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FACT SHEET

CLIMATE RISK PROFILE
WEST AFRICA

REGIONAL OVERVIEW

West Africa is one of the world's most vulnerable regions to climate variability and change. Increasing temperatures and shifting rainfall patterns are already affecting livelihoods, food security, and economic and governance stability. Extreme climate variability since the 1970s has resulted in agricultural losses, recurrent food crises, both water scarcity and extreme flooding, and environmental degradation. Warming across the region is greater than the global average, a trend expected to continue, with the greatest warming in the Sahel. The region's long coastline, home to densely populated cities and economic hubs, is experiencing sea level rise and severe coastal erosion, projected to increase with significant impacts to the coastal population, urban centers and ports, coastal aquifers, and the agriculture and fisheries sectors. Togo and Mauritania have lost more than 2 percent of gross domestic product (GDP) to coastal degradation and erosion in one year. Crops and livestock, a base for about 60 percent of livelihoods and 35 percent of GDP regionally, face increasing heat stress and variability in rainfall, including more frequent and damaging heavy rainfall events and diminishing rainfall in the west of the region. Transnational dimensions of climate impacts include food and water quality and availability, health conditions related to air quality, disruption of transportation networks, and migration. Climate vulnerability is compounded by high dependence on rainfed agriculture, rapid population growth, pervasive poverty, and inadequate access to safe water and sanitation. (38, 63, 83, 88, 96, 108, 110)

ORGANIZATION OF PROFILE

This profile, which covers 21 countries in West Africa (Figure 1), begins with a regional climate summary, followed by a discussion of climate risks by sector and a summary of the policy context and relevant projects in the region. Some sectors (agriculture, water resources, and ecosystems) are detailed for three subregions— the Sahel, Inland Forests, and Coastal subregions.

CLIMATE PROJECTIONS

- 1.6–2.9°C increase in temperature by 2050
- Decreased rainfall in the west of the region, increased in the east
- Increased frequency and intensity of heavy rainfall
- 17–45 cm rise in sea level by 2050s

KEY CLIMATE IMPACTS

Agriculture
Increased crop/livestock losses from drought, floods, pests and disease, and coastal erosion and inundation

Water
Reduced water quality and availability; intensifying flood events; coastal inundation and salinization

Ecosystems
Increased land degradation; loss of biodiversity and fisheries; coastal erosion; loss of mangroves

Human Health
Increased food insecurity, certain vector- and waterborne diseases, and flood-related mortality

Urban Areas
Intensified urban heat islands; increased water contamination and flood damage to urban infrastructure

Energy
Hydropower affected by evaporation, siltation, and river flow variability; increased flood damage to infrastructure

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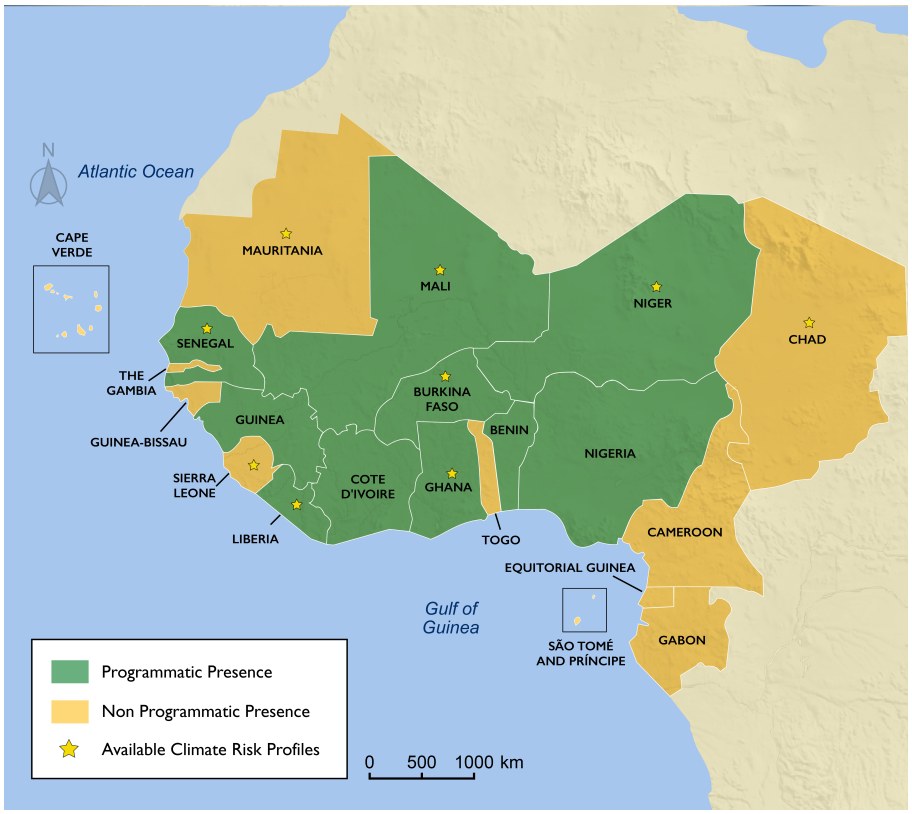
Figure 1. Map of West Africa



CLIMATE RISK PROFILE SECTIONS

REGIONAL CLIMATE SUMMARY

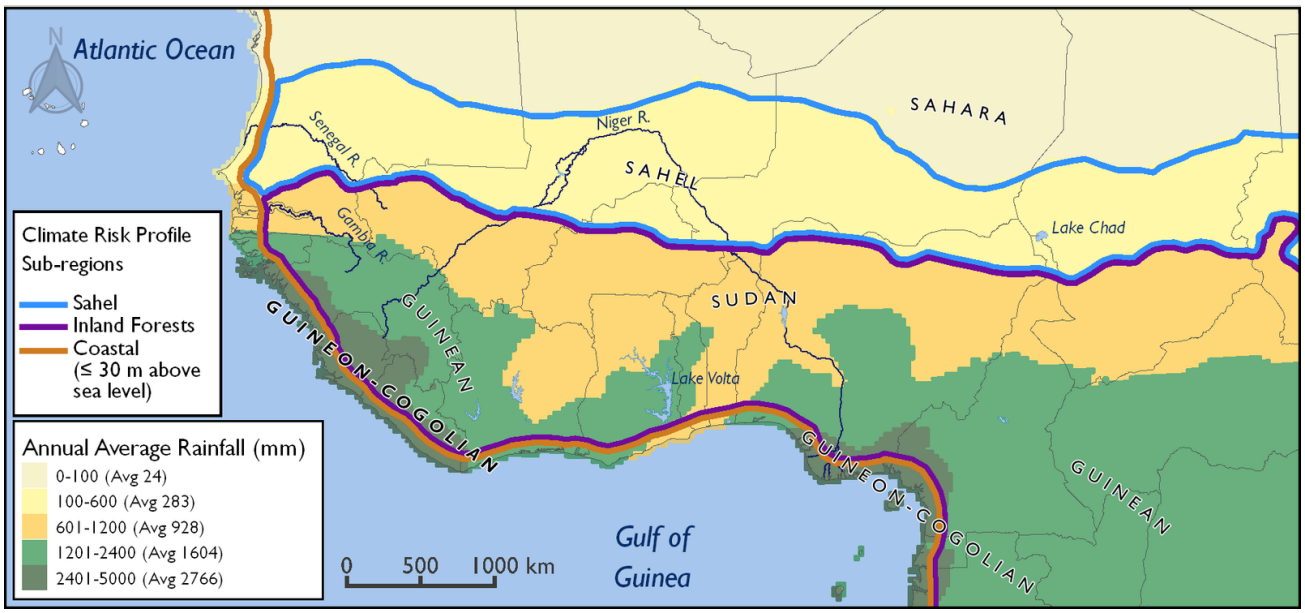
OVERVIEW

Covering approximately one-quarter of the continent, West Africa contains diverse bioclimatic regions including rainforests, coastal plains, lowland plateaus, deserts, and isolated highlands, such as the Guinea Highlands, Jos Plateau, Aïr Mountains, and Cameroon Highlands.

West Africa can be divided into four broad bioclimatic zones from north to south (Figure 2): the Sahel, Sudan, Guinean, and Guineo-Congolian. These regions follow a latitudinal rainfall gradient, with the lowest rainfall in the Sahel (as little as 100 mm annually) and increasing rainfall to the south, with the highest rainfall along the southern coast (up to 5,000 mm annually). This profile considers subregions that follow the bioclimatic zones but groups them into three subregions: the Sahel; the Inland Forests, which encompass most of the Sudan zone and the inland portions of the Guinean and Guineo-Congolian zones; and the Coastal subregion, which comprises the coastal areas across bioclimatic zones. (88)

In the summer (May–October), moist southwest winds originating over the Atlantic Ocean bring heavy rains of short duration. West African rainfall is highly variable in amount, time of onset, and duration, particularly in drier zones. The percent annual variability ranges from 10 to 20 percent in coastal areas and may exceed 40 percent in the Sahel and Sahara. The dry season (November–March) brings dust-laden Harmattan trade winds from the north that reduce humidity and can produce severe dust and sandstorms. Annual average temperatures are 22–28°C and maximum temperatures can reach more than 40°C in the Sahel in the summer (April–September). Table 1 contains information on temperature and rainfall of each climate zone. (13, 88)

Figure 2.Bioclimatic Zones and Subregions of West Africa



Source: Adapted from CILSS 2016.

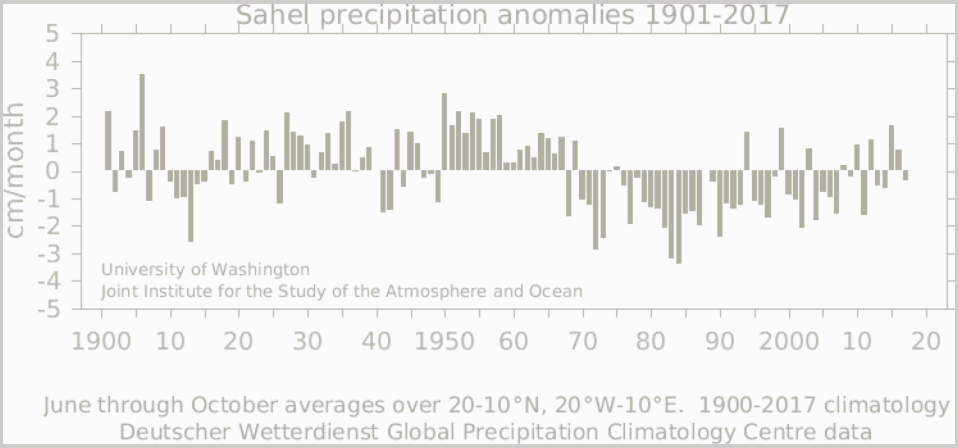
Table 1. Bioclimatic zones: Vegetation, rainfall, and temperature

Bioclimatic Zones	Rainfall and Seasonality	Temperature
Sahel Grassland, shrubs, and small trees	Average annual rainfall of 100–200 mm (north) to 500–600 mm (south), with a rainy season ranging from one to five months during June–October; maximum rainfall in August.	Average annual temperatures of 22–36°C
Sudan Savannah and open woodlands	One rainy season (May–October), with annual rainfall of 600 to 1,200 mm.	Average annual temperatures above 22–28°C
Guinean Dense, seasonally wet and dry forests	Two rainy seasons (April–July and September–October), with annual rainfall of 1,200–2,200 mm. Most rain, 75–80 percent, falls during April–July.	
Guineo-Congolian Dense rainforests	Two rainy seasons (April–July and September–October) or year-round rainfall; annual averages of 2,200–5,000 mm.	

Rainfall variability in the Sahel

Rainfall in the Sahel exhibits high interannual, decadal, and spatial variability (Figure 3), which makes detecting historical trends and projecting future ones difficult. Rainfall has alternated between periods of above-average conditions (1915 to 1930, 1950 to mid-1960s) and below-average conditions (mid-1960s to 1990) (average taken from 1901–2017). The largest rainfall deficits in the early 1980s marked a strong drought and a 40 percent decrease in long-term average rainfall. Although some recovery occurred in recent decades, cumulative rainfall has not returned to pre-1960s levels. Research also shows new patterns of variability emerging, including an east-west gradient. In the east (Niger and eastward), the number of years with above-average rainfall has increased, while in the west (western Mali and westward), the number of years with below-average rainfall has increased. Additionally, temporal variability appears to have shifted from multiyear wet and dry phases to interannual fluctuations. Studies have linked West Africa's rainfall variability to sea surface temperatures, increases in atmospheric carbon dioxide, and air pollution in the northern hemisphere. This marked decadal variability continues to pose a significant challenge to efforts at projecting future rainfall for the region. (3, 64, 88, 101)

Figure 3. Annual rainfall variability compared to average in the Sahel (1900–2016)



Source: UW/JISAO 2017.

HISTORICAL CLIMATE TRENDS

Observed climate trends across West Africa include: higher temperatures; increased rainfall in some areas and reduced rainfall in others, with high interannual and interdecadal variability, particularly in the Sahel (see previous box); increased frequency of heavy rainfall events; and rising sea levels. Table 2 provides more detail and examples of these changes across West Africa. (13, 26, 27, 28, 29, 30, 31, 32, 38, 63, 70)

Table 2. Historical climate trends across West Africa

	General historical trends	Examples
Temperature	• Increasing average temperatures slightly higher than the global average	• +0.5–0.8°C regionally between 1970 and 2010 • +1.5–2.0°C in the Sahel between 1950 and 2010, with greater warming in April, May, and June
Rainfall	• Growing climate divide between the west and east parts of the West African Sahel, with less rainfall in the west • Marked periods of decadal rainfall variability shifting toward interannual	• Decreased rainfall from 1901 to 2013 of -6 percent (Senegal, The Gambia), -4 percent (Burkina Faso, Mali), and -3 percent (Côte d'Ivoire) per 30 years • No change in rainfall from 1901 to 2013 in Niger, Ghana, Togo, and Benin • Increased rainfall from 1983 to 2013, ranging from

	General historical trends	Examples
	fluctuations, particularly in the Sahel and since the mid-2000s	+4 percent (Ghana, Togo, Benin) to +36 percent (Niger)
Heavy rainfall 	• Increased frequency of heavy rainfall events	• Increased proportion of rainfall from heavy rainfall events in the central Sahel from 17 percent (1970–1990) to 21 percent (2001–2010)
Sea level rise 	• Rising sea level	• +8.4 cm from 1942 to 2012 in Dakar, Senegal and a greater increase of about 25 cm since the 1930s in Takoradi, Ghana

Definitions of climate terms

Climate variability
Variations in the state of the climate on all spatial and temporal scales beyond that of individual weather events. Variability may be due to natural internal processes within the climate system (internal variability), or to variations in natural or anthropogenic external forcing (external variability).

Extreme weather event
An event that is rare at a particular place and time of year. Definitions of rare vary, but an extreme weather event would normally be as rare as or rarer than the 10th or 90th percentile of a probability. By definition, the characteristics of what is called extreme weather may vary from place to place in an absolute sense. When a pattern of extreme weather persists for some time, such as a season, it may be classed as an *extreme climate event* (e.g., drought or heavy rainfall over a season).

Climate change
Climate change refers to a change in the state of the climate that persists for an extended period, typically decades or longer. Climate change may be due to natural internal processes or external forces such as modulations of the solar cycles, volcanic eruptions, and persistent anthropogenic changes in the composition of the atmosphere or in land use.

Source: Adapted from IPCC 2014 (Annex II: Glossary).

FUTURE CLIMATE PROJECTIONS

Looking ahead, temperatures will continue to rise across the region, along with increased frequency and duration of heat waves. Rainfall continues to be variable, with increased rainfall in some areas and decreased rainfall in others. The onset of the rainy season will occur later in the spring, and heavy rainfall events will increase in frequency and intensity. Sea levels and surface temperatures will continue to rise as well. Table 3 includes more detail and examples of these changes across West Africa. (3, 8, 26, 27, 28, 29, 30, 31, 32, 63)

Table 3. Future climate projections across West Africa

	General future projections by 2050s	Examples (for 2050s)
Temperature 	• Increased temperatures regionwide, with the greatest warming in the Sahel	• +1.6 to 2.9°C (Niger, Burkina Faso, Mali, Niger, Mauritania) • +1.4 to 2.5°C (Senegal, The Gambia) • +1.3 to 2.3°C (Côte d'Ivoire, Ghana, Togo, Benin)
Hot days/nights; heat waves 	• Increased duration of long-lasting heat waves (+6–28 days), with generally a greater increase in the east	• +8–28 days (Burkina Faso, Mali, Niger) • +8–26 days (Ghana, Benin, Togo, Mauritania) • +6–23 days (Nigeria) • +6–18 days (Senegal, The Gambia)

	General future projections by 2050s	Examples (for 2050s)

Rainfall 	• Uncertain rainfall trends with models suggesting:
	  ○ decreased rainfall in western Mali, Senegal, and The Gambia
	  ○ no change or increased rainfall in the rest of the region
	• Likely delay in the spring rainy season onset (about 5 days by 2100)
		• Western Sahel: Most models show decreased rainfall with a range of -16 to +6 percent (Senegal, The Gambia)
		• Remainder of the region: Most models show increased rainfall with a range of 0 to +38 percent (Niger), -1 to +12 percent (Nigeria), -2 to +7 percent (Côte d'Ivoire, Ghana, Togo, Benin), and -3 to +11 percent (Burkina Faso, Mali)

Heavy rainfall 	• Increased frequency and intensity of heavy rainfall events	• Increased frequency (+1 to 43 percent) and intensity (+1 to 12 percent) of heavy rainfall events in much of the region (i.e., Nigeria, Ghana, Benin, Togo, Côte d'Ivoire, Burkina Faso, Mali) • Increased frequency (+16 to 75 percent) and uncertain trends for intensity (-4 to +21 percent in Niger • Uncertain trends in frequency of (-10 to +31 percent) and intensity (-2 to +14 percent) in Senegal and The Gambia
Dry spells 	• Generally increased dry spells in western Sahel (Senegal, The Gambia) • Generally reduced dry spells in the rest of the region	• Change in dry spells, with a range of -4 to +22 days (Senegal, The Gambia, Mauritania) • Change in length of dry spells, with a range of -11 to 0 days (Nigeria) and -8 to +1 days (Côte d'Ivoire, Ghana, Benin, Togo)
Sea level rise 	• Sea level rise of +17 to 45 cm	• +17 to 43 cm (Senegal, Nigeria) • +18 to 43 cm (Ghana, Benin, Togo) • +18 to 45 cm (Côte d'Ivoire)

CLIMATE RISKS BY SECTOR

AGRICULTURE – CROPS, LIVESTOCK, FISHERIES, AND VALUE CHAINS

The unique bioclimatic characteristics of the Sahel, Inland Forests, and Coastal subregions give rise to varied agriculture and livestock production systems that are at risk from climate change in overlapping, yet distinct ways. Weather-related crop and livestock losses that already cause economic losses and undermine food security in the region are expected to increase. Rising temperatures and evaporation rates are likely to increase water stress, particularly during the dry season. Increased rainfall is projected in some areas, although temperature and evaporation trends may counter the rainfall effect such that by the 2050s, water availability in the dry season is decreased compared to the present climate. Projections for increased heavy rainfall events around the region raise the risk of storm and flood damage to agricultural production. (41, 80)

Key impacts: Warming above 2°C will stress crops, potentially decreasing overall cereal yields by about 11 percent. Maize and rice will be especially affected throughout much of the Inland Forests subregion, while millet and sorghum yields could see decreases of 15–25 percent in places like Niger and Burkina Faso.

Key impacts: A rise in sea level of up to 1 meter by the 2050s would inundate 18,000 km^2 of West Africa's coastline, impacting cropland, important transport corridors, and livelihoods.

While much of the climate impact on agriculture may be local, impacts can extend beyond national borders. Decreased and more variable crop and livestock production and changes in livestock movements and fish stocks can have transnational implications for food availability and quality in addition to exacerbating conflict over land and water resources. Weather-induced disruption of transportation networks in one area can also constrain access to agricultural inputs and markets across borders. Climate risks to agriculture combined with rapid population growth may threaten the food security and economies of individual countries. (41)

The table below summarizes the climate risks across the three subregions. It is followed by a more detailed analysis for each subregion.

Climate Stressors and Climate Risks AGRICULTURE	
Stressors	**Risks**
Rising temperatures and evaporation rates	Increased crop failure and reduced grain quality and yields due to heat stress, water stress, heavy rainfall, flooding, erosion, and waterlogging
	Reduced livestock reproduction, growth rates, and milk production due to heat stress (Sahel, Inland Forests)
	Heat stress for farmers and pastoralists and reduced daylight hours available for agricultural work (due to heat)
Increased frequency and intensity of heavy rainfall events	Increased incidence of crop and livestock pests and disease (e.g., locusts, Rift Valley Fever, oil palm fungal diseases)
	Rangeland erosion and degradation, loss of perennial grasses, and diminished dry season grazing potential (Sahel)
	Early drying or loss of seasonal water sources for livestock
Increased rainfall in east and center; reduced rainfall and longer dry spells in western Sahel	Increased food prices, food insecurity, and migration to urban and southern areas
	Increased conflict between pastoralists and farmers due to expanding cultivation and altered pasture mobility patterns (Sahel)
Sea level rise	Disruption of transportation networks and access to agricultural inputs and markets (e.g., flood and landslide damage and destruction of roads and bridges)
	Damage to storage facilities and higher losses of stored crops and seeds (heavy rainfall events can damage stored crops/seeds; increased humidity levels increase risk of fungus growth in stored seeds)
	Loss of coastal agricultural lands to inundation, coastal erosion, and salinization

SAHEL SUBREGION

Crop Production

Agriculture is the predominant livelihood activity in the Sahel, where climate variability and extremes already have significant impact. Crop production is almost entirely reliant on the region's low and highly variable rainfall, making it extremely vulnerable to climate trends. Staple dryland crops include millet, sorghum, and cowpea, while cotton and groundnut constitute major cash crops. Agriculture accounts for 40–50 percent of GDP in Mali, Niger, and Chad, with lower percentages elsewhere in the Sahel. Crops and/or livestock are the principal source of livelihood for more than 70 percent of the population in Niger, Burkina, Mali, and Chad, and more than 50 percent in Senegal and Mauritania. With high dependence on variable agricultural

production, 30 million people in the Sahel face food insecurity and 4.7 million children under five are acutely malnourished. (66, 105)

Research estimates that an increase in temperature of more than 2°C stresses crops and decreases yields by 15–25 percent for millet and sorghum in Burkina Faso and Niger. Dry spells and drought, the largest threats to crops and livestock, could be amplified by increasing temperatures, delayed onset of the rainy season, and drying in the western Sahel (west of 11°W, particularly western Mali, Senegal, and The Gambia). Past periods of low rainfall, including from 1970 to 1990, led agroclimatic zones to shift south, displacing people and agricultural livelihoods. And drought across the Sahel in 2012 affected 24 million people and required significant and ongoing international humanitarian assistance. Increased intensity of heavy rainfall events will exacerbate already dangerous flood impacts that regularly lead to loss of crops and damage to cultivated land and grain stores; 2010 and 2013 were particularly bad years for widespread flooding. Locust outbreaks, devastating for crops, often follow heavy rains and flooding (e.g., 2004), and rising temperatures could shorten insect incubation and maturation periods, leading to increased numbers of locusts and other pests. Changes in temperature and rainfall are also likely to alter the distribution and timing of crop diseases and pests. A hotter, wetter climate, for example, increases the risk of mildew, leaf spot, and bacterial stem and root rot, while aphids, borers, bollworm, beetles, and whitefly thrive in a hotter, drier environment. (22, 42, 66, 86, 90, 103)

In addition to harsh climate conditions, declining soil fertility, small farm size, and low input rainfed production limit available adaptive responses to increasing climate impacts. With few exceptions, soils in the Sahel are low in nutrients, organic matter, and water retention capacity and at high risk of erosion. Already small farm sizes are decreasing further due to population growth (3 percent annually regionwide), which exceeds the rate of currently expanding cultivation. The consequence is increased pressure on arable land, increasing soil degradation, and limited scope for techniques such as fallowing land to preserve and restore soil fertility. Irrigation is extremely limited in the region; in Senegal and Burkina Faso, for example, less than 1 percent of agricultural land is irrigated and in Niger it is just 0.2 percent. (66, 94, 105)

Livestock Production Systems

Livestock production, primarily of cattle, goats, and sheep, is integral to livelihoods across the Sahel, where the sector accounts for more than 30 percent of agricultural GDP. Livestock provide critical sources of meat and milk production, income, investment, credit, and savings, and livestock numbers are increasing. As climate trends make crop production more tenuous, livestock production is expected to replace areas of mixed crop–livestock systems across the region. While typically more resilient to climate variability and extremes than crops, livestock are susceptible to heat stress, which reduces feed intake, reproduction rates, milk production, and longevity. Additionally, livestock are vulnerable to the impacts of temperature and rainfall trends on rangeland productivity, water availability, and pest and disease dynamics. A hotter and drier climate in Mali by 2030, for example, is expected to diminish forage yields by 5–36 percent and livestock weights by 14–16 percent. Meanwhile, hotter and wetter conditions, particularly possible in Niger, are likely to increase the risk of Rift Valley Fever. Moreover, livestock production is increasingly reliant on feed inputs, exposing the sector to the negative impacts of climate trends on crop production. (39, 47 63, 88, 91)

Drought is the most significant risk facing livestock production and may increase, particularly in the western Sahel centered around Senegal. Drought caused the largest impacts to the sector in recent decades, including in 2011–2012 when drought left more than 18 million people across the Sahel, many of them pastoralists and agropastoralists, in need of humanitarian assistance. Drought often occurs in combination with other shocks such as conflict, high food prices, or other extreme weather events. In Niger during 2009–2010, for example, drought followed by heavy rains and flooding led to estimated losses of 39 percent for sheep, 31 percent for goats, and 26 percent for cattle in agropastoral and pastoral areas. Drought also aggravates mortality and morbidity due to livestock diseases, triggers food price spikes, and increases conflicts over rangeland and water resources. (87, 96, 103)

Expanding cultivation, driven by a range of factors, including trends of recovering rainfall (centered around Niger), population growth, access to plows, and cropland degradation, may disrupt traditional livestock migration routes and exacerbate conflicts related to accessing water and rangeland. Historically, pastoralists maximized productivity by migrating herds south during the dry season and north during the wet season, and farmers and pastoralists often worked together (with pastoralists benefiting from grazing of crop residue and farmers benefitting from manure droppings). Land degradation and growing competition over water and land resources, however, are increasing concerns about conflict between the Sahel's farming and pastoralist communities. (88)

INLAND FORESTS SUBREGION

Crop and Livestock Production

Agriculture in the Inland Forests (south of the Sahel) is the main livelihood for the majority of people, although its contribution to GDP varies from 2.5 percent (Equatorial Guinea) to 41 percent (Togo). The agriculture sector mainly comprises smallholders using low-input systems that are almost entirely reliant on seasonal rainfall and highly vulnerable to climate variability and extremes. The main food crops are cereals (millet, sorghum, maize, and rice), cassava, yam, cowpea, and groundnut; the major cash crops are cocoa, coffee, and cotton. The livestock sector is also important for livelihoods, although less so than in the Sahel. (13, 88, 105)

This subregion also faces growing income loss and food insecurity associated with weather and climate impacts. Flooding following heavy rains in Benin in 2013, for example, led to losses of an estimated $20 million of crops and hundreds of livestock. Warming below 2°C accompanied by sufficient rainfall could bring increased sorghum and millet yields (in contrast to decreased yields in the Sahel), but diminished yields for rice and maize. Warming above 2°C is projected to decrease cereal production by 11 percent across the Inland Forests subregion, with maize and rice production and drier areas the most affected. These losses pose a significant threat to food security in places such as Sierra Leone, where rice accounts for 42 percent of caloric intake and is highly sensitive to increased rainfall intensity and pests that thrive in higher temperatures. In contrast to cereals, cassava appears more resilient to climate variability and may become an increasingly important staple. While livestock production systems are more sedentary than in the Sahel, the climate stressors related to heat stress and feed availability are similar. (21, 23, 48, 63, 82)

Inland fisheries

West Africa's inland fisheries are centered around the region's inland deltas, rivers, lakes, and large and small reservoirs. Key fisheries are located around river floodplains (e.g., Senegal, Niger, and Longone-Chari), inland deltas (e.g., the Inner Niger Delta in Mali), and lacustrine wetlands (e.g., Lake Chad). Inland capture fisheries are entirely artisanal and account for about 20 percent of the region's fish production. These fisheries are a critical component of food security, accounting for a substantial portion of animal protein intake. Historically, shifting rainfall patterns have had significant impacts on the region's freshwater fisheries. A decrease in the area flooded around the Inner Niger Delta in Mali during the 1970s and 1980s, for example, led to a decrease in fisheries' productivity. Reduced river flows, particularly likely in Senegal, The Gambia, and Mali, threaten to diminish biodiverse floodplains and prevent seasonal fish migrations critical for feeding and breeding. Rising temperatures alter water quality, nutrient availability, and dissolved oxygen content in water bodies, which can be detrimental to the growth and reproduction of important inland fish species such as characin and perch. Warming water temperatures may also increase stratification of lakes and reservoirs, limiting water circulation important for fisheries' productivity. (51, 88, 114)

COASTAL SUBREGION

Crop Production

Increasing heat stress, inundation, floods, coastal erosion, and salinization of land and water resources pose significant threats to coastal agriculture. Likely rainfall increases throughout much of the coastal area, with the exception around Senegal, also raise the risks of waterlogging and water stress, respectively. Rice, maize, cassava, yam, and tree crops such as cocoa, palm, and cashew are all key crops along the coast, with rice the most rapidly growing staple food in West Africa. Rice is highly sensitive to increased humidity and rainfall intensity and is vulnerable to pests and disease that thrive in warmer, wetter conditions, such as the rice gall midge, rice weevil, and bacterial leaf blight. In low-lying coastal areas, a relatively small rise in sea level can result in extensive land inundation and dispersion of saltwater inland, leading to salinization of land, surface water, and aquifers, all impacting coastal crops. In Senegal, coastal soils too saline for cultivation are already advancing inland, diminishing available arable lands. In Ghana, research suggests that a sea level rise of 30 cm would permanently inundate 20,000 hectares, decreasing coastal farmland by more than 3 percent. A sea level rise of 1 meter, possible by late this century, would inundate 18,000 km^2 of West Africa's coastline, impacting cropland throughout this subregion. (6, 13, 88, 90, 93, 107)

Coastal Fisheries

Sea level rise, warming ocean surface temperatures, and ocean acidification are expected to change the composition, production, distribution, and seasonality of coastal fish populations. Fisheries are important for coastal livelihoods, especially for women who dominate the processing, retailing, and local trading of fish products. Fish provide about 30 percent of the total animal protein intake in the region, with greatest importance in Benin, Ghana, and Sierra Leone, where more than one-half of the population consumes fish products daily. Each year, more than 1.6 million tons of fish are legally taken along West Africa's coast, with an estimated wholesale value of $2.5 billion. While many coastal countries in the region depend on fisheries for their national economies, food security, and foreign revenue, many fish stocks are in a state of decline due to coastal degradation and illegal, unreported, and unregulated fishing. (15, 51, 88, 110)

Climate Stressors and Climate Risks
COASTAL FISHERIES

Stressors	Risks
Rising sea surface temperature	Loss of coastal fish habitat (i.e., mangroves) and food sources (i.e., plankton)
Increased frequency and intensity of heavy rainfall events	Shifts in fish species distributions (poleward and into deeper waters) and productivity due to heat stress and altered ocean pH
	More frequent lost fishing days due to bad weather
Sea level rise	Loss of fisheries-based income and livelihoods
Ocean acidification	Reduced protein intake and nutrition deficits for the human population

Key impacts: Coastal fisheries across the region could see a 26 percent reduction by 2050, with greater losses in Ghana, Côte d'Ivoire, Nigeria, Liberia, Togo, and Sierra Leone.

Climate trends are already exacerbating these nonclimate stressors. Coastal fisheries' productivity depends primarily on coastal upwelling and associated plankton life, with these hydrological dynamics being impacted by warming ocean temperatures and sea level rise. In the productive Canary current along the coast of Senegal and Mauritania, for example, observations suggest that warming since the 1980s has led to decreased primary production. In the Gulf of Guinea, zooplankton biomass during the upwelling season has declined significantly. Rising temperatures and increased pollution from land-based runoff after heavy rains also raise the risk of disease among fish populations. Climate research estimates that coastal fisheries across the region will be reduced by 26 percent by 2050, with greater losses in Ghana, Côte d'Ivoire, Nigeria,

Liberia, Togo, and Sierra Leone. A decline in coastal fisheries will impact livelihoods and food security at both the household and regional level. (54, 63, 88)

AGRICULTURAL VALUE CHAINS

Climate variability and extremes are likely to impact agricultural value chains across components (inputs, production, processing, storage, transportation, and markets). For most small-scale producers, however, the highest risks are concentrated in the production stage of the value chain. This section focuses on climate risks for the small-scale production of three key export crops— shea, cocoa, and oil palm— as well as potential impacts to inputs and postproduction value chain components. (40)

Shea

Global shea production is localized in the West African Sahel, where nearly 2 billion shea trees grow across the savannah from Senegal to South Sudan. Production is largely informal and provides a critical source of jobs and income for an estimated 18 million women living primarily in rural communities. Women collect and process the shea fruit mainly from nurtured wild, rather than cultivated, trees. In Burkina Faso, for example, nearly 2 million shea trees provide an income for about 500,000 women and shea butter is the country's fourth largest export. (61, 102)

Shea trees have high genetic diversity, are well adapted to poor soils and dry environments, are fire-resistant, and have a lifespan of 200–300 years, making them somewhat resilient to climate variability and change. While their resilience is recognized, there is concern that increasing temperatures, potentially reduced rainfall (centered around Senegal), and increasing storm severity will be detrimental to tree productivity, survival, and reproduction. Increasing temperatures and shifting rainfall may lead to decreased tree productivity and a shift in suitable habitat to the relatively cooler and wetter south. In Mali, research demonstrated that most shea producer respondents perceived diminished shea productivity in recent decades and attributed the decline mainly to reduced rainfall. Even though trees are fire-resistant, temperature increase can raise the risk of wildfires, which can damage and destroy flowers, fruits, or the trees themselves. Projections for increased heavy rainfall frequency and intensity elevate the risk of tree damage and flowers dropping during high winds and heavy rains. Flooding can also damage tree roots and reduce fruit quality. There is additional concern that traditional methods of processing shea, which require large quantities of water and wood, may be impacted, as temperature and rainfall patterns impact water and wood availability and quality. (61, 88, 102)

Beyond climate risk, maintaining shea parklands with today's land use pressures has proved challenging. Deforestation and the expansion of cultivated agriculture, mining, and road networks are infringing on shea habitat. The slow maturation of the tree (full maturation at 45 years) and low survival rates for young trees have proved to be disincentives to investing in shea regeneration. (102)

Cocoa

About 70 percent of the world's cocoa is produced in West Africa, mainly by smallholders in Côte d'Ivoire, Ghana, Nigeria, and Cameroon. Côte d'Ivoire and Ghana alone cultivate more than one-half of the world´s cocoa. Sierra Leone, Togo, Liberia, and Guinea produce cocoa at smaller scales. An increasing area under cocoa cultivation, often at the expense of natural forests, has led to rising production in recent decades (although yields remain low at 300–600 kg per hectare). Major yield constraints include pests and disease, aging cocoa trees, and lack of inputs and land tenure security. Heat stress, damage from flooding and soil salinization, and land loss from coastal erosion will further diminish areas suitable for cocoa production by up to 50 percent by the 2050s, with significant local and global implications. (53, 80, 112)

In the 1970s and 1980s, reduced rainfall constrained yields, making important cocoa-producing areas in eastern Côte d'Ivoire and elsewhere unsuitable for production by the 1990s. While this trend has halted and possibly even reversed with increased rainfall in cocoa-producing areas since the early 2000s, increasing

temperatures and evapotranspiration could lead to similar deterioration in climate suitability for cocoa production in coming decades. Decreased water availability may not be a factor in normal years but increases the risk for water stress and crop losses in dry years. (80)

Key impacts: **West Africa's cocoa producing nations – especially Côte d'Ivoire, Togo, and Guinea – will lose substantial surface area suitable for cocoa cultivation due to rising temperatures.**

Increased temperatures are expected to lead to a decrease in the area of high climate suitability in all cocoa-producing countries except Cameroon. The areas most at risk of decreasing suitability are where maximum temperatures already reach the thresholds for cocoa (around 36°C). These areas are near the forest-savanna transition in Nigeria, Togo, and eastern Côte d'Ivoire; northern Liberia (where the country's cocoa production is currently concentrated); and parts of Guinea and Sierra Leone adjacent to northern Liberia. Côte d'Ivoire, Nigeria, Togo, and Guinea are each expected to lose more than 50 percent of land with high climate suitability for cocoa. The least at-risk areas are in the southern parts of Cameroon, Ghana, Côte d'Ivoire, and Liberia, where temperature is moderated by the ocean and elevation (Cameroon) and maximum temperatures are less likely to exceed 36°C. This differentiation in climate vulnerability may lead to shifts in cocoa production that could offset some of the climate-related losses but increase deforestation in areas where cocoa plantation is increased to maintain cocoa productivity. (53, 80)

How climate trends will impact pest and disease incidence is not well documented. Warming temperatures, however, could lead to an increase in diseases such as the cocoa swollen shoot virus, Phytophthora pod rot, and mirid insects; mirid insects alone cause annual cocoa crop losses of 25 percent in Ghana and 30–40 percent in Côte d'Ivoire. (112)

Oil Palm

Native to West Africa and naturally abundant in the region's tropical forests, oil palm has long been used domestically and is an increasingly important crop since the 1960s. Oil palm production is expanding across the Coastal and Inland Forest subregions, with Nigeria the world's fifth largest producer and Ghana, Côte d'Ivoire, Cameroon, Benin, Guinea, Liberia, Sierra Leone, Senegal, and Togo among the top 28 producers globally. Despite increasing production, the demand for palm oil in West Africa exceeds its supply and the region is a net importer of palm oil. Côte d'Ivoire is the region's only net exporter and 75 percent of its export remains in West Africa. Multinational companies are demonstrating increasing investment interest in West African palm oil production amid concerns about the forest degradation impacts of large-scale commercial production. The region produces crude palm oil, palm kernel oil, and other palm oil products. (79, 100)

Oil palm is at risk from rising temperatures that may inhibit productivity and increase fungal disease incidence and outbreaks that damage leaf growth. Ideal average maximum and minimum temperatures are 30–32^{o}C and 21–24^{o}C, respectively, with tree growth negatively impacted by warmer temperatures. While more research is needed, the concern is that increased temperatures and humidity may increase fungal growth at the same time that heat stress diminishes trees' disease resistance. Fusarium vascular wilt is the most damaging oil palm disease in West Africa and can lead to acute wilt, with death in a few weeks, or chronic wilt that leads to stunting. Other palm fungal diseases include ganoderma rots, *Thielaviopsis paradoxa*, and *Ceratocystis paradoxa*. Along the coast, sea level rise will lead to inundation and soil salinization, making low-lying areas unsuitable for oil palm production. Reduced rainfall and longer dry spells may become limiting factors for oil palm in the west of the region. (71)

Climate risks for agricultural inputs and postproduction processes

In addition to risks for production, there are likely climate impacts to the input, processing, storage, and transportation components of agricultural value chains. Decreasing crop productivity due to heat and/or water stress and changing pest and disease dynamics can lead to changes in demand for and availability of

agricultural inputs, including seed varieties, fertilizers, and pesticides. And land and water resources (inputs), already limited due to agricultural expansion and population growth, are likely to face increasing pressure as climate trends constrain productivity. Postharvest, agricultural products face additional spoilage risk related to increasing temperatures, humidity, pests, and disease. Product processing requiring water, including shea, is at risk from diminished or irregular water quality and/or quantity. Meanwhile, processing and storage facilities are increasingly exposed to flood and storm damage from intensifying heavy rainfall and extreme weather events. (40)

Key impacts: **Increased rainfall intensity threatens the West-East Trans-Sahelian highway (which connects Dakar to Ndgamena), while sea level rise, coastal erosion and inundation jeopardize roads along the Trans-Coastal highway between Dakar and Lagos.**

Transportation routes are critical for input and postharvest value chain components. Roads around the region may become seasonally or permanently impassable due to increased flooding and landslides and sea level rise along the coast. Unpaved feeder roads in rural areas are particularly susceptible to flooding that prevents the movement of agricultural goods. With many agricultural communities lacking an interconnected road network, an impassable road in one location can cut off access to large areas. In places such as Liberia and Sierra Leone, some roads already become impassable during the peak of the rainy season. In mountainous areas, including the Guinea Highlands, heavy rains increase the risk of landslides that damage and close roads and bridges. In the Sahel, projected increasing rainfall (centered around Niger) and rainfall intensity pose a particular challenge to the West-East Trans-Sahelian highway (Dakar to Ndgamena) and surrounding roads, as these have not been built to withstand heavy rains or flooding. Along the coast, parts of the Trans-Coastal highway between Dakar and Lagos are at risk from coastal erosion and inundation. In Togo, parts of the highway have already been rebuilt twice due to coastal erosion. (41, 110)

WATER RESOURCES

Warming temperatures, shifting rainfall patterns, and sea level rise threaten to diminish water quality and alter water availability with carry-on implications for agriculture, hydropower, and commercial and domestic water use across the region. West Africa is highly dependent on transboundary water resources, with 11 major transboundary river basins. The Niger River Basin, for example, extends across 10 countries from its source in southeastern Guinea. On average, countries are reliant on a source outside their borders for more than 40 percent of water supply, with the exception of island nations. More than 90 percent of the water supply in Mauritania and Niger and 50 percent in Mali and Chad comes from outside each country's boundaries. (62, 89)

Key impacts: **West Africa's major river basins are expected to see declines in river flow. By 2050, river flow in the Senegal and Gambia will decrease by 8 percent and 22 percent, respectively. Projected impacts for the Niger River vary, but models most suggest declines in average annual inflow by the 2050s. The Fouta Djallon Highlands, West Africa's "water tower," are expected to experience rainfall reductions of up to 26 percent by 2100.**

The region's river flow is linked to both rainfall and land use/land cover patterns. In the region's major river systems, river flow decreased by 20–60 percent during the 1970s and 1980s due to reduced rainfall and increasing water demand for domestic, agricultural, and industrial uses. Some rivers have shown recovered flow since 1994 (e.g., the Niger River), with recovery linked to both rainfall and increased runoff from expanding cultivation. Increases in heavy rainfall events across the region are likely to lead to more rapid runoff and flooding that can reduce water quality, groundwater recharge, and basin water-holding capacity (due to sedimentation) across borders. These factors, combined with increasing water demand, are expected

to increase water scarcity, which could raise tensions over water resources among water users within and across national borders. (89, 93)

Climate stressors come in addition to the major drivers of water availability and quality— population growth, urbanization, agricultural development, and land use change. The table below summarizes climate risks to water resources across West Africa, and is followed by more detailed analyses for each subregion. (13, 63)

Climate Stressors and Climate Risks WATER RESOURCES	
Stressors	**Risks**
Rising temperatures and evaporation rates	Diminished or more variable river flow, water availability, and groundwater recharge, affecting hydropower, irrigation, industrial, and domestic sources
Increased frequency and intensity of heavy rainfall events	Early drying or loss of seasonal water sources
	Diminished water quality due to contamination and siltation from rapid runoff and flooding and warmer surface waters that accelerate bacterial growth
Increased rainfall in east and center; reduced rainfall and longer dry spells in western Sahel	Increased flood and siltation damage to water and sanitation, hydropower, and irrigation infrastructure
	Salinization and pollution of coastal aquifers
Sea level rise	Increased tensions over water access where availability per capita diminishes

SAHEL SUBREGION

Water scarcity is a key challenge in the Sahel, where drought and variable rainfall regularly lead to food insecurity, health impacts, displacement, and migration. The region's water supply is highly seasonal, concentrated in sparse river networks, and often transboundary, creating significant management challenges. Water supplies are mainly undeveloped, further limiting availability. Increasing demand and rainfall variability have led to decreased flows, water shortages, and depleted reservoirs in many areas. The Lake Chad Basin holds the largest lake in the Sahel and is home to 38 million people. The lake has shrunk to 3 percent of its original area since the 1960s due to increased water use (e.g., population growth and dams) and rainfall variability. As a result, disputes over access to water, fisheries, and ownership of land exposed by receding waters have increased dramatically. Boko Haram has exploited this instability and the combination of environmental stressors and conflict has displaced 2.4 million people. With increasing evaporation rates and ongoing unsustainable water use, concerns persist that Lake Chad and other surface water bodies are in danger of being reduced to seasonal waterbodies or running dry entirely. Mali's Lake Faguibine, for example, has been dry or nearly dry since the 1970s, forcing more than 200,000 farmers and fishermen to abandon their livelihoods. (35, 37, 85, 87, 88, 89)

Temperature, rainfall, and evaporation trends threaten to further restrict surface and groundwater availability. River basins such as the Senegal, The Gambia, Western Niger, and Upper Volta are particularly vulnerable to reduced flows. Research estimates that river flow in the Senegal and Gambia will decrease by 8 percent and 22 percent, respectively, by 2050. The Bani River Basin of Mali is also projected to experience substantially reduced flows. Countries that have low, unevenly distributed resources that currently meet water needs per capita, such as Burkina Faso, Mauritania, and Niger, are expected to experience water vulnerability or stress[1] by 2025. (9, 63, 89)

[1] Water vulnerability is defined at 1,700–2,500 m^3 of water per capita annually; water stress is 1,000–1,700 m^3.

Already insufficient drinking water supplies are under increasing pressure from temperature and rainfall trends that affect water availability and quality. For rural populations living farther away from major river systems, access to drinking water continues to be a significant challenge. For example, in Niger, just 49 percent of the rural population has access to an improved water source, while 48 percent walk 30 minutes or more for drinking water. Reduced water availability during dry spells leads to increased effort for water collection, often meaning that women and children walk longer distances for water with carry-on impacts for livelihoods and health. Limited surface water makes groundwater a primary source of water for many people in the region, but some aquifers have slow recharge rates, limiting their viability for increased use over the long term. (43, 87, 89)

INLAND FORESTS SUBREGION

In the Inland Forests, climate trends and population growth are expected to lead to water vulnerability or stress by 2025 in countries including Benin, Côte D'Ivoire, Ghana, and Togo. Meanwhile, increased heavy rainfall events are likely to exacerbate existing water contamination issues from oil and mining industries in the Niger Delta and from the gold industry in Burkina Faso, Côte d'Ivoire, Ghana, and Mali. The gold industry has already been linked to mercury and cyanide contamination of rivers, drinking water, and fisheries. (49, 89)

River flow projections for the Inland Forests subregion vary by basin. The Fouta Djallon Highlands of Guinea, known as the water tower of West Africa, are expected to experience rainfall reductions of up to 26 percent by the end of this century. In Liberia, runoff in the St. Paul River Basin is projected to decrease 1–25 percent by the 2020s, impacting hydropower production at the Mount Coffee power plant and the water supply for the capital, Monrovia. Any decrease in water availability is especially significant in places like Sierra Leone, where 40 percent of water points already do not provide sufficient water during the dry season. With expected increased rainfall over the main Niger Basin and the main Volta Basin, river flow may increase, but increased evaporation is likely to offset some of this gain or even lead to decreased river flow in the Volta. (50, 55, 63, 65, 89, 109)

COASTAL SUBREGION

Rising sea levels are the key threat to coastal surface and groundwater sources, although water resources also face the impacts of increasing temperatures and flooding similar to those elsewhere in West Africa. Coastal aquifers in West Africa experience the dual threats of high rates of groundwater extraction and sea level rise. In these aquifers, a freshwater layer typically floats on top of a denser saltwater layer, with a saline area where the two layers meet. A rising saltwater layer and diminishing freshwater layer lead to salinization, forcing people to switch to other water sources. Increasing upstream surface water withdrawals and/or drying conditions diminish groundwater recharge near the coast and increase the threat of aquifer salinization. There is further risk that increasingly heavy local rainfall and flooding can wash pollutants from sewage and industrial sources into coastal aquifers. Coastal aquifers are generally linked, so changes in one location impact freshwater availability across the aquifer system. Most coastal towns and all major coastal cities depend on groundwater for domestic and industrial use and aquifers are at substantial risk of salinization and pollution. In Dakar and its suburbs, for example, about 80 percent of the city's water comes from a coastal aquifer that is increasingly affected by salinization and pollution, posing substantial health threats to the population. (63, 74, 92)

ECOSYSTEMS

West Africa's remarkably diverse ecosystems span coastal mangroves, rainforests, savannahs, inland deltas, and the near desert conditions of the northern Sahel. Ecosystems face increasing land degradation from warming temperatures and altered rainfall patterns, while species face heat and water stress and altered habitat suitability. Invasive species are often more adaptable to increased temperatures and variable climate conditions and can establish in (and sometimes even prefer) degraded lands. Climate trends may

drive native and invasive species range shifts within and across national borders. Wildfires can also move across borders, with detrimental impacts for land and water resources and air quality. Coastal habitats are at additional risk of inundation, coastal erosion, and salinization.

Key impacts: The region's key ecosystems are under threat from climate change and variability. Some 2,300 km² of the Guinean Forests of West Africa Biodiversity Hotspot are less than 1 meter below sea level and could experience inundation as a result of projected sea level rise.

The table below summarizes climate risks to ecosystems across West Africa, followed by a more detailed analysis of climate risks to ecosystems for each subregion. (73)

Climate Stressors and Climate Risks ECOSYSTEMS	
Stressors	**Risks**
Rising temperatures and evaporation rates	Increased heat and water stress for plant and animal species, including reduced productivity of inland fisheries
	Reduced and shifted ranges for native species and expanded ranges for invasive species, leading to biodiversity loss
Increased frequency and intensity of heavy rainfall events	Increased wildfire frequency and severity
	Increased erosion and land degradation from heavy rainfall events, particularly following longer dry spells
Increased rainfall in east and center; reduced rainfall and longer dry spells in western Sahel	Diminished vegetation cover where rainfall is reduced
Sea level rise	Loss of mangrove forests, river deltas, and low-lying coastal areas to inundation, coastal erosion, flooding
Ocean acidification	Salinization of coastal land, rivers, and wetlands
	Loss of tourism potential as wildlife and habitats are impacted

SAHEL SUBREGION

The Sahel's savannahs, grasslands, wetlands, lakes, and rivers host a diversity of plant and animal species that provide food, medicine, biomass energy, and income. Recurrent drought, deforestation, erosion, invasive species, and poaching, however, have degraded this subregion in recent decades. Significant cropland and settlement expansion has further replaced biodiverse woodlands and grasslands. The "regreening" of the Sahel following the droughts of the 1970s and 1980s returned some tree cover (mainly of more drought-tolerant and nonnative species) but also coincided with an expansion of the Sahara that has been linked to global climate trends. The rainfall decline from the 1970s to 1990s led the Sahel ecological zone to shift 25–35 km southward, resulting in loss of grassland and acacia ecosystems and arable land. This shift prompted outmigration from the northern Sahel and the consequent expanded conversion of natural areas to agriculture in the south. Large ungulate herds and endangered species such as the Sahara cheetah, northern giraffe, and lion, once common, are now largely absent outside of protected areas (e.g., Aïr and Ténéré National Nature Reserves in Niger and Sahel Partial Faunal Reserve in Burkina Faso). (10, 13, 36, 84)

During the dry season, increased evaporation rates threaten to dry out habitat and water resources vital to the subregion's flora and fauna, including migratory bird species that use the southern Sahel as a stopover point before crossing the Sahara Desert. Inland wetlands in the Sahel support critical habitat for fish, migratory birds, and wildlife. Communities also depend on wetlands for farmland and fisheries. And while heat stress is a looming risk for many species, savannah chimpanzees in Senegal already experience

physiological stress responses to seasonal heat and lack of water, which are likely to be exacerbated by climate trends. Increased temperatures and altered rainfall regimes exacerbate nonclimate stressors that are negatively impacting Sahelian ecosystems, including overextraction of water, increased pollution and sedimentation, and dam building. (63, 88, 113)

INLAND FORESTS SUBREGION

The Inland Forests ecosystems provide critical habitat and are a source of food, fuel, and income. The Guinean Forests of West Africa Biodiversity Hotspot has high levels of species richness and endemism, with about 9,000 plants, 917 birds, and 416 mammals. With five critically endangered primate species and an additional 21 endangered, these forests are among the world's top priorities for primate conservation. While this area remains critical for biodiversity, it has been substantially altered and degraded in recent decades by agricultural expansion and overexploitation. Crop area in West Africa doubled from 1975 to 2013 to cover 22 percent of the land surface, while forest cover reduced by 37 percent, with higher losses in Guinea, Sierra Leone, Nigeria, and Ghana. Household dependence on firewood and charcoal and the expansion of timber harvesting, oil extraction, and mining activities are other significant contributors to the loss and pollution of forested areas. This subregion is now mainly a human-dominated landscape of cultivated and fallow fields and settlements surrounding forest remnants. (11, 12, 13, 88)

The subregion's remaining forests are key to providing and regulating water resources across West Africa, but ecosystem services are increasingly threatened by land degradation and tree mortality linked to heat and water stress, forest fire, and heavy rainfall events. Fires that spread from agricultural burning already drive the loss of forest cover, particularly in Ghana and Côte d'Ivoire. Accelerated erosion and land degradation related to heavy rainfall increase siltation of wetlands, rivers, and reservoirs, such as Ghana's Lake Volta, which in turn adversely impacts fish habitat, growth, and reproduction. Assessments show varying levels of species vulnerability to climate trends but suggest that some plant species, including wild relatives of chickpea and Bambara groundnut, will dramatically decline. Tropical flora and fauna are particularly sensitive to warming due to limited existing seasonal and interannual temperature variability. There is further concern that human responses to climate trends could accelerate agricultural expansion and deforestation, directly impacting biodiversity and ecosystem function. (2, 5, 11, 56, 81)

COASTAL SUBREGION

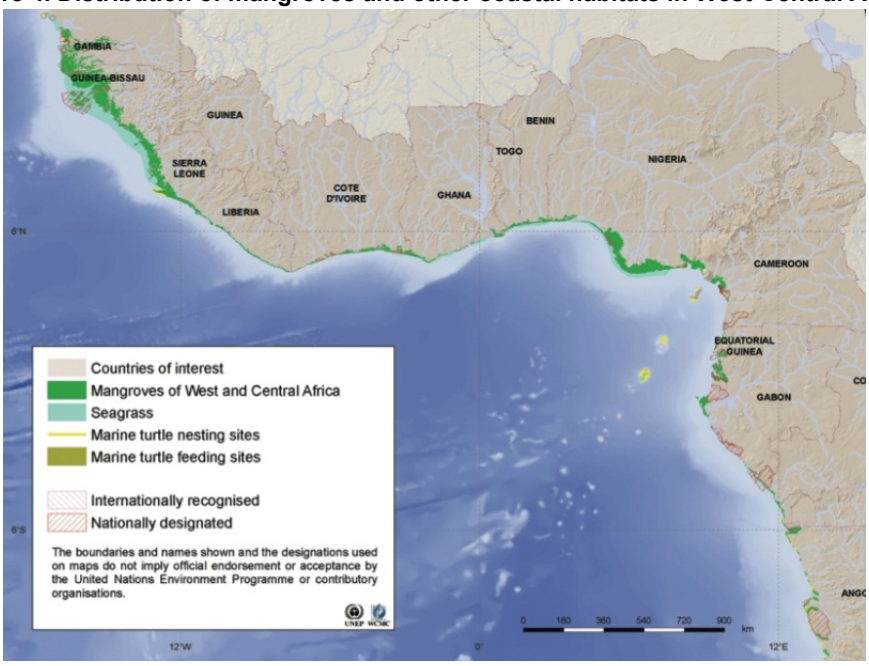
Coastal mangroves, estuaries, and wetlands provide an array of ecosystem services, including water filtration, fish and wildlife habitat, and shoreline protection. Coastal waters are home to more than 1,000 fish species, several cetacean species, and five endangered sea turtle species. Rising sea levels accentuate coastal erosion, damage wildlife habitat (e.g., inundating river deltas), and harm mangrove forests. This subregion contains the coastal area of the Guinean Forests of West Africa Biodiversity Hotspot; approximately 2,300 km^2 of this hotspot are less than 1 meter above sea level and an additional 600 km^2 are below 2 meters above sea level. The areas of the hotspot most vulnerable to sea level rise are southern Sierra Leone, southwestern Nigeria, and western Cameroon, and the lower stretches and estuaries of major rivers, including the Rokel (Sierra Leone), Sanaga (Cameroon), and Niger (Nigeria). (11, 106)

Combined sea level rise and warming sea surface temperatures threaten mangroves throughout the Coastal subregion (Figure 4). West Africa's mangroves comprise 13 percent of mangrove forests globally and cover more than 2.4 million hectares, including in Nigeria and Guinea Bissau, two of the world's most mangrove-rich countries. Mangroves play critical roles in trapping sediment along the coast and buffering against storm surges. The forests provide vital breeding grounds and nursery habitat for the region's coastal and marine fishing industry as well as habitat for birds, mollusks, crustaceans, and other invertebrates. Communities depend on mangroves for fuelwood, building material, honey, fodder, and traditional medicines. Overexploitation, coastal development, and sea level rise diminished mangrove forests in the region by 20–30 percent in the last quarter century, with even higher losses of 40 percent and 60 percent in Nigeria and

Senegal, respectively. In Cameroon, sea level rise led to dieback of the seaward edge of mangroves at rates of up to 3 meters per year from 1975 to 2010. (63, 95, 110)

Sea level rise and mangrove decline, combined with the impacts of dams and ports that suppress sand replenishment, are leading to coastal erosion, which has occurred at up to 30 meters in a given year in some locations. This erosion of the coastline diminishes key habitat for species such as sea turtles and further exposes coastal forests, agricultural land, and human populations to sea level rise and storm surges. Coastal species, such as migratory shorebirds and amphibians, are also impacted by rising land and ocean temperatures that affect reproduction and food availability. Intensifying heavy rainfall events are likely to exacerbate the domestic and industrial pollution that already affects large areas of the coast, including the Korle Lagoon (Accra), Lagos Lagoon, and Ebrie Lagoon (Abidjan). (11, 33, 77, 108)

Figure 4. Distribution of mangroves and other coastal habitats in West-Central Africa



Source: USAID 2014f.

HUMAN HEALTH

Increased risk of food insecurity, flood- and drought-related mortality and displacement, heat stress, and infectious disease are the most pressing climate-related challenges to human health in West Africa. Food security in particular has a transnational dimension given projected decreases in regional agricultural production and increases in global food prices and price volatility. West Africa is exposed to global food price fluctuations as it imports key staples, including 40 percent of rice regionally, with rice imports accounting for 70 percent of consumption in Senegal. The Ebola crisis in 2014, while not linked to climate change, illuminated the devasting impacts of emerging infectious diseases as well as the transnational implications of disease outbreaks. The crisis-related border closures and transport restrictions raised food prices and decreased food availability. Health issues are often exacerbated by weak health care systems, poor hygiene and sanitation practices, and dispersed populations. With many health impacts similar across the region, specifics for subregions are not elaborated. (17, 69, 73)

Heat stress and associated risks of cardiovascular and respiratory disease are likely to increase due to longer and hotter heat waves in addition to overall warmer temperatures, particularly in the already hot Sahel and among children and the elderly. High temperatures are already associated with increased mortality in Ghana and Burkina Faso and heat-related mortality is projected to increase across the region through this

century. Evidence also exists of increasing dust during the harmattan in Nigeria, which may be linked to warming temperatures and increased evaporation over the Sahara. Diminished air quality from dust or increasing wildfires exacerbates cardiovascular and respiratory diseases with cross-border health implications. (63, 68, 116)

Key impacts: Rising temperatures and increased rainfall variability will lead to shifts in the distribution, timing, and severity of climate-sensitive diseases like meningitis and malaria. Meningitis occurrence appears to be expanding southward from the Sahel. Areas of endemic and seasonal malaria risk, however, are projected to shrink across the region where temperatures will exceed mosquitoes' thermal tolerance, particularly in Sahelian countries where warming is expected to occur at faster rates.

The incidence and distribution of vector- and waterborne diseases are also likely to be affected by warming temperatures in combination with more frequent and intense heavy rains. Cholera outbreaks, recurrent in the region, are linked to heavy rains and flooding, which bring contaminated water and sewage into sources used for drinking, bathing, and washing. Diarrheal disease also increases under flood conditions and is already a leading cause of undernutrition mortality in children. Increasing the risk factor for waterborne disease in West Africa is the fact that in USAID/West Africa's 21 target countries, 34 percent of the population (117 million people) lack access to safe drinking water and 73 percent (253 million) lack access to sanitation. Temperature and rainfall trends will also lead to shifts in the distribution, timing, and severity of climate-sensitive diseases like meningitis and malaria. Warming trends appear to be expanding meningitis occurrence southward from the Sahel. Areas of endemic and seasonal malaria risk, however, are projected to shrink across the region where temperatures will exceed mosquitoes' thermal tolerance, especially in Sahelian countries, where warming is expected to occur at faster rates. Malaria may expand in the region's highland areas, such as in Cameroon, Gabon, and Equatorial Guinea. (46, 96, 97, 98)

Climate Stressors and Climate Risks HEALTH	
Stressors	**Risks**
Rising temperatures and increased heat wave duration	Increased heat wave and heat stress-related mortality and morbidity (e.g., cardiovascular and respiratory diseases, heat exhaustion, heatstroke)
Increased frequency and intensity of heavy rainfall events	Diminished food and nutrition security due to gradual decreases in agricultural productivity and extreme weather and climate events
	Increased incidence of waterborne diseases, such as cholera, meningitis (dust-related), and leishmaniasis (sand fly vector)
Increased rainfall in east and center; reduced rainfall and longer dry spells in western Sahel	Increased incidence of malaria in Cameroon and Equatorial Guinea highlands; similar or decreased incidence elsewhere
	Increased flood-related mortality, morbidity, and displacement
Sea level rise	Increased flood damage to health care facilities

Climate trends have other implications for flood- and drought-related mortality, displacement, and food insecurity. In recent years, flooding during the wet season has been frequent and severe. Floods in 2017 led to death, displacement, and loss of livestock and crops across the region. Niger alone incurred 56 deaths and more than 206,000 people were affected, including through damage to 12,000 homes and the loss of 16,000 livestock. The 2009 floods affected 600,000 people in Burkina Faso, Ghana, Niger, Senegal, and Sierra Leone. Increased temperatures, reduced rainfall (centered around Senegal), and a greater proportion of rainfall coming in heavy rainfall events threaten to exacerbate drought conditions, with substantial impacts on food security and nutrition. During the 2011–2012 drought, for example, more than 18 million people in

the Sahel faced severe food shortages, with more than 1 million children at risk of severe acute malnutrition. Projections for increased rainfall (centered around Niger) may bring some drought relief but could be offset by rising temperatures and evaporation. Niger remains highly vulnerable to drought, having experienced 13 drought events from 1900–2013, affecting 23.7 million people and leading to 85,000 deaths. Aside from extreme events, food and nutrition security are at risk from gradually diminished agricultural productivity as a result of climate trends. (57, 67, 76, 115)

Along the West African coast, an estimated 5 million people live between 0–3 meters above sea level. Coastal erosion and flooding, projected to increase with sea level rise, are already displacing coastal households and communities. In addition to displacement, coastal flooding affects more than 500,000 people annually through diminished water quality, increased disease risk, and damage to water, health, and sanitation infrastructure. (88, 107)

Climate and environment-related migration

Climate change is a growing driver of human migration, with implications for the health and wellbeing of migrants and sending and receiving communities. Diminished agricultural productivity, coastal erosion and inundation, and flood and drought occurrence have local and transnational impacts as people respond by moving within countries and across borders. West Africa already has the highest number of intraregionally mobile people of any region in the world. Migration has long been a livelihood strategy across the region and is key to diversifying household incomes. Remittances from migrants have been used as a source of investment in adaptation measures, including for agricultural productivity. Not all migration improves resilience, however; some households use migration simply to survive and as a last-resort coping strategy. Additionally, migrants frequently reside in marginal lands (such as coastal or riverine flood zones) or urban heat islands that are becoming more dangerous due to climate trends. As climate stressors increase pressure on local livelihoods, there is also a risk that those who are able will migrate, leaving the most vulnerable behind in increasingly unviable circumstances. In destination communities, the influx of migrants can increase pressure on local land and water resources and overwhelm health and sanitation services with the risk of impacting food security, water availability and quality, and health care access. (24, 63, 115)

URBAN AREAS

While West Africa's population is still majority rural, the urban population increased from just 8 percent in 1950 to nearly 44 percent in 2015. The Sahel droughts of the late 1960s through the 1980s initiated extensive rural to urban migration and climate factors continued to contribute to the movement of people to inland and coastal cities in recent years. Some cities, such as Ouagadougou and Mbouda, are growing at rates of more than 7 percent annually. Nigeria, with more than 80 million people living in cities, has the world's ninth largest urban population. This rapid urban growth is expanding informal settlements in low-lying areas, where vulnerable residents are at risk of increased flooding and sea level rise, water scarcity, and heat extremes that impact human health and safety, economic activities, and urban infrastructure and services. Consistent with trends across Africa, climate vulnerability levels are very high among West Africa's rapidly growing urban populations. (13, 25, 63, 88, 104)

Key impacts: Rising temperatures will increase the number of hot days and hot nights across the region, with particularly acute impacts in rapidly growing cities. Nigeria's urban population of more than 80 million will experience more intense urban heat islands, with those living in slums or informal settlements most affected.

Temperature and rainfall trends threaten urban areas across the region, compounding problems of inadequate water supply, sanitation, and disaster risk management. With vast expanses of impermeable

surfaces and limited stormwater management, urban areas are quick to flood, putting lives and infrastructure at risk. In June 2015, flash flooding after heavy rains in Accra displaced more than 9,000 people, killed more than 200, damaged infrastructure, and exacerbated an ongoing cholera outbreak. While flood risk is growing across the region, dry season water scarcity for urban areas is also of concern as water availability is impacted by the combination of climate (e.g., increased evaporation, more rapid runoff) and nonclimate (increased demand, land use change) factors. Cities in the Sahel are particularly at risk from dry season water shortages. In the 2016 dry season, Ouagadougou's 2 million residents suffered water shortages and cuts to water services lasting up to seven days. (4, 75)

Climate Stressors and Climate Risks URBAN AREAS	
Stressors	**Risks**
Rising temperatures **Increased frequency and intensity of heavy rainfall events** **Increased rainfall in east and center; reduced rainfall and longer dry spells in western Sahel** **Sea level rise**	Intensified urban heat islands, leading to heat wave and heat stress-related mortality and morbidity (i.e., cardiovascular and respiratory diseases, heat exhaustion, heatstroke) and overheated buildings
	Urban industrial and residential pollutants increasingly washed into water supplies; diminished water quality and/or availability; increasing risk of waterborne disease and water shortages
	Increased flood and landslide damage to urban infrastructure (i.e., buildings, water and sanitation, transportation, telecommunications, and power)
	Disruption of urban transportation networks (road, port, rail, and air) due to heavy rainfall events and subsequent flooding
	Increased pressure on often inadequate urban stormwater management systems
	Increased population displacement, particularly from informal settlements in floodplains and adjacent to the coast
	Loss of coastal cities' land base, water resources, and infrastructure to inundation, flooding, saline intrusion, and coastal erosion

Urban populations are also exposed to growing urban heat island effects, which can raise temperatures well above those of surrounding rural areas. Urban heat extremes are associated with increased mortality from cardiovascular and respiratory diseases, heatstroke, and dehydration. Overheated buildings are already increasing health risks in the region, including a rising risk of heat exhaustion among school children in places such as the Cameroon cities of Yaoundé and Douala. (16, 60, 72)

THE CASE OF COASTAL CITIES

Along West Africa's rapidly urbanizing coast, 12 cities have a population of more than 500,000 and the expanding urban corridor along the 500-km coastline from Accra to the Niger Delta has the highest population density in the region. These coastal cities are highly vulnerable to impacts from sea level rise and heavy rainfall, including flooding and inundation, coastal erosion, and salinization of coastal aquifers. Flooding leads to widespread water contamination, as less than 10 percent of urban areas along the coast have access to sewerage services. In Lagos, where an estimated 70 percent of the 21 million residents live in informal settlements, vulnerable people face regular flood damage to their homes. Annual damages from coastal flooding in the region are expected to reach $11 billion by the 2050s. Sea level rise of 1 meter, possible by 2100, would inundate substantial parts of Lagos, Port Harcourt, Abidjan, Grand Bassam, Sassandra, and San Pedro. (1, 7, 13, 93, 107, 108, 110)

Coastal erosion reaches up to 23–30 meters annually in some areas and is projected to intensify due to sea level rise and heavy rainfall in addition to nonclimate drivers. Côte d'Ivoire's Abidjan harbor has seen some of the highest erosion rates; greater Dakar (home to 90 percent of Senegal's manufacturing and industry), Conakry, Freetown, Monrovia, Accra, and Cotonou are other hotspots. In Keta (Ghana), extensive coastal

erosion has displaced more than one-half of the city's population. Coastal urban water supplies are threatened by saltwater intrusion into coastal surface waters and aquifers and by increasingly heavy and frequent rainfall events that wash urban pollution into water sources. Ports and offshore oil production and exploration are also associated with coastal cities and are at risk from sea level rise. (20, 93, 107, 110)

ENERGY

Population, economic, and urban growth are contributing to increasing power demand in West Africa, where energy supply is in constant shortage. The lack of reliable electricity is a key constraint to livelihoods and economic growth. With an estimated 50 percent or more of the region's hydropower potential untapped, hydropower could meet the region's entire electricity demand with substantial investment and cooperation. Increased evaporation, more extreme heavy rainfall events, and reduced river flow in some areas, however, are projected to increase flood damage to dams and turbines, reservoir evaporation and siltation, and river flow variability, creating challenges for hydropower development. (59)

Key impacts: **Variable hydrological conditions will continue to challenge electricity output throughout West Africa. By 2050, the combined effects of climate and development will reduce hydropower potential in the Volta River Basin by nearly 50 percent.**

Climate Stressors and Climate Risks ENERGY	
Stressors	**Risks**
Rising temperatures and evaporation rates	Decreased or more variable water availability for hydropower generation and thermal power generation cooling systems
Increased frequency and intensity of heavy rainfall events	Reduced hydropower reservoir capacity due to increased sedimentation
Reduced rainfall and longer dry spells in western Sahel	Increased damage to hydropower infrastructure (dams and turbines) from flooding and river sediment loads
Sea level rise	Increased damage to power transmission and distribution infrastructure from surface and seawater flooding, landslides, coastal erosion, and storm surges, leading to outages or shortages

West Africa has very low electricity access rates, particularly outside urban areas and rural centers, and electricity is some of the most costly in the world. Access rates range from below 20 percent in Liberia, Niger, and Burkina Faso to more than 60 percent in Senegal and almost 80 percent in Ghana. In Nigeria, 60 percent of the population has electricity but this leaves 74 million Nigerians without electricity in the populous country. Where there is electricity, access is unreliable as power outages are common. The West African Power Pool (an agency of ECOWAS) is working to develop power generation and transmission infrastructure, including an integrated regional power market, to make electricity more accessible, reliable, and affordable. The market would link countries with low energy production to the region's main producers—Nigeria, Ghana, and Côte d'Ivoire. Smaller-scale investment is targeting development of off-grid solar, wind, and micro-hydro development around the region. (45, 105)

There are hopes that hydropower development will increase production around the region. Nigeria, for example, is planning the 3,050-megawatt (MW) Mambila hydroelectric power plant to help meet development goals. Variable hydrological conditions, however, already limit output from existing facilities. In Ghana, the Akosombo, Kpong, and Bui dams account for about 50 percent of the country's installed power generation capacity (more than 4,000 MW). Generation nationally, however, rarely exceeds 2,400 MW due to variable

river flow, inadequate fuel supplies, and dilapidated infrastructure. The system's low performance leads to frequent power outages, including 159 days of blackouts in 2015, with negative consequences for businesses and households. Power outages and constraints in 2014 are estimated to have cost Ghana $680 million and 2 percent of GDP. While much depends on still uncertain precipitation projections, research estimates that the combined effects of climate trends and development will reduce hydropower production potential in the Volta River Basin by nearly 50 percent by 2050. In Liberia, concerns about reduced river flow are particularly concerning, as hydropower accounts for 70 percent of the just 126 MW of installed electrical generation capacity. In Senegal, where trends of reduced rainfall are more certain, hydropower contributes about 10 percent to the country's electric supply and is highly susceptible to reduced river flow and increased evaporation from reservoirs. (14, 18, 52, 58, 99)

Nigeria is the largest oil and gas producer in Africa, with most of its production exported out of the region. Production is concentrated on the coast, where development has contributed to loss of mangroves and coastal erosion. Now coastal oil and gas production are increasingly vulnerable to sea level rise, storm surges, and coastal flooding. Flooding in 2012 led to losses of more than $630 million due to lost production and infrastructure damage. (34)

REGIONAL CLIMATE POLICY CONTEXT

REGIONAL INSTITUTIONS

Strong regional coordination to address climate change is lacking, but the Economic Community of West African States (ECOWAS), the Permanent Interstate Committee for Drought Control in the Sahel (CILSS), and the CILSS agency AGRHYMET are initiating efforts. ECOWAS, with a mandate to promote economic integration among its 15 member countries,[2] is working to build climate change adaptation capacity across the region, with a focus on climate-smart agriculture. The ECOWAS Directorate for Environment houses a coordinator for climate change, and its Directorate for Agriculture and Rural Development is working to integrate climate-smart agriculture into regional and national agriculture investment programs. In 2017, ECOWAS signed an MOU with the African Union's African Risk Capacity Agency to further address climate risk. (19)

Subregional bodies that address climate change impacts include:

- Economic Community of West African States (ECOWAS)
- Permanent Interstate Committee for Drought Control in the Sahel (CILSS)
    - AGRHYMET (a specialized agency of CILSS)
- *West African* Science Service Center on Climate Change and Adapted Land Use (WASCAL)
- Sahel and Sahara Observatory (OSS)
- Abidjan Convention Secretariat
- West African Economic and Monetary Union (UEMOA)
- Transboundary river basin organizations including the Organization for the Development of the Senegal River Basin (OMVS) in Dakar, the Niger Basin Authority (NBA) in Niamey, and the Lake Chad Basin Commission (LCBC) in N'Djamena.

[2] Benin, Burkina Faso, Cape Verde, Côte d' Ivoire, The Gambia, Ghana, Guinea, Guinea Bissau, Liberia, Mali, Niger, Nigeria, Sierra Leone, Senegal, and Togo.

REGIONAL CLIMATE-RELATED POLICIES

All West African countries are party to the United Nations Framework Convention on Climate Change (UNFCCC), have ratified the Paris Agreement, and have submitted one or more national communications to the UNFCCC, with the exception of Guinea-Bissau (has signed but not ratified the Paris Agreement) and Equatorial Guinea (has not submitted a national communication or ratified the Paris Agreement).[3]

- ECOWAS Agricultural Strategic Policy Framework 2025 (ECOWAP) (2016)
- ECOWAS Environmental Policy (2008)
- ECOWAS Guidelines for the Establishment and Strengthening of National Platforms for Disaster Risk Reduction in West Africa (2010)
- ECOWAS Policy for Disaster Risk Reduction (2006)

SELECTED ONGOING EXPERIENCES

Below are selected projects focused on climate change adaptation, or some aspect of it, in West Africa. Many more country-specific projects with an adaptation focus exist but are not listed here.

Selected Program	Amount	Donor	Year	Implementer
West Africa Coastal Areas Management Program	$222 million	World Bank, Nordic Development Fund	2018–2023	World Bank Group and the Governments of Benin, Côte d'Ivoire, Ghana, Mauritania, and Togo
Senegal River Basin Climate Change Resilience Development Project	$84.6 million	GEF, World Bank	2013–2021	L'Organisation pour la mise en valeur du fleuve Senegal (OMVS)
Regional Sahel Pastoralism Support Project	$248 million	World Bank	2015–2021	Permanent Interstate Committee for Drought Control in the Sahel (CILSS)
West Africa Biodiversity and Climate Change (WA-BICC)	$48.8 million	USAID	2015–2020	Tetra Tech ARD
Training Programme on Climate Change Adaptation and Disaster Risk Reduction in Agriculture	€0.82 million	Italian Ministry of Foreign Affairs	2017–2018	World Meteorological Organization, IBIMET-CNR, and AGRHYMET
Future Climate for Africa Program (in West Africa—Burkina Faso, Senegal)	Not available	CDKN, UKAid, NERC	2013–ongoing	CDKN
Integrated and Sustainable Management of Shared Aquifer Systems and Basins of the Sahel Region	$6.2 million	IAEA member states and the EC under the Peaceful Uses Initiative	2012–2017	International Atomic Energy Agency (IAEA); UNESCO, JICA, and the Sahara and Sahel Observatory
Building Resilience and Adaptation to Climate Extremes and Disasters (BRACED) (series of 8 projects in West Africa)	€1.3 million	DFID	2014–2018	KPMG, ODI, and others by project
Sustainable and Thriving Environments for West Africa Regional Development (STEWARD)	Not available	USAID	2008–2016	USFS-IP and Mano River Union

[3] As of September 2018.

West Africa Regional Fisheries Program	$46 million	World Bank	2009–2016	Governments of Cabo Verde, Liberia, Senegal, and Sierra Leone
Building Capacity of ECOWAS for Effective CAADP Implementation in West Africa	$4 million	Spain	2012–2016	FAO
Canary Current Large Marine Ecosystem Project	$28 million	GEF with financing	2010–2015	FAO, UNEP, and participating countries
African and Latin American Resilience to Climate Change (ARCC)	Not applicable	USAID	2011–2014	Tetra Tech ARD

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