast, the number of tropical nights with a minimum temperature >26°C, an even higher threshold, increase during spring months by midcentury (2040–2059) compared to the historical reference period. Montserrado County experiences the largest increase by 2040–2059, with an anomaly of 41.83 (10.02, 89.11) nights annually, roughly half of which occurs during spring months. Coastal areas like Montserrado are also projected to experience a large increase in warm spells, reflecting a longer-term shift in daily maximum temperatures. For 2040–2059, Montserrado is projected to experience an increase in 255.00 days (128.00 days, 301.00 days) annually on the Warm Spell Duration Index compared to the 1994–2015 reference period (**see Table 4**).[19] Montserrado County's increase in number of days with high maximum temperatures and high nighttime minimums point to elevated risks associated with more prolonged heat exposure. With this in mind, **Table 4** summarizes three key county-level temperature anomalies projected for 2040–2059 to monitor.

[19] This value indicates the number days with consecutive daily maximum temperatures greater than the 90th percentile of daily maximum temperature calculated over a five-day window annually. Warm Spell Duration Index projections use 1.00° × 1.00° (100 km × 100 km) data resolution.

TABLE 4. Key County-Level Projected Anomalies to Monitor for 2040–2059 (Ref. Period 1995–2014) Under SSP3-7.0

Projected Anomalies for 2040–2059 Under SSP3-7.0 (Ref. Period 1995–2014)			
County	**Hot Days (No. Days T-max >30°C) Annually**	**Tropical Nights (No. Nights T-min >26°C) Annually**	**Warm Spell Duration Index (No. Days) Annualized**
Liberia	102.39 (59.22, 148.47)	11.98 (3.77, 33.32)	125.26 (35.37, 265.97)
Southern Region			
Grand Gedeh (interior)	102.41 (60.61, 142.62)	0.67 (0.00, 9.06)	133.31 (54.49, 278.49)
River Gee (interior)	103.04 (65.78, 149.50)	0.05 (0.00, 2.56)	142.14 (71.08, 274.02)
Maryland (coast)	94.89 (64.24, 155.58)	25.11 (11.00, 64.81)	**252.67** (147.11, 283.51)
Grand Kru (coast)	91.39 (61.44, 155.44)	**40.14** (19.56, 90.01)	242.23 (167.73, 275.33)
Sinoe (coast)	**108.42** (71.48, 158.29)	16.45 (8.55, 39.52)	188.26 (120.52, 286.57)
Central Region			
River Cess (coast)	112.72 (73.10, 164.24)	16.55 (6.23, 40.61)	213.37 (131.73, 288.52)
Grand Bassa (coast)	117.12 (73.24, 170.43)	21.11 (7.29, 55.81)	195.76 (93.36, 283.67)
Nimba (interior)	97.71 (48.48, 135.22)	4.43 (0.03, 21.40)	120.57 (27.24, 268.79)
Northern Region			
Margibi (coast)	113.24 (73.54, 167.49)	22.25 (3.68, 58.43)	244.00 (119.89, 298.00)
Montserrado (coast)	**118.04** (77.56, 169.67)	**41.83** (10.02, 89.11)	**255.00** (128.00, 301.00)
Bomi (coast)	117.08 (77.82, 162.83)	37.70 (8.61, 77.95)	254.04 (127.84, 299.46)
Grand Cape Mount (coast)	99.84 (66.26, 142.10)	29.04 (8.41, 56.61)	197.79 (92.63, 273.47)
Bong (interior)	99.02 (54.53, 140.97)	6.10 (0.06, 26.86)	152.43 (52.92, 267.53)
Gbarpolu (interior)	95.72 (49.81, 140.31)	3.41 (0.05, 16.58)	148.02 (56.79, 262.97)
Lofa (interior)	92.33 (33.06, 135.53)	3.02 (0.10, 17.11)	113.39 (26.72, 257.96)

10th percentile and 90th percentile values shown in parentheses. Largest anomalies for each region are bolded and above average anomalies for hot days and warm spell days are shaded orange. The smallest anomalies (< 5 days or nights) from the reference period are shaded gray. Warm Spell Duration Index projections use 1.00° × 1.00° (100 km × 100 km) data resolution. Hot days increase higher along the northern and central coast and southern interior, while tropical nights and warm spells increase higher along the coasts. See text for interpretation.

Precipitation

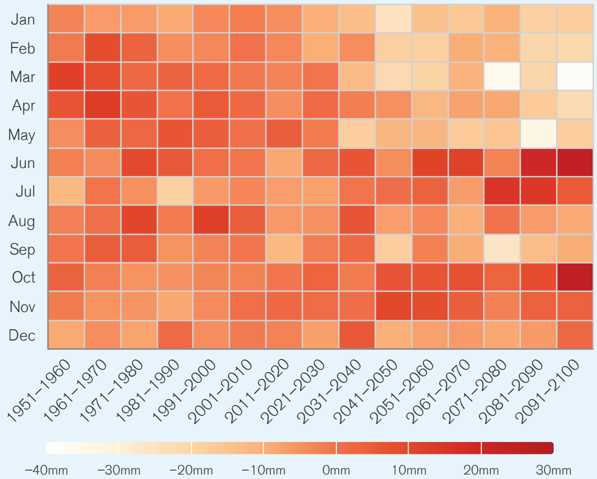
Projected precipitation patterns under SSP3-7.0 reflect potential shifts in the intensity of the wet and dry monsoon seasons and their timing, however the extents of these wet and dry shifts display a wide range of uncertainty by midcentury. At the national level, annual precipitation totals decrease from the 1995–2014 reference period by –18.16 mm (–212.05 mm, 122.62 mm) over 2020–2039 under SSP3-7.0 and decrease –18.41 mm (–376.92 mm, 230.00 mm) over 2040–2059. SSP3-7.0 predicts that the southern and central coasts will experience the greatest annual decreases in precipitation during 2020–2039 and 2040–2059 compared to the reference period. Meanwhile, during 2020–2039, the northern interior will experience relatively little annual change but by midcentury, the northern coast and central and southern interior will experience the least annual change. **Figures 6a–c** detail how precipitation anomalies vary unevenly by region and season from the 2020–2039 period to 2040–2059 period.

The greatest annual precipitation decrease of –47.57 mm (–154.56 mm, 96.27 mm) over 2020–2039 and –55.20 mm (–292.00 mm, 166.28 mm) over 2040–2059 occurs in Grand Kru on the southern coast (**see Figure 6a**). By midcentury, Grand Kru is projected to experience the greatest seasonal decrease during winter months nationally of -41.66 mm (–106.00 mm, 40.95 mm) with the largest declines from January to March. During the drier winter and spring months in northern Liberia, counties are projected to experience monthly precipitation decreases of at least –10% for the 2040–2059 period compared to the 1995–2014 reference period. Grand Cape Mount (northern coast) is expected to receive the largest precipitation decrease of –12.88% (–50.98%, +15.66%) during winter months over this projected period, followed by Lofa and Bomi. This trend, suggesting a greater intensity of dry monsoon conditions, continues throughout the spring months in the north.

Montserrado on the northern coast is expected to experience a shift in annual precipitation from a projected decrease of –29.29 mm (–274.49 mm, 182.60 mm) annually over 2020–2039 to only –6.93 mm (–435.05 mm, 329.23 mm) annually by midcentury (**see Figure 6b**). Monthly anomalies decrease much further during spring months than during winter months by midcentury, with a drop of –49.98 mm (–199.34 mm, 122.11 mm) or roughly twice as much as in Grand Kru during spring months. However, summer months along the northern coast are expected to receive more precipitation over 2020–2039 than the reference period. For example, during this time period, Montserrado is projected to receive an increase of 29.26 mm (–116.04 mm, 131.69 mm) during summer months and a summer increase of roughly half as much by midcentury. Relatively little annual change occurs in the northern and central interior over 2020–2039, but by midcentury, the least annual change occurs in the central and southern interior, with the largest increase of 7.45 mm (–288.13 mm, 161.11 mm) in Nimba (**see Figure 6c**). Smaller decreases during the winter months of -6.69 mm (–48.24 mm, 19.92 mm), larger increases of 22.58 mm (–78.91 mm, 112.10 mm) during summer months, and larger increases of 12.37 mm (–111.16 mm, 74.70 mm) during the transitional fall months help explain this trend. Both scenarios SSP1-2.6 and SSP2-4.5 predict wetter anomalies than SSP3-7.0 by midcentury (see Annex for more detail).

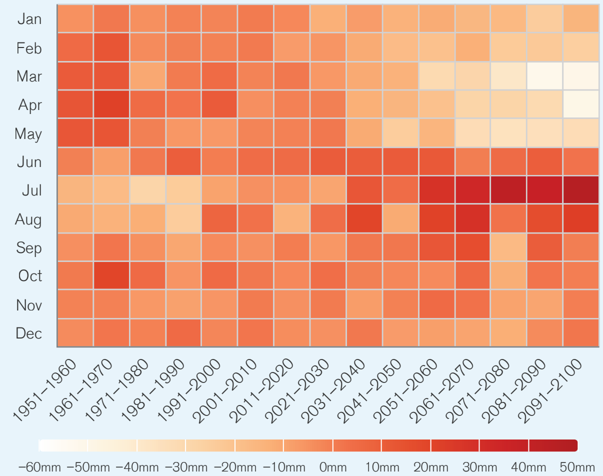
Liberia's average largest 5-day precipitation totals – a measure of prolonged precipitation intensity – are also projected to shift by midcentury compared to the 1995–2014 reference period (**see Figures 7a–c**). Grand Kru County (**Figure 7a**) is expected to have the largest annually projected 5-day precipitation anomalies in the south with the greatest monthly increase in July of 23.03 mm (–31.42 mm, 57.32 mm) before the monsoon's middle dries period. The highest uncertainty occurs during the monsoon's onset of June (a median of 3.67 mm but a range of –199.14 mm and 88.72 mm) and the largest monthly decrease in intensity of –12.35 mm (–87.44 mm, 67.97 mm)

FIGURE 6A. Projected Precipitation Anomaly (Ref. Period 1995–2014) Under SSP3-7.0 for Grand Kru (Southern Coast)



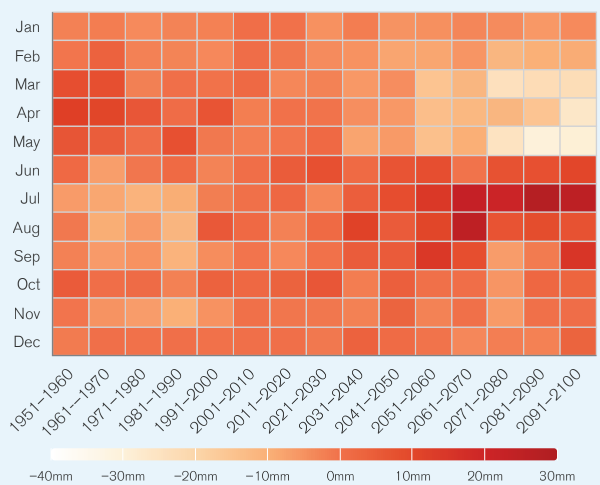
Note the negative monthly precipitation anomalies from January to March by 2040–2059 (x-axis), while significant monthly precipitation increases do not occur during the wet monsoon season until near the end of the century.

FIGURE 6B. Projected Precipitation Anomaly (Ref. Period 1995–2014) Under SSP3-7.0 for Montserrado (Northern Coast)



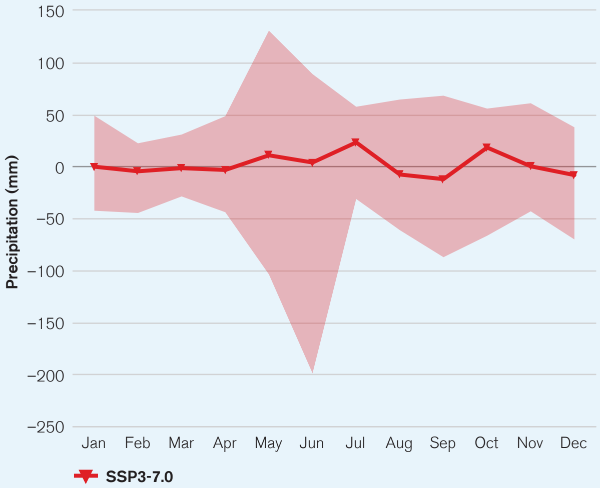
Note the larger monthly decreases in precipitation during spring months by 2040–2059 compared to Grand Kru, as well as the larger summer increase in precipitation. The x-axis has a wider range than **Figure 6a** and **Figure 6c**.

FIGURE 6C. Projected Precipitation Anomaly (Ref. Period 1995–2014) Under SSP3-7.0 for Nimba (Central Interior)



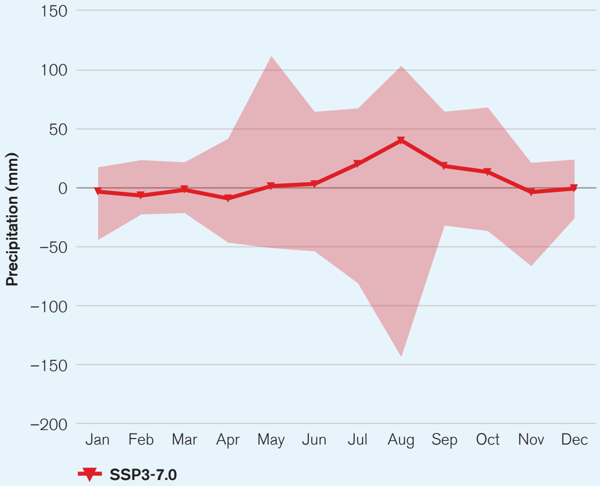
Note the reduced precipitation decreases during winter and spring months by 2040–2059 compared to Montserrado (**Figure 6b**), as well as the greater increases during summer and fall months.

FIGURE 7A. Projected Average Largest 5-Day Cumulative Precipitation Anomaly (in mm) Under SSP3-7.0 for 2040–2059 (Ref. Period 1995–2014) in Grand Kru County



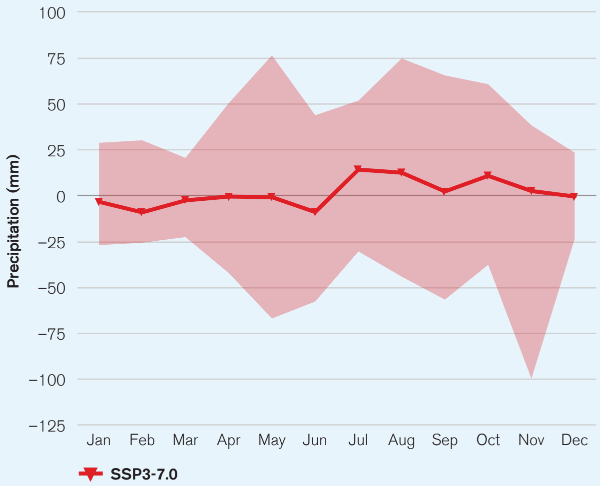
See text for interpretation of each county's median monthly anomalies and shaded probability distributions. Shaded areas indicate 10th and 90th percentiles. Note Grand Kru's peaks in May, July, and October but decline in intensity during September. The greatest uncertainty occurs during the onset of the wet monsoon season.

FIGURE 7B. Projected Average Largest 5-Day Cumulative Precipitation Anomaly (in mm) Under SSP3-7.0 for 2040–2059 (Ref. Period 1995–2014) in Grand Cape Mount County



Note peaks from July to October with the greatest uncertainty during the peak of the wet monsoon season. Grand Cape Mount's y-axis is not as wide as Grand Kru's (**Figure 7a**).

FIGURE 7C. Projected Average Largest 5-Day Cumulative Precipitation Anomaly (in mm) Under SSP3-7.0 for 2040–2059 (Ref. Period 1995–2014) in Grand Bassa County



Note peaks in July, August, and October with high uncertainty during both the onset and end of the wet monsoon season. Grand Bassa's y-axis is the narrowest.

occurs in September, indicating a potentially later shift in timing of the wet monsoon's second annual peak. Grand Cape Mount on the northern coast (**Figure 7b**), meanwhile, experiences a significant increase in intensity across much of the wet monsoon season and has the wettest increase in intensity nationally of 39.84 mm (–144.08 mm, 103.20 mm) during the peak month in August. As opposed to the southern coast, Grand Cape Mount faces the greatest future uncertainty in intensity during the peak of the wet monsoon season. Compared to Grand Kru and Grand Cape Mount, the largest monthly 5-day precipitation anomalies for Grand Bassa on the central coast contain high uncertainty at both the onset and end of the wet monsoon season (**Figure 7c**).

These projected trends point to potential shifts in the timing, duration, and likelihood of extreme precipitation that require multiple metrics to understand comprehensively. Observed amplified warming trends in the Sahara have been found to enhance the southwesterly flow of monsoon moisture further north into the Sahel during the summer months.[20] This factor comports with SSP3-7.0 projections for more intense wet monsoon days. Changes in sea surface temperatures in the East Atlantic Ocean, which tend to correlate with El Niño events among many other factors, will continue to be a notable influence on the interannual strength and temporal variation of Liberia's future monsoon precipitation (see section on climate-related hazards).[21]

Extreme Precipitation Events

By midcentury, Liberia is likely to more frequently experience extreme precipitation event occurrence. For the projected period of 2035–2064, the largest 1-day precipitation amounts associated with 10-year historical return periods will be at least two times more likely to occur in the northern highland counties (**see Table 5**). Amounts associated with 25-year and 50-year historical return periods will also be at least two times more likely to occur everywhere in Liberia, except in the southeast. Amounts associated with 100-year historical return periods will be nearly three times more likely to occur by midcentury nationwide, particularly in the northern interior. For example, the projected future return periods for 100-year events will dramatically shift to occurring every 30.90 years in Lofa, every 31.96 years in Bong, and every 33.06 years in Nimba. SSP1-2.6 and SSP2-4.5 forecast slightly higher frequencies (longer future return periods) compared to the SSP3-7.0 scenario detailed in **Table 5**. More frequently occurring extreme precipitation events underscore future health risks related to flood impacts, agricultural yields, disease ranges, and critical infrastructure, including for water, sanitation, and hygiene.

---

[20] Cook, K. H., and Vizy, E. K. (2019). Contemporary climate change of the African monsoon systems. Current Climate Change Reports, 5, 145-159. DOI: https://doi.org/10.1007/s40641-019-00130-1

[21] USAID (2013). Liberia climate change assessment. URL: https://pdf.usaid.gov/pdf_docs/PA00KDJM.pdf; Hagos, S. M., and Cook, K. H. (2007). Dynamics of the West African monsoon jump. Journal of Climate, 20(21), 5264-5284. DOI: https://doi.org/10.1175/2007JCLI1533.1

TABLE 5. County-Level Change in Annual Exceedance Probability of Largest 1-Day Precipitation for Different Event Recurrence Intervals (2035–2064, Center 2050)

	Return Period			
County	**10-yr**	**25-yr**	**50-yr**	**100-yr**
Liberia	1.96 (1.07, 2.84)	2.21 (1.04, 3.58)	2.53 (0.97, 4.23)	2.91 (0.94, 5.00)
Southern Region				
Grand Gedeh	1.83 (1.04, 2.84)	2.06 (1.04, 3.55)	2.34 (0.98, 4.14)	**2.63** (0.91, 4.81)
River Gee	1.51 (0.96, 2.80)	1.63 (0.94, 3.45)	1.74 (0.94, 4.04)	1.86 (1.00, 4.74)
Maryland	1.40 (0.69, 2.26)	1.51 (0.51, 2.69)	1.54 (0.40, 3.08)	1.55 (0.92, 3.53)
Grand Kru	1.49 (0.80, 2.43)	1.60 (0.67, 2.93)	1.67 (0.60, 3.39)	1.73 (0.96, 3.92)
Sinoe	1.66 (0.98, 2.78)	1.78 (0.97, 3.44)	1.94 (0.95, 4.04)	2.11 (0.94, 4.74)
Central Region				
River Cess	1.77 (0.98, 2.69)	1.98 (0.86, 3.40)	2.20 (0.73, 3.99)	2.52 (0.65, 4.68)
Grand Bassa	1.87 (1.13, 2.67)	2.14 (0.96, 3.47)	2.40 (0.79, 4.08)	2.83 (0.72, 4.79)
Nimba	2.11 (1.10, 2.84)	2.37 (1.04, 3.56)	2.71 (0.89, 4.09)	**3.15** (0.79, 4.71)
Northern Region				
Margibi	1.75 (1.16, 2.68)	2.00 (1.00, 3.41)	2.22 (0.94, 4.06)	2.50 (0.96, 4.83)
Montserrado	1.71 (1.15, 2.68)	1.96 (1.00, 3.39)	2.18 (0.97, 4.05)	2.41 (1.00, 4.83)
Bomi	1.71 (1.15, 2.69)	1.96 (1.00, 3.39)	2.17 (0.97, 4.05)	2.41 (1.00, 4.83)
Grand Cape Mount	1.81 (1.01, 2.72)	2.06 (0.99, 3.42)	2.27 (0.99, 4.12)	2.52 (0.99, 4.82)
Bong	1.98 (1.17, 2.80)	2.30 (1.05, 3.68)	2.66 (0.91, 4.41)	3.18 (0.86, 5.28)
Gbarpolu	1.91 (1.07, 2.87)	2.21 (1.04, 3.64)	2.51 (1.04, 4.43)	2.85 (1.05, 5.38)
Lofa	2.02 (1.08, 2.81)	2.35 (1.06, 3.62)	2.81 (1.03, 4.41)	**3.26** (1.01, 5.35)

The largest 1-day precipitation amounts associated with an event of a certain historical return period would be two times more likely to occur by midcentury (or have a change factor of two). Change factors >2 are shaded orange and increase in counties further north and inland. The largest change factors are bolded. 10th and 90th percentiles are provided in the parentheses. See text for interpretation.

According to the INFORM Risk Index, Liberia's greatest hazard exposure corresponds with river and coastal flooding, further exacerbated by sea level rise.[22] Sea level rise exposes heavily populated parts of the coast to frequent inundations and erosion. More intense precipitation and floods strain critical infrastructure in urban and rural areas as well as the country's productive agriculture, forests, and fisheries. Excess rainfall and higher temperatures exacerbate Liberia's already high rate of vector-borne and waterborne diseases such as cholera, malaria, yellow fever, schistosomiasis, and diarrheal diseases. While not common historically, incidents of drought may increase in the future, affecting water management and energy production and requiring further study. Past and future impacts associated with Liberia's notable climate-related hazards are discussed below.

Sea Level Rise and Sea Surface Temperature

Historically observed sea surface temperatures (1992–2010) for coastal Liberia fluctuated between a seasonal peak in April (29.25°C) at the end of the dry monsoon season, a dip by the end of May that corresponds with the onset of the wet monsoon season, and a low point during August (26.28°C) near the peak of summer monsoon.[23] Sea surface temperatures in the East Atlantic (and globally through ENSO) are one of the primary drivers of interannual and decadal climate variability in Liberia.[24] Warmer sea surface temperatures in the East Atlantic Ocean weaken thermal differences between land and sea, therefore reducing the extent that the wet monsoon travels inland. This results in increased precipitation along the coast and decreased precipitation in the interior, as is common during El Niño events. The inverse effect would result from cooler sea surface anomalies. While average annual observed sea surface temperature variations (1993–2012) were consistently positive across seasons and years, decadal variations make longer-term trends and climate implications more difficult to predict.

Sea level rise and coastal inundation will increasingly threaten Liberia's extensive and productive coastal zones. The coast is home to nearly 60% of Liberia's population, much of which is densely settled and growing rapidly. Sea level rise has resulted in increased rates of inundation, storm surges, erosion, and other coastal hazards that are threatening coastal settlement, infrastructure, and health and sanitation in communities like West Point, Monrovia and Buchanan.[25] The rate of sea level rise, expected to vary minimally from north to south (grid 6°N, 11°W), is projected to increase 0.24 m (0.16 m, 0.33 m) by 2050 and 0.72 m (0.52 m, 1.00 m) by 2100 under SSP3-7.0 with a historical baseline of 1995–2014.[26] Approximately 95 km^2 of land in the coastal zone of Liberia will be inundated as a result of one-meter sea level rise, with about 50% (48 km^2) of the total land loss due to inundation on the sheltered coast and shoreline retreat.[27] Estimates suggest that more than 230,000 people are

---

22 European Commission (2023). INFORM Index for Risk Management. Liberia Country Profile. URL: https://drmkc.jrc.ec.europa.eu/inform-index/INFORM-Risk/Country-Risk-Profile

23 World Bank Climate Change Knowledge Portal (2023). Liberia Sea Level Rise. URL: https://climateknowledgeportal.worldbank.org/country/liberia/impacts-sea-level-rise

24 Rodríguez-Fonseca, B., Janicot, S., Mohino, E., Losada, T., Bader, J., Caminade, C., Chauvin, F., Fontaine, B., García-Serrano, J., Gervois, S., Joly, M., Polo, I., Ruti, P., Roucou, P. and Voldoire, A. (2011) Interannual and decadal SST-forced responses of the West African monsoon. Atmospheric Science Letters 12, 67–74. DOI: https://doi.org/10.1002/asl.308

25 USAID (2017). Liberia Climate Change Risk Profile. URL: https://www.climatelinks.org/sites/default/files/asset/document/2017_USAID%20ATLAS_Climate%20Risk%20Profile_Liberia.pdf

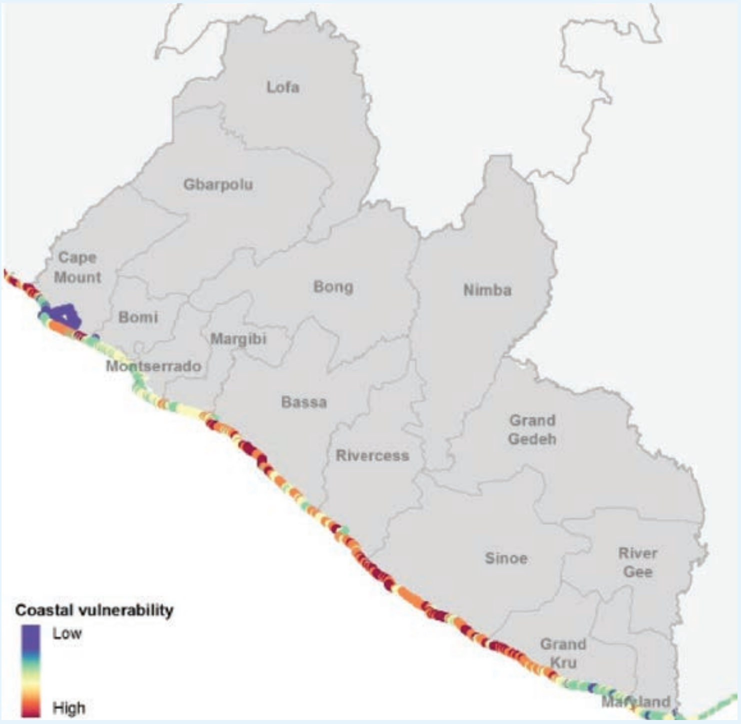
26 NASA (2023). Sea Level Projection Tool. URL: https://sealevel.nasa.gov/ipcc-ar6-sea-level-projection-tool; note the figures inside parentheses represent 17th and 83rd percentiles, respectively.

27 Environmental Protection Agency (2018). National Policy and Response Strategy on Climate Change. URL: http://www.epa.gov.lr/sites/default/files/National%20Policy%20and%20Response%20Strategy%20on%20Climate%20Change%20Final%20Document-min_0.pdf

at risk and 2,150 km^2 will be lost with a one-meter sea level rise by the end of the century. Damages and loss of infrastructure and land for major cities such as Monrovia, New Kru Town, River Cess, Buchanan, and Robertsport are estimated at $250 million.[28] The country's most vulnerable coastal areas to erosion are in Grand Bassa, Rivercess, Sinoe, and Grand Kru Counties (**see Figure 8**). Coastal protection provided by mangroves is relatively high in Grand Bassa and Rivercess Counties, and to a lesser extent in Sinoe County.[29]

The rate of sea level rise along Liberia's coast exhibits discernible differences by the end of the century according to each scenario.[30] Under SSP3-7.0, sea level rise is projected to increase 0.50 meters above the historical baseline near Monrovia (Montserrado) by around 2070 (**see Figure 9**). However, this rate of change is slower under SSP2-4.5 and SSP1-2.6, as sea level rise does not reach this threshold until around 2090 under the

FIGURE 8. Liberia's Coastal Vulnerability[31]



Based on qualitative estimates of coastal exposure comprising erosion rates and inundation extent. Red areas are more vulnerable, blue areas are less vulnerable.

---

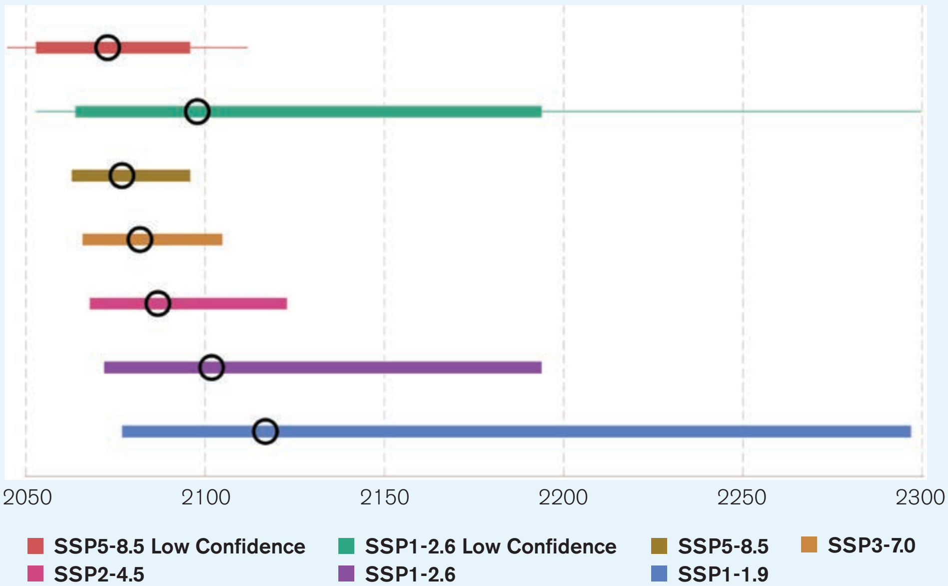
28 USAID (2013). Liberia Climate change assessment. URL: https://pdf.usaid.gov/pdf_docs/PA00KDJM.pdf

29 Neugarten, R., Alam, M., Martinez, N.A., Honzak, M., Juhn, D., Larsen, T., Moull, K., Rodriguez, A.M., Wright, T., Walsh, L. and Donovan, J. (2017). Natural capital mapping and accounting in Liberia—understanding the contribution of biodiversity and ecosystem services to Liberia's sustainable development. Conservation International. URL: https://www.researchgate.net/publication/321304662_Natural_Capital_Mapping_and_Accounting_in_Liberia_Understanding_the_contribution_of_biodiversity_and_ecosystem_services_to_Liberia's_sustainable_development

30 NASA (2023). Sea Level Projection Tool. URL: https://sealevel.nasa.gov/ipcc-ar6-sea-level-projection-tool

31 Neugarten, R., Alam, M., Martinez, N.A., Honzak, M., Juhn, D., Larsen, T., Moull, K., Rodriguez, A.M., Wright, T., Walsh, L. and Donovan, J. (2017). Natural capital mapping and accounting in Liberia—understanding the contribution of biodiversity and ecosystem services to Liberia's sustainable development. Conservation International. URL: https://www.researchgate.net/publication/321304662_Natural_Capital_Mapping_and_Accounting_in_Liberia_Understanding_the_contribution_of_biodiversity_and_ecosystem_services_to_Liberia's_sustainable_development

FIGURE 9. Projected Timing of 0.5-Meter Sea Level Rise Along Liberia's Coast Under Various Scenarios (Ref. Period 1995–2014)[32]



Thick bars show 17th–83rd percentile ranges, and black circles show median value. Thin bars also show 5th–95th percentile ranges for SSP1-2.6 Low Confidence and SSP5-8.5 Low Confidence scenarios. Data reflects grid at 6°N, 11°W.

former scenario and after 2100 for the latter, both with higher uncertainty. Compared to SSP3-7.0 which rises 0.72 m (0.52 m, 1.00 m) by 2100, SSP2-4.5 rises 0.61 m (0.41 m, 0.87 m) while SSP1-2.6 rises 0.48 m (0.29 m, 0.71 m) over the same timeframe. Rates of sea level rise can mostly be attributed to changes in temperature, salinity, and ocean currents.

Flood and Drought Risk

Incidents of flooding and drought will likely occur with greater intensity and frequency in the future, influenced by ENSO. Between 1998–2016, riverine floods directly affected more than 50,000 people, including a record number within the last decade.[33] A recent noteworthy example occurred across Montserrado and Margibi in 2017 during the peak of the wet monsoon season.[34] Of Liberia's rivers pictured in **Figure 10b**, the National Disaster Management Agency identifies the most flood-prone areas along the Lofa River (Lofa, Bomi), downstream St. Paul River (Montserrado), downstream Farmington River (Margibi, Grand Bassa), and St. John River (Grand Bassa, Nimba).[35] Intense precipitation and flooding cause erosion that threaten rice yields; exports such as cacao,

---

[32] NASA (2023). Sea Level Projection Tool. URL: https://sealevel.nasa.gov/ipcc-ar6-sea-level-projection-tool

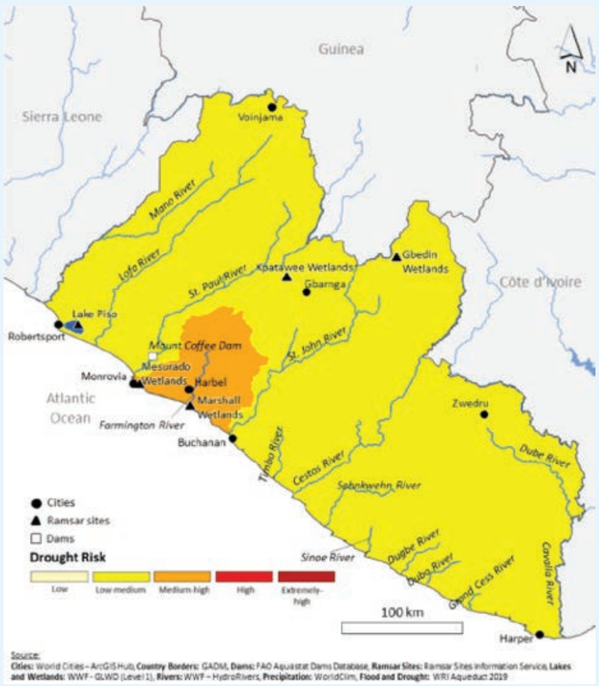
[33] International Fund for Agricultural Development (2018). Liberia Agricultural Risk Assessment Study. URL: https://www.p4arm.org/app/uploads/2019/04/Liberia_Agricultural-risk-assesment-study.pdf

[34] International Federation of Red Cross and Red Crescent Societies (2018). Liberia: Montserrado and Margibi Floods Emergency Plan of Action Final Report. URL: https://reliefweb.int/report/liberia/liberia-montserrado-margibi-floods-emergency-plan-action-final-report-dref-operation

[35] Environmental Protection Agency (2021). National Adaptation Plan 2020–2030. URL: https://unfccc.int/sites/default/files/resource/LIBERIA_%20NAP_%20FINAL_%20DOCUMENT.pdf

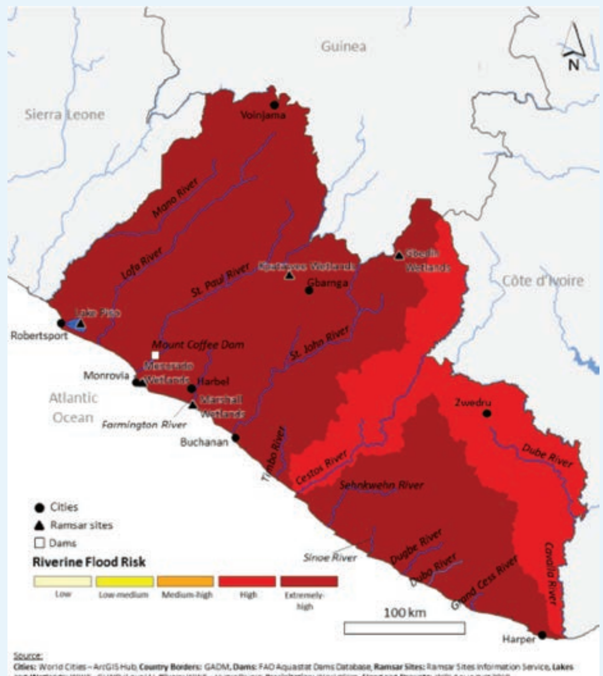
coffee, and rubber; and forest growth. Water contamination and disease outbreaks linked to limited access to sanitation and waste management tend to spike during heavy flooding episodes. One estimate predicts cases of cholera in Liberia, which already affected tens of thousands in recent decades, may increase 10% by the end of the century and particularly affect Monrovia's informal settlements.[36] While Liberia is not a drought-prone country historically, a wide range of future uncertainty in seasonal precipitation totals increases the likelihood of multifold types of droughts, especially in the Farmington River watershed (**see Figure 10a**). The St. Paul River, which powers 70% of the country's municipal electricity and fluctuates between a flow rate above 1,400 m^3/s in September and only 50 m^3/s in February, would endure further strain from up to 25% decreases in projected runoff during the 2020s.[37] More intense dry seasons would also affect the viability of inland fisheries as well as rural supplies of potable well water. Due to a lack of data on drought incidence and susceptibility in Liberia,[38] potential changes in seasonal precipitation require further investigation.

FIGURE 10A. Liberia's Drought Risk[39]



Note the highest drought risk in the Farmington River watershed (Margibi, Grand Bassa) and Monrovia.

FIGURE 10B. Liberia's Riverine Flood Risk[40]



Note the highest riverine flood risk in upstream and downstream portions of northern Liberia and parts of coastal southern Liberia.

---

[36] USAID (2017). Liberia Climate Change Risk Profile. URL: https://www.climatelinks.org/sites/default/files/asset/document/2017_USAID%20ATLAS_Climate%20Risk%20Profile_Liberia.pdf

[37] USAID (2021). Liberia Water Resources Profile. URL: https://winrock.org/wp-content/uploads/2021/08/Liberia_Country_Profile-Final.pdf; USAID (2017). Liberia Climate Change Risk Profile. URL: https://www.climatelinks.org/sites/default/files/asset/document/2017_USAID%20ATLAS_Climate%20Risk%20Profile_Liberia.pdf

[38] International Fund for Agricultural Development (2018). Liberia Agricultural Risk Assessment Study. URL: https://www.p4arm.org/app/uploads/2019/04/Liberia_Agricultural-risk-assesment-study.pdf

[39] USAID (2021). Liberia Water Resources Profile. URL: https://winrock.org/wp-content/uploads/2021/08/Liberia_Country_Profile-Final.pdf

[40] USAID (2021). Liberia Water Resources Profile. URL: https://winrock.org/wp-content/uploads/2021/08/Liberia_Country_Profile-Final.pdf

KEY NATIONAL DOCUMENTS

- First Adaptation Communication to the UNFCCC (AdCom) (2021)
- Second National Communication to the UNFCCC (SNC) (2021)
- Revised Nationally Determined Contribution (NDC) (2021)
- First Biennial Update Report to UNFCCC (BUR1) (2020)
- National Policy and Response Strategy on Climate Change (NPRSCC) (2018)
- Natural Capital Mapping and Accounting (2017)
- Initial National Communication to the UNFCCC (NC1) (2013)
- Climate Change Gender Action Plan (ccGAP) (2012)
- National Disaster Management Policy (2012)
- National Adaptation Programme of Action (NAPA) (2008)
- Environmental Protection and Management Law (2002)

ANNEX OF PROJECTED CLIMATE SCENARIOS

Compared to SSP3-7.0, which results in the greatest temperature and precipitation shifts nationally across all key metrics by the end of the century (see Table 6), SSP1-2.6 and SSP2-4.5 demonstrate Liberia's different rates of change and severity of climate impacts as a result of carbon emission reductions. As illustrated in **Figure 11a**, SSP1-2.6 has the lowest annual mean temperature increase – an anomaly of 1°C by 2080–2099. Mean temperature rises by an anomaly of approximately 2°C by end-of-century under SSP2-4.5 and close to 3°C by end-of-century under SSP3-7.0. Under SSP3-7.0, the anomalous annual number of high Heat Index days increases dramatically above the reference period (nearly five months) by 2080–2099 nationally. Whereas by the end of the century, the number of high Heat Index days increases less than two months under SSP2-4.5 and barely any median days at all under SSP1-2.6. The annual number of tropical nights (T-min >26°C) experienced nationally by the end of the century increases much higher (roughly three months) above the reference period under SSP3-7.0, compared to the one-month annual increase over the same time period under SSP2-4.5 and even fewer nights under SSP1-2.6. The greatest change in tropical nights occurs across coastal areas under each scenario.

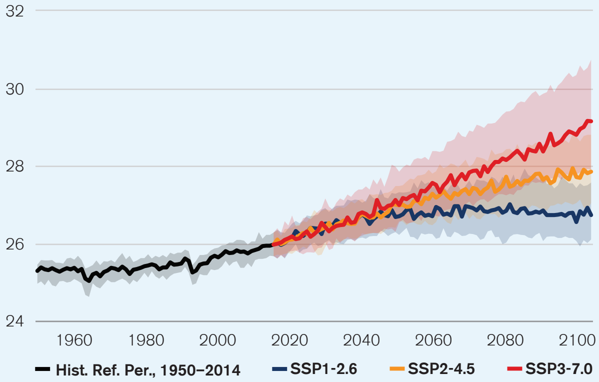
The projected precipitation patterns countrywide under the three scenarios produce noticeable variation by the end of the century (**see Figure 11b**). Whereas the annual precipitation forecasted by SSP1-2.6 rises steadily across the century starting in 2020–2039, precipitation under SSP2-4.5 only significantly increases by the end of the century. On the other hand, annual precipitation under SSP3-7.0 decreases from the reference period starting in 2020–2039 and reaches an anomaly of –36.33 mm (–530.80 mm, 433.82 mm) by the end of the century. SSP3-7.0 displays a very large range of uncertainty (almost 1,000 mm) though the other two scenarios still project some potential for experiencing negative anomalies by the end of the century. Precipitation intensity, as measured by the average largest 5-day cumulative precipitation annually, increases the most from the reference period by the end of the century (>20 mm) under SSP3-7.0. Northern counties tend to experience the greatest increases in intensity under all scenarios by the end of the century.

TABLE 6. Key National-Level Projected Anomalies Through End-of-Century (Ref. Period 1995–2014) Under SSP1-2.6, SSP2-4.5, and SSP3-7.0 Scenarios

Metric	SSP1-2.6 Projection		
	2020–2039	2040–2059	2080–2099
Annual Mean Temperature	0.69°C (0.39°C, 0.99°C)	0.98°C (0.54°C, 1.53°C)	1.00°C (0.44°C, 1.78°C)
Tropical Nights (No. Nights T-min >26°C) Annually	2.87 (0.95, 6.68)	5.93 (1.52, 15.44)	6.08 (1.18, 23.37)
Annual Precipitation (mm)	**30.78** (–88.98, 156.70)	**43.40** (–70.77, 246.48)	**49.78** (–85.96, 253.34)
Average Largest 5-Day Cumulative Precipitation (mm) Annually	3.23 (–54.63, 45.70)	11.59 (–47.62, 60.55)	9.69 (–53.23, 49.66)
Metric	**SSP2-4.5 Projection**		
	2020–2039	**2040–2059**	**2080–2099**
Annual Mean Temperature	0.69°C (0.38°C, 0.95°C)	1.19°C (0.72°C, 1.76°C)	1.96°C (1.19°C, 2.81°C)
Tropical Nights (No. Nights T-min >26°C) Annually	2.94 (0.98, 6.47)	8.66 (3.05, 20.35)	29.70 (7.88, 77.82)
Annual Precipitation (mm)	3.78 (–89.08, 139.68)	13.66 (–186.08, 234.75)	**48.98** (–150.42, 385.48)
Average Largest 5-Day Cumulative Precipitation (mm) Annually	4.36 (–52.80, 43.54)	15.25 (–48.78, 61.01)	18.60 (–47.17, 79.65)
Metric	**SSP3-7.0 Projection**		
	2020–2039	**2040–2059**	**2080–2099**
Annual Mean Temperature	0.67°C (0.38°C, 1.09°C)	1.36°C (0.86°C, 2.10°C)	**2.85°C** (1.91°C, 4.22°C)
Tropical Nights (No. Nights T-min >26°C) Annually	2.57 (0.90, 7.45)	11.98 (3.77, 33.32)	**91.14** (25.24, 233.08)
Annual Precipitation (mm)	**–18.16** (–212.05, 122.62)	**–18.41** (–376.92, 230.00)	**–36.33** (–530.80, 433.82)
Average Largest 5-Day Cumulative Precipitation (mm) Annually	5.93 (–71.20, 60.98)	16.28 (–71.64, 64.93)	**22.89** (–54.80, 83.03)

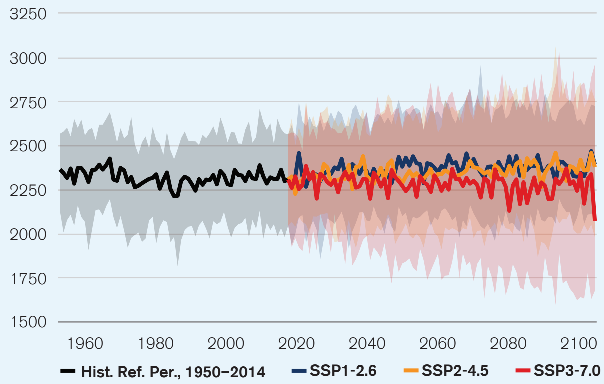
10th percentile and 90th percentile values are shown in parentheses. Key values or shifts over time are shaded orange and bolded. See text for interpretation.

FIGURE 11A. Projected Average Mean Temperature in Degrees Celsius Nationwide (Ref. Period 1995–2014) Under Various Scenarios



Shaded areas indicate ranges of 10th–90th percentiles. Note clearly higher increase of SSP3-7.0 starting midcentury.

FIGURE 11B. Projected Precipitation in Millimeters Nationwide (Ref. Period 1995–2014) Under Various Scenarios



Shaded areas indicate ranges of 10th–90th percentiles. Note the greatest uncertainty and precipitation decrease compared to the historical period by the end of the century under SSP3-7.0, but precipitation increases over the same time period under SSP1-2.6 and SSP2-4.5. Probability ranges for all scenarios extend above and below the historical reference period, indicating a potential likelihood for precipitation decreases or increases.

CLIMATE RISK COUNTRY PROFILE

LIBERIA

WORLD BANK GROUP