GHANA

AFRICAN DEVELOPMENT BANK

NATIONAL CLIMATE CHANGE PROFILE

PRODUCED IN COLLABORATION WITH:
African Climate & Development Initiative, University of Cape Town;
Climate Systems Analysis Group, University of Cape Town;
Energy Research Centre, University of Cape Town; Cirrus Group.

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GHANA

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ACKNOWLEDGEMENT

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1. BACKGROUND

1.1. Geographic and socio-economic context

The Republic of Ghana (henceforth 'Ghana'), situated along the coast of West Africa's Gulf of Guinea region of the Atlantic Ocean, is a diverse and rapidly-developing country with a population of ~28 million people. Bordered by the Atlantic Ocean in the south, Togo to the east, Burkina Faso to the north and Côte d'Ivoire to the west, Ghana is increasingly a regional hub for services, trade, manufacturing and transport. Ghana has undergone considerable economic growth and transformation, partially through the development of the country's rich natural resource base (including production of oil, as well as minerals and agricultural exports such as cocoa), resulting in rapid if fluctuating annual increases of GDP growth rate, from ~4.8% in 2009 to a peak of ~14% in 2011. However, as a result of multiple global economic pressures and falling commodity prices, combined with increased external debt and public investment pressures, Ghana's economy underwent a period of downturn in the period ~2013-2016 from which it is currently recovering. At present (2017), Ghana is estimated to be Africa's 11th largest economy with an annual GPD of ~USD 42.7 billion, equivalent to annual per capita income of ~USD 1,513 (20th in Africa). Approximately 53% of Ghana's population are urban (increasing at ~3.4% annually), of which ~4 million live in the Greater Accra metropolitan area. Of the remaining rural population, the large majority are dependent on various forms of mixed agriculture and livestock production (~43% of total population, contributing ~20% of GDP), and fishing in the coastal zones as well as inland freshwater fisheries (~5% of GDP). Ghana's warm tropical climate includes zones of relative aridity in the northern region as well as humid, monsoon-influenced regions in the southwest, and as a result the country is vulnerable to climate-related hazards such as drought and rainfall variability as well as floods and extreme rainfall events. Floods in particular are estimated to have impacted ~1.16 million Ghanaians in the period ~1996–2016. Approximately 10.6 million people live in Ghana's coastal zones and as a result are likely to be vulnerable to hazards such as coastal erosion, storms surges and flooding. Ghana's ND-GAIN Index score (which summarizes a country's relative vulnerability to climate change, in addition to national readiness and adaptive capacity), is ~49.1, the 9th highest score in Africa. For Ghana this index indicates that the country has initiated steps towards responding to climate change, but that the adaptation needs and urgency to act are high. Key socio-economic and demographic indicators are further presented and summarised in Table 1-1, below.

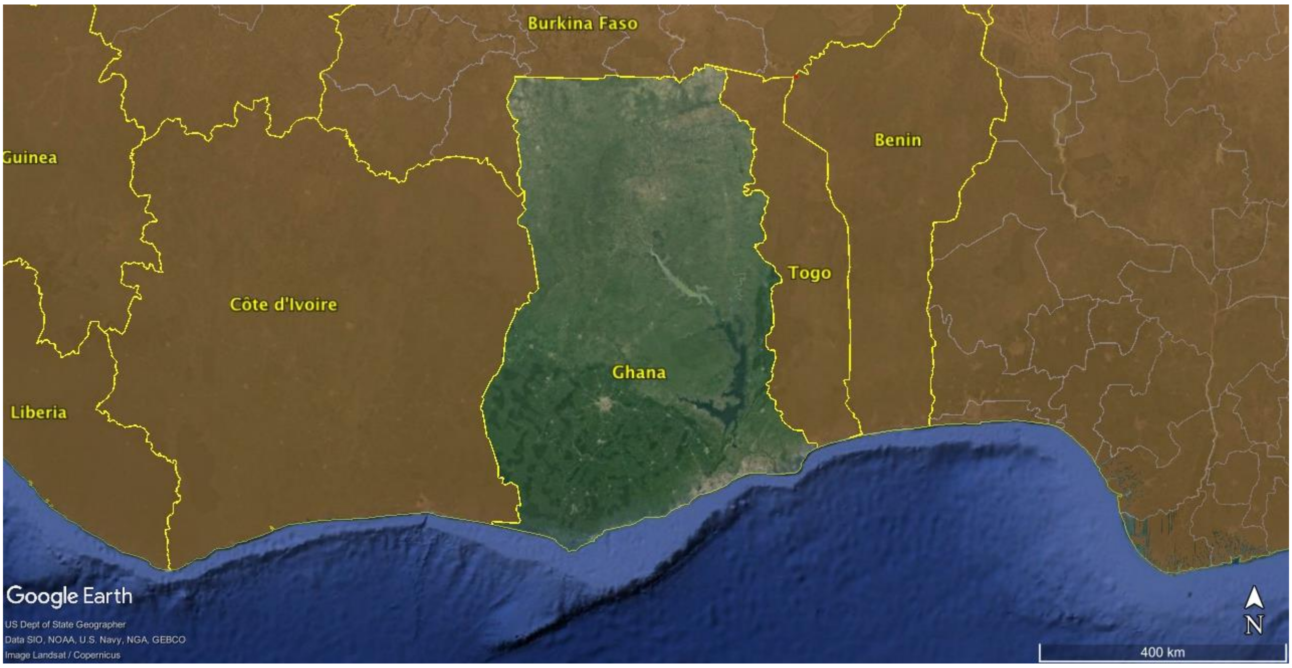


Figure 1 1: Map of Ghana

Table 1-1: Socio-Economic Context of Ghana (reference year ranges from 2014 - 2017)

VARIABLE	SCORE/TOTAL	UNIT	RANK (OUT OF 54)
Geography, Socio-Economy and Demographics			
Population[1]	28,656,723	people	13
Population growth rate[1]	2.2	% population .yr-1	36
Population density[1]	126	People/km2	13
Land area[1]	227,615	km2	33
% Urban population[1]	52.5	% population	15
% Urbanisation rate[2]	3.4	% population .yr-1	31
Economy: total GDP[2]	42.7	USD billions .yr-1	11
Economy: GDP by PPP[2]	121	billion international dollars .yr-1	12
Economy: GDP/capita[2]	1,513	USD per capita /yr	20
Population below the poverty line[3]	25.2	% below USD 1.90 per day	33
Gender Inequality Index[4]	55.4		23
GINI co-efficient[3]	42.8		27
HDI[5]	0.58		15
Access to electricity[6]	78.3	% population	11
Summary indicators of climate change vulnerability			
Workforce in agriculture[6]	42.0	% workforce	25
Population undernourished[7]	5.0	% population	36
Number of people affected by drought[8]	1,162,190	people	13
Number of people affected by flood events[8]	10,670,130	people	7
Population living within 100 km of coast[9]	37.9	% urban population	37
Population living in informal settlements [5]	266	cases per 1000 population at risk	13
ND-Gain Vulnerability Index[10] 49.1		9	5
0.45		7	9
0.47		42	51

2. CLIMATE AND WEATHER

Ghana has a tropical climate with high rainfall and hot and humid conditions over most of the country, though less rainfall along the south eastern coast and over the north. The northern half of the country experiences a long single rainy season peaking during late boreal summer (August – September). The southern parts experience two peaks in the rainfall; the first in June and the second in September – October. Temperatures generally peak at the beginning of the rainy season with a secondary peak toward the end of the rainy season. The boreal winter (December – January) is generally cooler and dry. The river catchments or water region of Ghana extend northward beyond the border of the country into Burkina Faso. This area is generally drier with a shorter wet season than Ghana itself.

The climate within Ghana and its water region show quite clear differences in terms of the magnitude and seasonality of rainfall. Therefore, four sub-regions are distinguished here. The Ghana regions are illustrated in Figures 2-1 and 2-2, below, and summary descriptions can be found in Table 2-1 below.

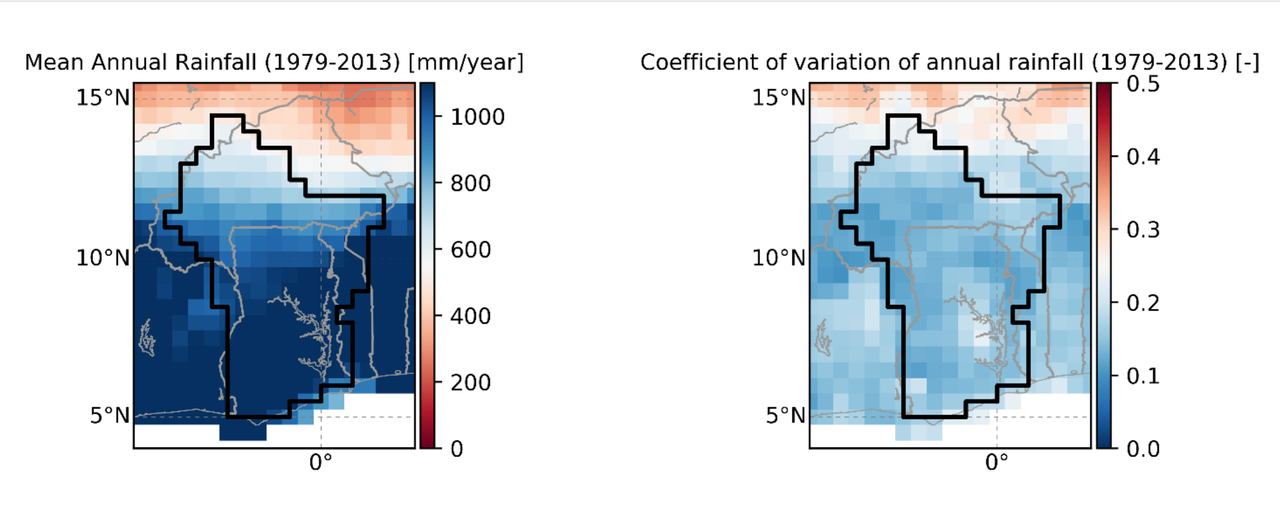
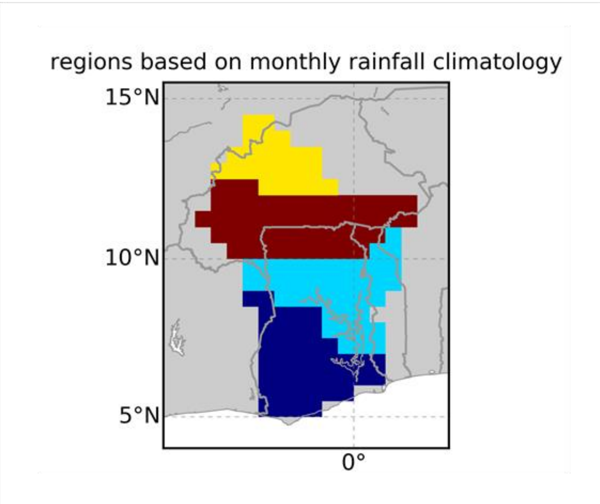


Figure 2-1: Main characteristics (magnitude and variability) of rainfall in Ghana and its region



Coloured regions on the map (above) correspond to the colours used in rainfall and temperature graphs (below)

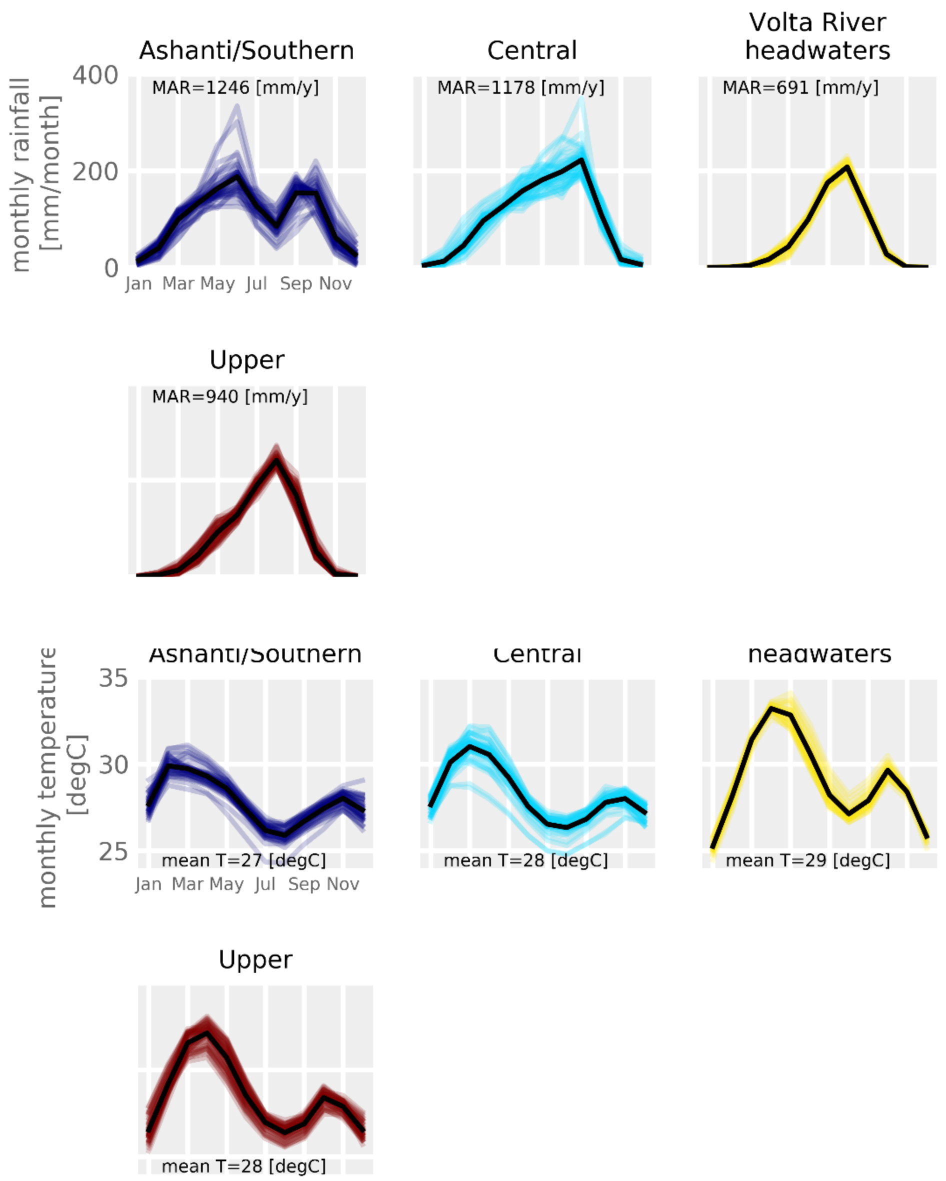


Figure 2-2: Rainfall regions of Ghana based on similarity of standardised rainfall climatology, and their rainfall climatologies

Table 2-1: Main characteristics of rainfall of Ghana region

VOLTA RIVER HEADWATERS	A region where the average daily temperature is 29° C and the mean annual total rainfall is 690 mm/year. Rainfall increases from the north to the south-west and the variability of rainfall from year to year is relatively low to moderate. The region experience a clear wet and dry season. The wet season lasts from around June to September, peaking at around 200 mm/month during August. The dry season last from November to March. Temperatures fluctuate by around 9° C within the year with the warmest temperatures (~34° C) occurring at the start of the rainy season (May – June) with a secondary peak at the end of the rainy season (September – October). Coolest temperatures (~25° C) occur during the dry boreal winter (December – January).
UPPER	A region where the average daily temperature is 28° C and the mean annual total rainfall is 940 mm/ year. Rainfall increases from the north to the south across the region and variability in rainfall from year to year is moderate to low. The region experience a clear wet and dry season. The wet season lasts from around May to September, peaking at around 250 mm/month during August. The dry season last from November to February. Temperatures fluctuate by around 6° C within the year with the warmest temperatures (~32° C) occurring at the start of the rainy season (May) with a secondary peak at the end of the rainy season (October). Coolest temperatures (~26° C) occur during the dry boreal winter (December – January).
CENTRAL	A region where the average daily temperature is 28° C and the mean annual total rainfall is 1180 mm/ year. Rainfall increases from the north-west to the south-east across the region and variability in rainfall from year to year is moderate to low. A long wet season occurs from around April to October, peaking at around 200 mm/month during September. Little rainfall occurs during the boreal winter months (November – February). Temperatures fluctuate by around 6° C within the year with the warmest temperatures (~32° C) occurring at the start of the rainy season (April) with a smaller secondary peak (~29° C) at the end of the rainy season (October). Coolest temperatures (~26° C) occur during the dry boreal winter (December – January).
ASHANTI/SOUTHERN	A region where the average daily temperature is 27° C and the mean annual total rainfall is 1250 mm/year. Rainfall is high over the full region and the year to year variability is moderate to low. Rainfall occurs during a long season from March – September, but there are two clear peaks; the first in April (200 mm/month) and the second in September – October (170 mm/month). Little rainfall occurs during the boreal winter (December – February). Temperatures fluctuate by around 6° C within the year with the warmest temperatures occurring in May (32° C) but there is a secondary peak during October (29° C). Coolest temperatures (26° C) occur during the dry boreal winter (December – January).

2.1 Observed historical climate variations and climate trends

The majority of Ghana experiences **moderate to low rainfall variability** on an inter-annual basis. On **decadal time scales** Ghana also experiences **some variability** with some periods being relatively drier or wetter than others. This variability can be seen in the supporting evidence plots provided in the supplementary Appendix **(Figures A-1 to A-4).**

Long term trends in all regions except the Central Region show small but statistically significant **increasing temperature** trends over the period 1979 – 2015. The long term trend in total annual rainfall is strongly positive and statistically significant over the Volta River Headwaters Region and slightly positive over the Upper Region. No trend is found over the Central Region and the trend in total annual rainfall is strongly negative over the Ashanti/Southern Region. A strong and statistically significant decreasing trend in the frequency of rain events is seen over all four regions, but an upward trend in the frequency of extreme rainfall events is found over the three more northern regions. Long term trends and variability in the Ghana regions are summarized in **Table 2-2** below and illustrated further in the supplementary Appendix **(Figures A-1 to A-4).**

Table 2-2: Summary of trends in rainfall and temperature attributes in Ghana (1979 - 2015)

REGION	MEAN T [DEG C/DECADE]	TOTAL RAINFALL [MM/DECADE]	EXTREME RAINY DAYS [DAYS/DECADE]	RAINY DAYS [DAYS/DECADE]
Volta River Headwaters	+0.16	+44.9	+3.9	-4.6
Upper	+0.11	upward	+2.8	-5.5
Central	not evident	Not evident	upward	-5.0
Ashanti/Southern	+0.06	-67.4	not evident	-6.5

2.2 Projected (future) climate change trends, including temperature, precipitation and seasonality

Projected changes in main attributes of climate for the Ghana region are summarized in Table 2-3, below, and described in Sections 2.2.1 and 2.2.1. Additional analysis and visualisation of projections be found in Figures A-5 to A-8 in the supplementary Appendix.

2.2.1 Projected changes in precipitation from present to 2100

Rainfall projections across the Ghana regions show no consistent signal in the projections of total annual rainfall. The frequency of rainfall events are projected to remain the same or to decrease over the more southern parts, but the frequency of extreme events may increase into the future. There is less agreement in the direction of change in the frequency of rain events or extreme rain events over the more northern parts. It must be noted that these results are derived from GCM projections which may not accurately represent changes in extreme rainfall dynamics. They are, however, consistent with the increased convective rainfall intensity (e.g. thunderstorm-related rainfall) expected in a warmer climate.

2.2.2 Projected changes in temperature from present to 2100

Air temperature is projected to be about 1°C - 3° C warmer in the Ghana region by the 2050s. By 2100 the range of projected temperatures is greater ranging from showing projected increases of 3.5°C to 7°C.

Table 2-3: Summary of projected climate changes across regions of Ghana for key climate variables by 2050

REGION	AVERAGE TEMPERATURE [°C]	TOTAL ANNUAL RAINFALL [MM/YEAR]	NUMBER OF HEAVY RAINFALL [DAYS/YEAR]	RAINY DAYS [DAYS/YEAR]
Volta River Headwaters	**Increasing** +1°C to +2.5°C by 2050s but changes evident in next decades	No consistent signal in projections	No consistent signal in projections	No consistent signal in projections
Upper	**Increasing** +1.5°C to +3°C by 2050s but changes evident in next decades			**Normal to decreasing,** ranging from no change to a decrease of as much as 10% by 2050, however signals diverge, and no consistent signal is evident by 2100
Central			**Normal to increasing**, ranging from slight decrease to strong increase of up to 50% by 2100	**Normal to decreasing,** ranging from no change to a decrease of as much as 10% by 2050, however signals diverge, and no consistent signal is evident by 2100
Ashanti/Southern	**Increasing** +1°C to +2.5°C by 2050s but changes evident in next decades			**Normal to decreasing**, ranging from no change to a decrease of as much as 20% by 2100. Change could become evident from 2020.

2.3 Expected climate vulnerabilities

NOTE: Determining vulnerability of different sectors to climate variations or change is extremely challenging as there are many factors involved in vulnerability and different approaches can yield different results. The vulnerabilities presented here are based on UNFCCC reporting documents, such as national communications or national adaptation plans of action where available, and other literature where UNFCCC documents are not available.

Tropical Ghana is increasingly considered to be a regional hub in terms of trade, transport, manufacturing and services, though agricultural exports have been an important driver of economic growth and agricultural activity is the main source of income or subsistence for around half the population. Increasing temperatures and changing rainfall patterns pose a risk to the climate sensitive agricultural sector, a concern for both households and for the economy at large. The other half the population of Ghana lives in urban areas, of which around one third live in slums with lack of proper access to critical services such as health care, water supply and proper housing, deeming them vulnerable to extreme temperatures and rainfall events, as well as the slower knock-on effects that climate change may have on the economy. Around one sixth of Ghana's population live in coastal zones, where the low lying human settlements and associated developments, as well as fishing activities, are vulnerable to sea-level rise and associated stresses.

Table 2-4: Broad scale sectoral vulnerabilities and potential climate change impacts in Ghana

SECTOR	IMPACTS
Agriculture	- Crop loss and reduced yields due to increased temperatures, changes in rainfall and salinization of coastal aquifers - Increased incidence of pests and disease - **Crop loss owing to shifting rainfall patterns, including delayed onset of rainy season and increased length of dry spells** - Desertification and loss of agricultural and grazing land, especially in the north
Fisheries	- Loss of habitat and breeding grounds, especially mangroves - Changed fish migratory patterns - Increased human migration to the coast, increasing pressure on marine fisheries - Decreased protein consumption due to lower fishing yields - Reduced inland fish stocks owing to increased temperatures and reduce river flow
Water resources	- Increased variability of run-off, leading to decreased availability of surface and ground water, especially in the north - Increased coastal erosion and salinization of coastal aquifers - Reduced water storage, negatively affecting hydropower production, especially in the Volta River basin - Increased potential for transboundary conflicts over water
Built infrastructure and human settlements	- Damage to and destruction of infrastructure due to coastal flooding from increased sea levels and storm surge - Increased potential for migration from rural to urban areas
Human health	- Increased prevalence of water-borne diseases, especially during flooding events - Increased prevalence of vector-borne diseases such as malaria - Increased prevalence of respiratory diseases due to increased Harmattan winds - Increased potential for malnutrition and stunting owing to drought, especially in the north

3. CLIMATE CHANGE MITIGATION, GREENHOUSE GAS EMISSIONS AND ENERGY USE

The major carriers of Ghana's energy mix, and the energy demands of major economic sectors, are summarised in Section 3.1, below. The major sources of GHG emissions, described by fuel source and sector, are described in Section 3.2. The latter section also includes summarised statistics on Ghana's agriculture sector, historical land use change and vegetation cover.

3.1 National energy production and consumption

The tables and figures below describe Ghana's energy sector, including national electricity production, primary energy supply and national energy consumption by fuel carrier. As described in Section 1, Ghana's economy includes a strong emphasis on production of oil, contributing ~5.4 MTOE or ~56% of total annual energy production. In addition, the country has begun the exploration of natural gas reserves which do not yet currently contribute significantly to national energy production. Biomass energy is the dominant energy used by rural households, as well as many urban households, for domestic energy, which contributes ~3.6 MTOE or 37% of national energy production (Table 3-1).

Unless stated otherwise, all energy figures are derived from UN Stats (2014) [10]; World Energy Council (2016); [11]; and the World Resources Institute (2013) [12]. Agriculture & forestry-related emissions are also reported from Food and Agriculture Organisation (2014-2017) [14] and Global Forest Watch. (2015-2017) [15].

3.1.1 National energy production, primary energy supply and national energy consumption

Ghana's energy sector includes a strong emphasis on the production and consumption of fossil fuels, supported by the oil reserves developed in the period since ~2007. National production of oil, totalling 5.4 MTOE, supplies national demand for oil consumption of 3.5 MTOE as well as export of crude oil and refined oil products. Total annual consumption of energy, estimated at 6.8 MTOE, also includes ~2.4 MTOE (35%) contributed by biomass fuels in the form of firewood and charcoal in urban areas (Table 3-2). Electricity contributes a relatively small proportion (~13%) of total national energy consumption, although the proportion of the population with access to the electricity grid has increased from ~45% in 2000 to ~76% at present. Hydropower contributes ~64% of Ghana's electricity (~0.7 MTOE), with the remainder largely contributed by oil and gas. At present, non-hydro renewable energies do not contribute significantly to Ghana's electricity production, however the government has established targets to increase the share of renewable energies in on-grid and off-grid applications (Section 4).

The sectors that account for the majority of Ghana's energy consumption (totalling 6.8 MTOE) (Table 3-3) include the transport and residential sectors, accounting for 2.4 MTOE each (fuels consumed by the residential sector include electricity, woodfuel, and mixed fossil fuels). The industrial sector, which includes the mining and processing of mineral resources, consumes 1.4 MTOE while the commercial and services sector consumes 0.3 MTOE. Other important economic sectors, including the agriculture, forestry and fisheries sectors as well as other unspecific sectors account for the remaining ~0.3 MTOE of national energy consumption. The total annual GHGs emitted by the abovementioned sectors and fuel carriers are described further in Section 3.2.

GHANA

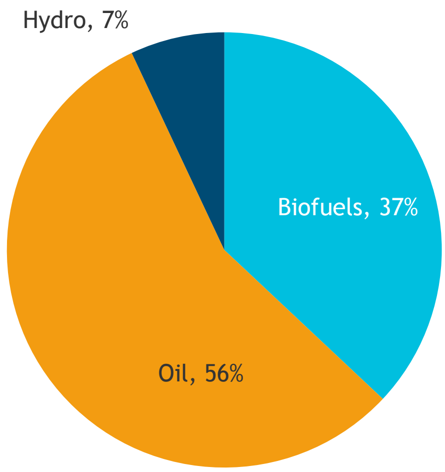


Figure 3-1: Distribution of Ghana's national energy production between major energy carriers (2014-2016)

Table 3-1: National energy and electricity production in Ghana (2014-2016)

NATIONAL ENERGY PRODUCTION		
Source	**Total (MTOE)[1]**	**% of total energy production**
Oil[12]	5.4	55.5
Hydro[12]	0.72	7.38
Biofuels[12]	3.63	37.12
Total national energy production	9.77	
Electricity[6]	Hydro	64.70
	Non-Hydro renewable	0.03
	Oil	17.07
	Gas	18.20

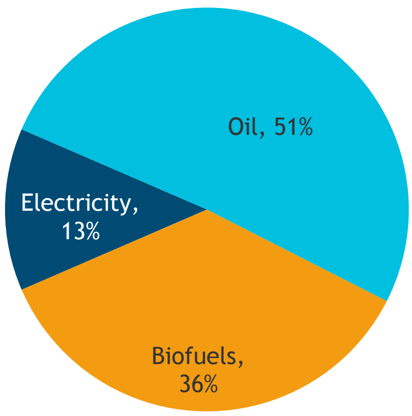


Figure 3-2: Distribution of Ghana's national energy consumption by major energy carriers

Table 3-2: Ghana's national energy consumption by energy source

CONSUMPTION BY ENERGY SOURCE[12]	
Source	**Total (MTOE)**
Oil	3.5
Biofuels	2.4
Electricity	0.9
Total national energy consumption by source	6.8

1 Energy is expressed in 'Megatonnes of Oil Equivalent', where 1 Tonne Oil Equivalent = 11,630 KiloWatt hours (KWh)

Table 3-3: Ghana's national energy consumption by sector (2014-2016)

CONSUMPTION BY SECTOR[12]	
Source	**Total (MTOE)**
Industry	1.4
Transport	2.4
Residential	2.4
Commercial and public services	0.3
Agriculture / forestry	0.1
Fishing	0.0
Non-energy use	0.2
Total national energy consumption by sector	6.8

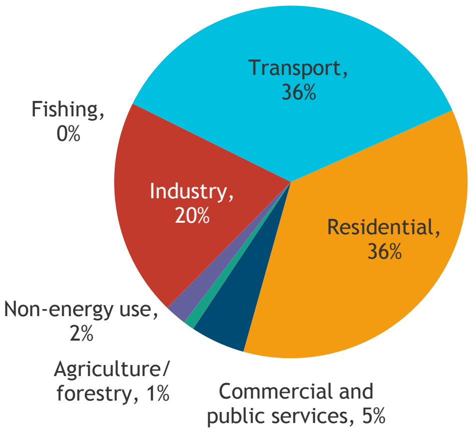


Figure 3-3: Distribution of Ghana's national energy consumption by sector (2014-2016)

Table 3-4: Ghana's national total primary energy supply (estimated for 2014-2016)

TOTAL PRIMARY ENERGY SUPPLY[12]		
Source		**Total (MTOE)**
Oil	Crude-oil	0.8
	Oil products	3.4
Gas		0.5
Hydro		0.7
Biofuels		3.6
Electricity		-0.04
Total primary energy supply		9.0

3.2 National greenhouse gas emissions by source and sector

Section 3.2.1, below, describes Ghana's GHG emissions from fuel combustion – these figures include direct combustion of fuels as a primary energy carrier as well as conversion to other forms of energy (e.g. as electricity). The latter figures are based on statistics from the International Energy Agency (IEA). Section 3.2.2, further below, describes GHG emissions from all sectors of national energy consumption, which therefore includes emissions from fuel combustion, industrial/manufacturing processes, household-level energy consumption and AFOLU (Agriculture, Forestry and Other Land Use). The latter figures are compiled by the World Resources Institute's Climate Access Indicator Tools (CAIT), which employs different methodologies and reporting standards to the IEA. Therefore, while there is some resultant duplication between the two datasets, each provides slightly different approaches to categorisation of major GHG emitting sectors and are both included for consideration. Section 3.2.3 provides additional details on Ghana's Land Use and Land Use Change sector, including detailed summaries of emissions from the agriculture sector and historical land use changes.

3.2.1 GHG emissions from fuel combustion, by source and sector

As described in Section 3.1, oil and oil products are the primary fuel source for the formal energy sector, and as a result the latter fuels contribute 13 MT CO_2e out of a **total of 13.6 MT CO_2e** greenhouse gas (GHG) emissions from **fuel combustion (excluding biomass)**. The sectors which account for the largest share of Ghana's GHG emissions from fuel combustion are: i) the transport sector, including 6.7 MT CO_2e from road transport as well as 0.5 MT CO_2e from other forms of transport (primarily shipping); ii) electricity and heat production, contributing 3.5–3.7 MT CO_2e; and iii) manufacturing, industrial and construction sector, contributing 1.7 MT CO_2e. Other sources contributing to GHG emissions from fossil fuel combustion are the residential (0.6 MT CO_2e) and non-residential (0.4 MT CO_2e) sectors, plus ~0.1–0.4 MT CO_2e attributable to secondary uses and fugitive emissions within the energy sector.

Table 3-5: Ghana's national greenhouse gas emissions from fuel combustion

NATIONAL GHG EMISSIONS FROM FUEL COMBUSTION BY FUEL SOURCE AND SECTOR [13]		
Source / Sector		**Total emissions (MT CO_2e)**
Oil		13.0
Gas		0.6
Total fuel source emissions		**13.6**
Electricity and heat production		3.5
Other energy industry own use*		0.1
Manufacturing industries and construction		6.7
Transport	Road	6.7
	Other	0.5
	Total	7.2
Other	Residential	0.6
	Non-residential	0.4
	Total	1.1
Total sector emissions		13.6

** Includes emissions from own use in petroleum refining, the manufacture of solid fuels, coal mining, oil and gas extraction and other energy-producing industries.*

3.2.2 GHG emissions from primary energy consumption, by source and sector

In addition to GHG emissions from direct fuel combustion and other processes in the energy sector (totalling ~17.4 MT CO2e), the largest proportion of Ghana's GHG emissions result from activities in the sectors of agriculture (contributing 9.3 MT CO2e) and land use change and forestry (~8.5 MT CO2e). The activities which drive emissions from the latter sectors are likely to include inter alia emissions related to household energy needs, particularly collection of firewood and production of charcoal to supply urban demand. In addition, emissions from Ghana's agriculture sector are driven by clearance of vegetation for expansion of agriculture, degradation and loss of land cover as a result of overgrazing, and emissions related to enteric fermentation and manure management in the livestock sector (described further in Table 3-7, Section 3.2.3, below). In addition, industrial processes and the waste management sector contribute an additional 1.6 MT CO2e and 2.6 MT CO2e, respectively. Therefore, the combined total GHG emissions of all sectors, including fuel combustion and other energy uses, land use change, industrial processes and waste management, is estimated to be ~39.4 MT CO2e.

Table 3-6: Ghana's national greenhouse gas emissions from primary energy consumption (estimated for 2014-2016)

NATIONAL GHG EMISSIONS FROM PRIMARY ENERGY CONSUMPTION BY SOURCE AND SECTOR [14]		
Source / Sector		**Total emissions (MT CO_2e)**
Energy	Electricity and heat	3.7
	Manufacturing and construction	1.7
	Transport	7.2
	Other fuel combustion	4.4
	Fugitive emissions	0.4
	Energy sub-total	17.4
Industrial processes		1.6
Agriculture		9.3
Waste		2.6
Land use change and forestry (LUCF)		8.5
Total emissions (including LUCF)		39.4

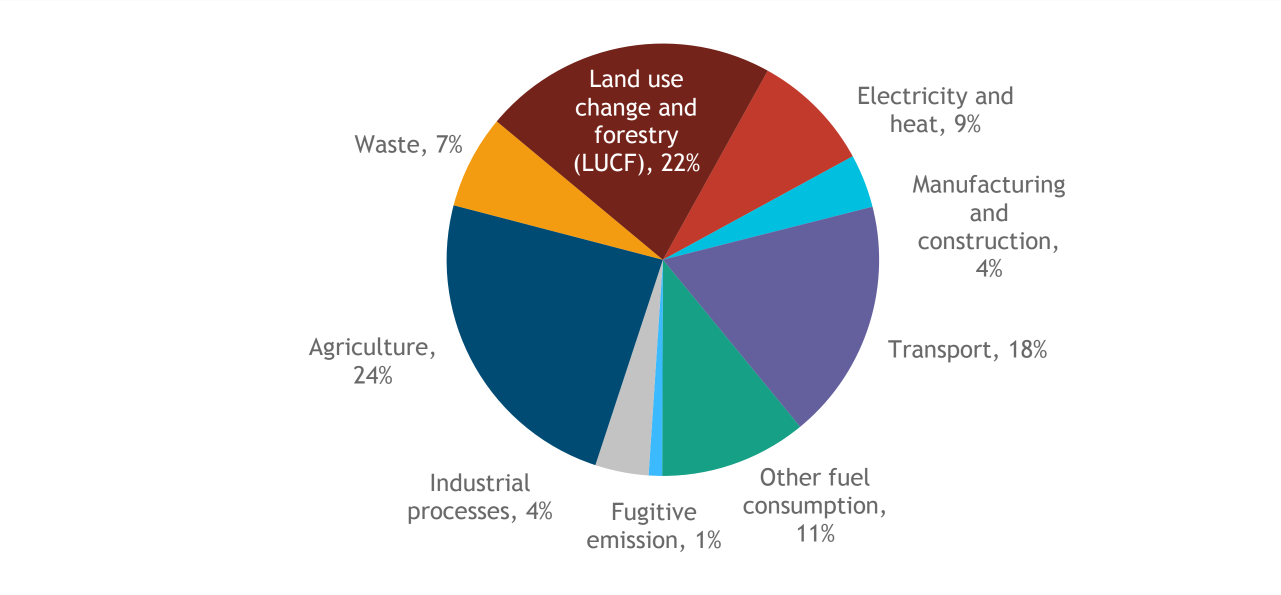


Figure 3-4: Distribution of Ghana's GHG emissions by major sectors

3.2.3 GHG emissions from agricultural practices

Ghana's total annual GHG emissions from the sectors of agriculture, forestry and land use change contribute ~17.5–18 MT CO_2e (Tables 3-6 – 3-7). Table 3-7, below, estimates the activity-level emissions within these sectors. The agriculture sector, which contributes emissions of ~9.2–9.3 MT CO_2e includes emissions of ~4.7 MT CO_2e from activities related to enteric fermentation and manure management in the livestock sector. Emissions from Ghana's agricultural sector also include ~2.6 MT CO_2e from burning of savanna, 0.3 MT CO_2e from rice cultivation, and 0.2 MT CO_2e each from crop residues and use of synthetic fertilisers.

Ghana's emissions from land use change, totalling ~8.3-8.5 MT CO_2e, include 8.1 MT CO_2e from forest land change and an additional 0.1 MT CO_2e from burning of biomass and establishment of croplands – activities in these areas include clearance for expansion of new farmlands, harvesting of woody biomass as domestic fuel and removal of timber for forestry. Table 3-8, below, provides further detail on emissions from the land use change and forestry sector in Ghana.

Table 3-7: National annual greenhouse gas emissions from agricultural practices, forestry and other land use in Ghana (estimated for 2014-2017)

VARIABLE		ANNUAL EMISSIONS (MT CO_2E)
Annual GHG emission from agricultural practices [15]	Burning - crop residues	0.1
	Burning - savanna	3.6
	Crop residues	0.2
	Cultivation of organic soils	0.0
	Enteric fermentation	2.3
	Manure management	0.2
	Manure applied to soils	0.1
	Manure left on pasture	2.1
	Rice cultivation	0.3
	Synthetic fertilizers	0.2
	Sub-total (Agricultural practices)	**9.2**
Annual GHG emission from land use change [15]	Cropland	0.1
	Forest land	8.1
	Burning biomass	0.1
	Sub-total (Land use change)	**8.3**
Total emissions		17.5

Up to 72% of Ghana's land cover (~17.3 million hectares) includes some form of forested tree cover, varying in density according to rainfall from the country's humid south-east to the relative aridity of the north. Approximately ~11.1 million hectares of Ghana's land cover is classified as '10-30%' canopy cover, equivalent to savanna woodland.

In addition, Ghana's forestry sector includes ~2.5 million hectares of '30-50%' forest and ~3.7 million hectares of dense tropical forest with canopy cover greater than 50%. Ghana's rich forest resources include multiple commercially-valuable species which are exploited both by legal and illegal logging activities. Consequently, it is estimated that Ghana's remaining latter forested areas with canopy cover greater than 30% are subject to annual deforestation rates of ~0.4 – 0.8%. Global Forest Watch estimates that the remaining forest and woodland areas of Ghana contain a biomass carbon stock of ~714 million tonnes.

Table 3-8: Vegetation cover and land use change in Ghana (estimated for 2015)

VARIABLE		TOTAL (HECTARES)	TOTAL (% OF LAND AREA)	UNIT
Total tree cover [16]	10-30% canopy cover	11,121,317	46.62	% of total land area
	30-50% canopy cover	2,523,377	10.6	
	50-100% canopy cover	3,683,707	15.4	
	Total	17,328,401	72.6	
Land use change and agricultural expansion	Historical annual rate of deforestation [17] Cropland		0.1	% of previous year
			0.4	
			0.8	
	Area of agricultural land [18]	16,669,175	69.9	% of total land area
	Historical annual area converted to agricultural land [18]	104,958	0.6	% of previous year

4. SUMMARISED NATIONAL PRIORITIES FOR CLIMATE CHANGE ADAPTATION AND MITIGATION

Ghana's main priority actions related to climate change are described in the country's submissions to the UNFCCC through the Intended Nationally Determined Contributions (INDC) document. The document includes detailed descriptions of the country's major commitments and priorities related to GHG mitigations (Table 4-2, below) as well as major priorities related to adaptation, derived from the draft National Adaptation Plan (NAP) (Table 4-3, further below).

"Ghana's emission reduction goal is to unconditionally lower its GHG emissions by 15 percent relative to a business-as-usual (BAU) scenario emission of 73.95MTCO2e by 2030." Ghana's INDC provides particularly detailed cost estimates for proposed adaptation and mitigation priority actions, including 20 mitigation and 11 adaptation programme of actions in 7 priority economic sectors for the period 2020-2030. The total estimated investment needs for the proposed activities are ~USD 22.6 billion, of which ~USD 16.3 is anticipated to be provided through international support and the remainder from domestic sources.

Of that total investment requirement, Ghana's INDC estimates that ~USD 9.8 billion is needed for mitigation-related actions, of which ~USD 2.02 billion will be leveraged by the Ghanaian national budget. Ghana's estimated adaptation investment costs are ~USD 12.79 billion, of which ~USD 8.29 billion is conditional on international support. The annex of the Ghana INDC includes detailed estimates of costs as well as potential co-benefits to be generated by proposed conditional and unconditional activities.

Table 4-1, overleaf, gives details on Ghana's GHG reduction targets outlined in the country's INDC, with information on target gases and sectors, the use of international markets in achieving targets (e.g. the use of carbon credits), and accounting methods used to quantify GHG emissions (e.g. inclusion of land use and land use change).

Table 4-1: Summary of Ghana's INDC commitments for reduction of GHG emissions

GHG EMISSIONS REPORTED IN INDC (MT CO2E/YR)	BASE LEVEL	REDUCTION TARGET	TARGET YEAR	SECTORS AND GASES	USE OF INTERNATIONAL MARKETS	LAND-USE INCLUSION / ACCOUNTING METHOD
58.84	BAU	15 percent (unconditional)	2030	CO_2, CH_4, N_2O, HFC-22, HFC-410; Energy including transport, industrial process and product use, AFOLU and waste.	Ghana intends to generate compliance grade emission reductions units from actions in the waste and energy sectors and REDD+	BAU and emission scenarios were estimated based on IPCC AFOLU accounting rules.

4.2 National priorities for climate change mitigation

As described in Section 1 and Section 3 (above), Ghana's economy is relatively diverse and urbanised, acting as a regional service and transport hub with well-developed agricultural and fishery sectors. Consequently, the country's INDC identifies detailed mitigation priorities and actions in thematic areas including the energy, industry, waste management and AFOLU (Agriculture, Forestry and Other Land Use) sectors. Within each sector, Ghana's INDC identifies detailed, costed actions for unconditional (i.e. voluntary, nationally budgeted) and conditional (i.e. conditional on external support) actions. Proposed activities and investments within each sector are further categorised according to 'Technology Type', based on the categories of technologies listed by the Green Climate Fund's (GCF) impact indicators for mitigation projects (key for technology types provided below Table 4-2).

With respect to Ghana's proposed activities to mitigate against climate change through the energy sector, Ghana's proposed INDC mitigation actions include diverse and detailed measures to reduce emissions through generation and distribution of electricity (which at present is primarily generated by fossil fuels and hydroelectricity). Priorities identified include a strong focus on increased efficiency of generation, transmission and use of electricity. Ghana's INDC intends to expand renewable energy facilities for off- and on-grid generation of electricity, including multiple unconditional and conditional investments in solar PV, wind turbines, hydroelectricity, and small-scale biogas digesters. In addition, measures are proposed to reduce emissions from charcoal production and use, including distribution of efficient stoves and kilns as well as measures to introduce sustainable harvesting and community management of woodlots for charcoal production. In addition, proposed measures to increase efficient energy use include distribution of efficient LED lighting and solar home lighting.

Mitigation priorities for Ghana's AFOLU sector are largely based on the implementation of the national REDD+ strategy, including reforestation of degraded areas, enrichment planting, management of wildfires and sustainable management of cocoa plantation areas. Mitigation priorities identified for Ghana's transport sector are based on reducing emissions from vehicles by introduction of integrated public transport systems such as a Rapid Bus Transit system for Accra, conditional on external support. With respect to mitigation options for Ghana's industrial and manufacturing sectors, options noted include reduced emissions through distribution of power factor correction devices to industrial-scale electricity users. In the waste management sector (which contributes GHG emissions of ~3 MT CO_2e), Ghana aims to implement systems for integrated waste management including collection of compost and generation of methane, as well as the establishment of up to 200 biogas digesters at public school and prison facilities.

Table 4-2: Mitigation priorities in Ghana's INDC

PRIORITY SECTOR	SECTOR-SPECIFIC ACTION	TECHNOLOGY TYPE[2]
Energy	Scale up renewable energy penetration by 10% by 2030 - small-medium hydro installed capacity up to 150-300MW - wind power capacity up to 50-150MW - solar 55 mini-grids with an average capacity of 100kW which translates to 10MW	1
	Promote clean rural households lighting Increase solar lantern replacement in rural non-electrified households to 2 million	1, 3
	Expand the adoption of market-based cleaner cooking solutions - Scale up adoption of LPG use from 5.5% to 50% peri-urban and rural households up to 2030 - access and adoption of 2 million efficient cook stoves up to 2030	3
	Double energy efficiency improvement to 20% in power plants	1
	Scale up the 200,000 solar home systems for lighting in urban and selected non-electrified rural households	1, 3
AFOLU	Promote Sustainable utilization of forest resources through REDD+ - 10,000ha annual reforestation/afforestation of degraded lands - enhancement of forest carbon stocks through 5,000ha per annum enrichment planting and enforcement of timber felling standards - Wildfire management in the transition and savannah dry lands in Ghana - 45% emission reduction through results-based emission reduction in cocoa landscape	4
Waste	Adopt alternative urban solid waste management - Improve effectiveness of urban solid collection from 70% to 90% by 2030 and disposed all to an engineered landfills for phase-out methane recovery from 40% in 2025 to 65% by 2030 - Scale up 200 institutional biogas in senior schools and prisons double the current waste to compost installed capacity of 180,000tonne/annum by 2030	5

*2 *GCF Technology Type Key (derived from GCF's Results Framework for mitigation)*

1. Reduced emissions through increased lower emission energy access and power generation.

2. Reduced emissions through increased access to low-emission transport.

3. Reduced emissions from buildings, cities, industries and appliances.

4. Reduced emissions from land use, deforestation, forest degradation, and through sustainable management of forests and conservation and enhancement of forest carbon stocks.

5. Strengthened institutional and regulatory systems for low-emission planning and development.

6. Increased number of small, medium and large low-emission power suppliers.

7. Lower energy intensity of buildings, cities, industries, and appliances.

8. Increased use of low-carbon transport.

9. Improved management of land or forest areas contributing to emissions reductions.

PRIORITY SECTOR	SECTOR-SPECIFIC ACTION	TECHNOLOGY TYPE[3]
Industry	Double energy efficiency improvement to 20% in industrial facilities - Scaling up of installation of power factor correction devices in 1,000 commercial and industrial facilities (capacitor banks)	3
	Green Cooling Africa Initiative Abatement of fluorinated-gases from stationery air-conditioners	3, 5

4.3 National priorities for climate change adaptation

Ghana's INDC includes detailed descriptions of intended national programs to adapt to climate change, including actions in the sectors of AFOLU, Water, Human health, as well as various community-based and institutional-level actions. Several of these actions, including in the AFOLU sector, are likely to have synergies and overlaps with mitigation-related actions. In the latter sector, Ghana's primary adaptation priorities are focused on sustainable land use, through identification of sustainable approaches to utilising forest products and building agricultural resilience. In the water sector, Ghana aims to introduce mechanisms for sustainable management and utilisation of water. An overarching objective of Ghana's adaptation plans, which spans multiple sectors, is to establish resilient infrastructure in the built environment, including promotion of early warning and disaster risk planning, managing climate-induced health hazards, and implementing city-wide resilience planning. Ghana's INDC adaptation priorities are further described in Table 4-3, below with proposed activities and investments categorised according to 'Technology Type', based on the categories of technologies listed by the Green Climate Fund's (GCF) impact indicators for adaptation projects (key for technology types provided below Table 4-3).

*3 *GCF Technology Type Key (derived from GCF's Results Framework for mitigation)*

1. Reduced emissions through increased lower emission energy access and power generation.

2. Reduced emissions through increased access to low-emission transport.

3. Reduced emissions from buildings, cities, industries and appliances.

4. Reduced emissions from land use, deforestation, forest degradation, and through sustainable management of forests and conservation and enhancement of forest carbon stocks.

5. Strengthened institutional and regulatory systems for low-emission planning and development.

6. Increased number of small, medium and large low-emission power suppliers.

7. Lower energy intensity of buildings, cities, industries, and appliances.

8. Increased use of low-carbon transport.

9. Improved management of land or forest areas contributing to emissions reductions.

Table 4-3: Adaptation priorities in Ghana's INDC

PRIORITY SECTOR	SECTOR-SPECIFIC ACTION	TECHNOLOGY TYPE[4]
AFOLU	Sustainable land use - Agriculture resilience building in climate vulnerable landscapes - Value addition-based utilization of forest resources	2, 3, 4,7
Water	Integrated water resources management	1, 2, 4
Community based	Resilience for gender and the most vulnerable	3, 5
Institutional	Early warning and disaster prevention City-wide resilient infrastructure planning	6, 8
Health	Managing climate-induced health risk	1, 2

*4 *GCF Technology Type Key (derived from GCF's Results Framework for mitigation)*

1. Reduced emissions through increased lower emission energy access and power generation.

2. Reduced emissions through increased access to low-emission transport.

3. Reduced emissions from buildings, cities, industries and appliances.

4. Reduced emissions from land use, deforestation, forest degradation, and through sustainable management of forests and conservation and enhancement of forest carbon stocks.

5. Strengthened institutional and regulatory systems for low-emission planning and development.

6. Increased number of small, medium and large low-emission power suppliers.

7. Lower energy intensity of buildings, cities, industries, and appliances.

8. Increased use of low-carbon transport.

9. Improved management of land or forest areas contributing to emissions reductions.

5. ASSUMPTIONS, GAPS IN INFORMATION AND DATA, DISCLAIMERS

The observed and projected climate trends described in Section 2 'Climate and Weather' are derived from a combination of publicly-available observational data and CMIP5 climate models. Detailed information is included in Section 6. Appendix 1, including '6.1.b. Historical Trends and Variability Analysis' and '6.1.c. Climate Projections Visualisations'.

Unless stated otherwise, all statistics reported in Section 1 ('Geographic and Socio-Economic Context' and Section 3 'Climate change mitigation, greenhouse gas emissions and energy use') are derived from databases of publicly available datasets managed by international or multilateral agencies including inter alia The World Bank Group, the United Nations, World Resources Institute and International Energy Agency.

Unless stated otherwise, all energy and greenhouse gas emission figures are derived from UN Stats (2014); World Energy Council (2016); the World Resources Institute (2013), and the International Energy Agency (2016). Agriculture & forestry-related emissions are also reported from Food and Agriculture Organisation (2014-2017) and Global Forest Watch. (2015-2017).

Full references are provided as a supplementary appendix.

As a result of the use of standardised methodologies and data sources across the 25 countries included in this AfDB Climate Change Profile, statistics and estimates reported herein may differ from other publicly available datasets or national estimates. Readers are advised to always check for updated publications and newly released national datasets.

This AfDB Climate Change Profile series is intended to provide a brief touch-stone reference for climate change practitioners, project managers and researchers working in African countries. The figures and estimates provided herein are intended to inform the reader of the main climate-related challenges and priorities, however these should be used to inform a process of additional research and in-country consultations. The University of Cape Town, the African Development Bank and its Boards of Directors do not guarantee the accuracy of figures and statements included in this work and accept no responsibility for any consequences of its use.

6. APPENDIX 1

1.a Supporting evidence

The climate projections detailed in Chapter 2 (above) are supported by rigorous analysis of observed and model projections data. More details of this analysis and supporting figures can be found below.

1.b Historical trends and variability analysis

The analysis of historical trends and variability of key climate variables is presented below. This analysis uses the WATCH Climate Forcing dataset which has been selected as the most broadly representative of station observations across Ghana. Long term (1979 to 2015) trends as well as inter-annual variability (decade to decade) has been analysed for total annual rainfall, number of rainfall days, number of extreme rainfall days, and daily mean temperatures for each of the four climate regions across Ghana. The plots below detail **inter-annual variability** (dotted lines), **decadal variability** (smooth bold solid curves) and **long term trends** (thin straight lines) for each region and statistic. This allows for comparison of different types of variability against the long term trend. It can be seen that for rainfall statistics, inter-annual and decadal variability are typically fairly large compared to long term trends. For example, for total annual rainfall, the Central region has very high inter-annual (1000mm in some years to 1550mm in other years) and moderate decadal variability (1050mm in some decades to 1500mm in other decades). Long term trends are not statistically significant but could be around 30mm over the 30 year period.

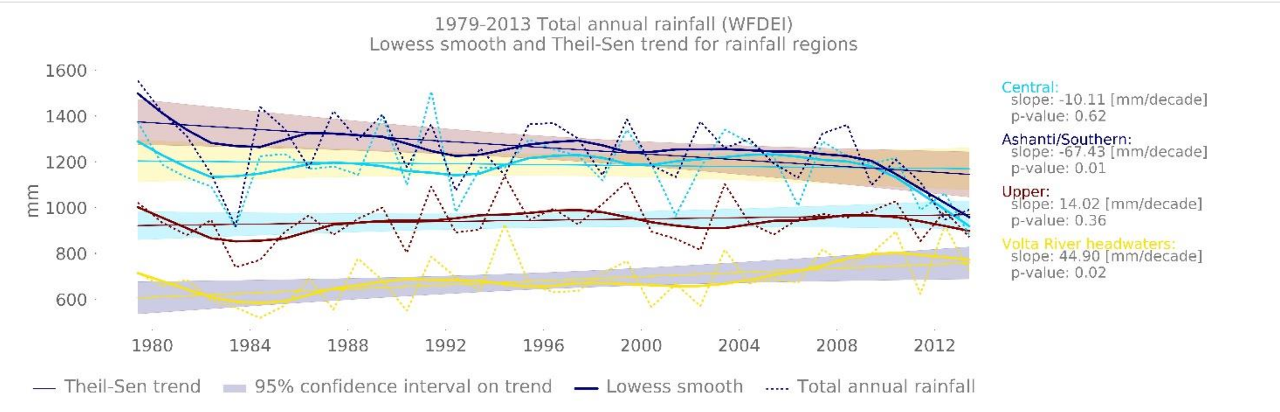


Figure A-1: Long term trends and variability in total annual rainfall for rainfall regions

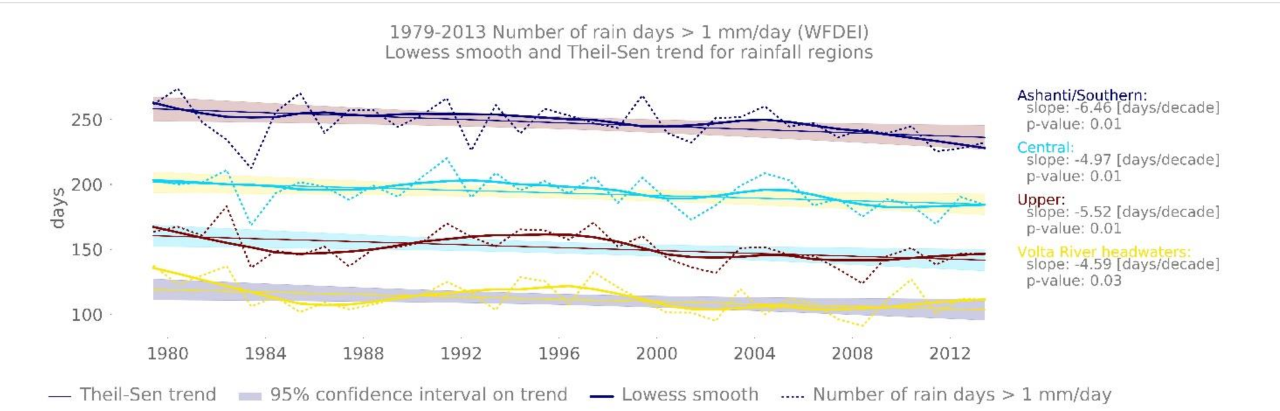


Figure A-2: Long term trends and variability in frequency of rainfall events for rainfall regions

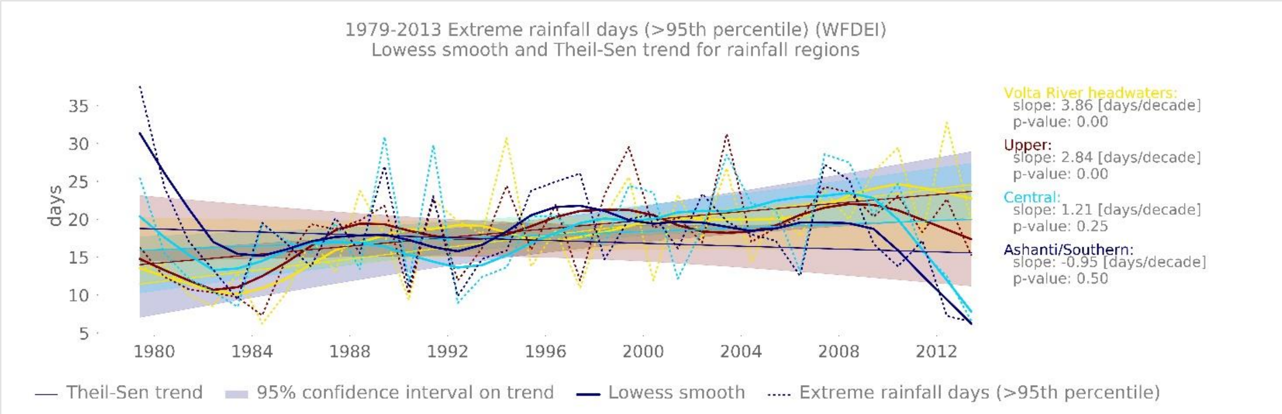


Figure A-3: Long term trends and variability in extreme rainfall events for rainfall regions

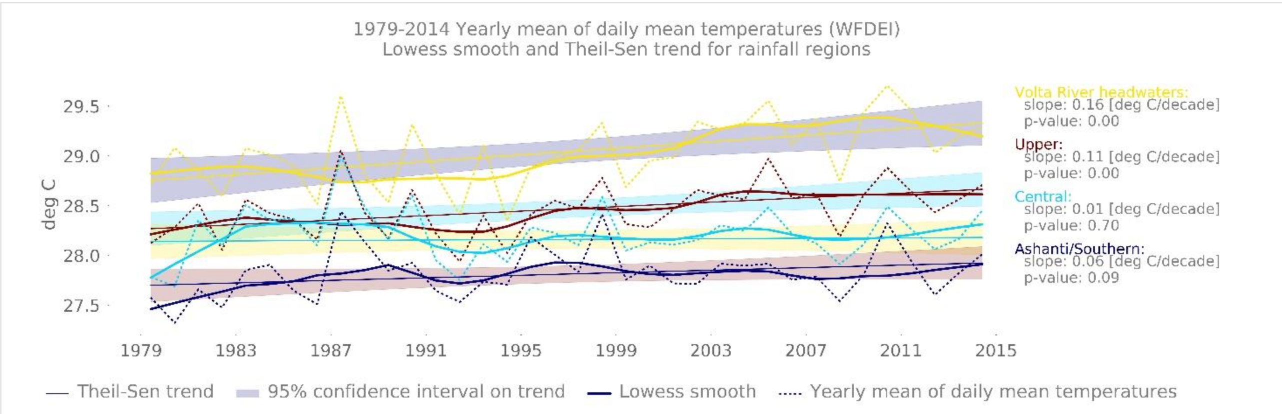


Figure A-4: Long term trends and variability in daily mean air temperatures for rainfall regions

1.c Climate projections visualizations

The plots below (Figures A-5 – A-8) are called plume plots and they are used to represent the different long term projections across the multiple climate models in the CMIP5 model archive used to inform the IPCC AR5 report. The plots show projected variations in different variables averaged over the climate regions. The blue colours indicate variations that would be considered within the range of natural variability, so in other words, not necessarily the result of climate change. The orange colours indicate projection time series where the changes would be considered outside of the range of natural variability and so likely a response to climate change. It is important to note that these are global climate model projections and so likely do not capture local scale features such as topography and land ocean boundary dynamics. They also may not capture small scale features such as severe thunderstorms that can have important societal impacts. Finally, these projections are averages over relatively large spatial areas and it is possible that different messages would be obtained at small spatial scales and if various forms of downscaling are performed.

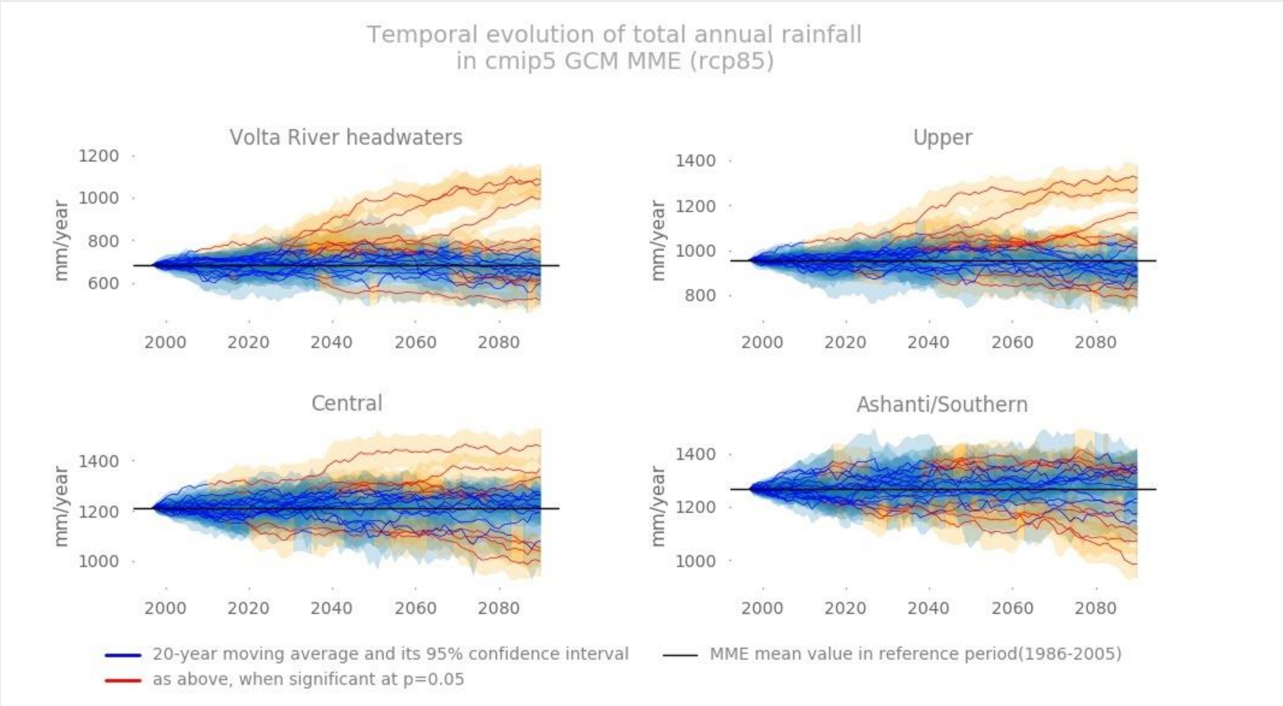


Figure A-5: Projected changes and emergence of changes in total annual rainfall

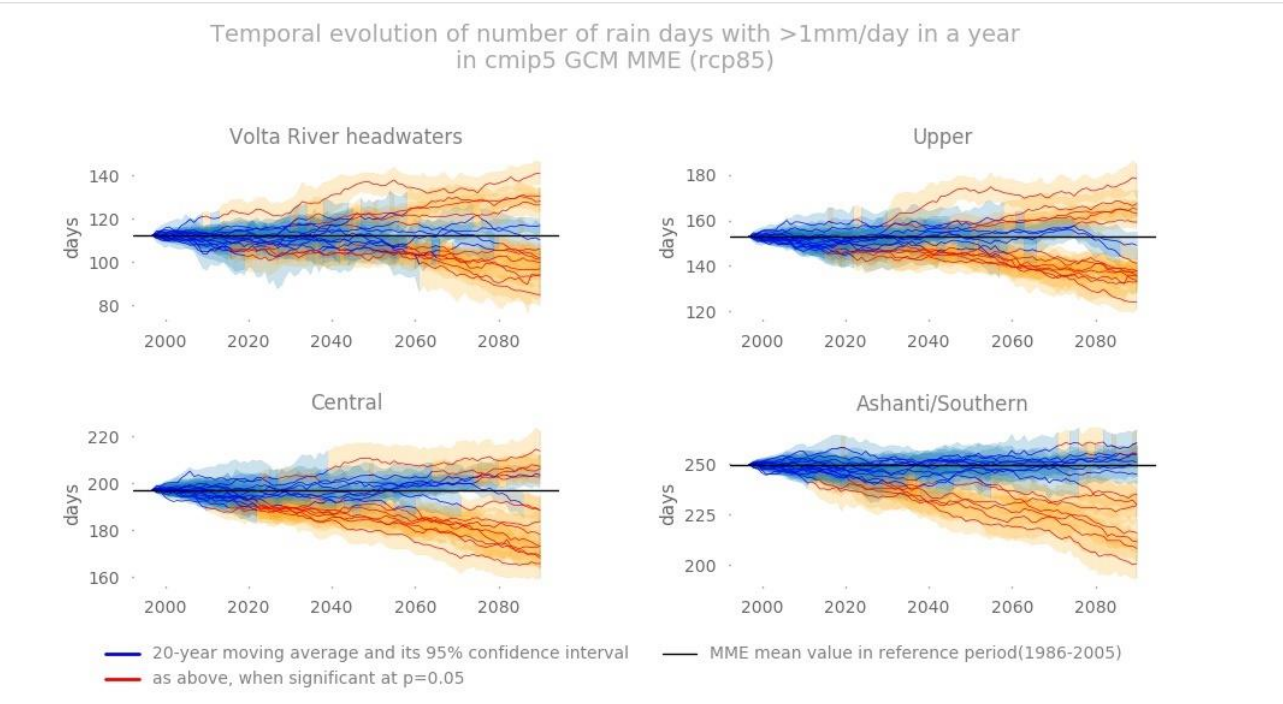


Figure A-6: Projected changes and emergence of changes in number of rain days per year

GHANA

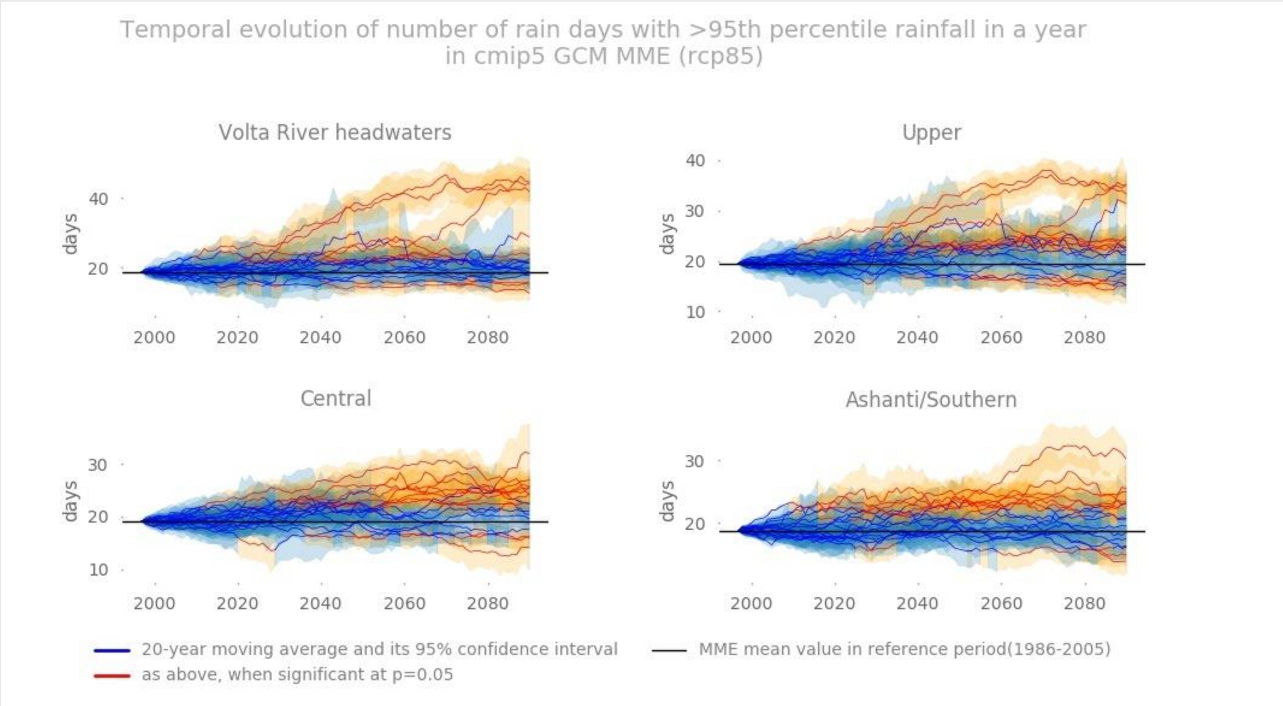


Figure A-7: Projected changes and emergence of changes in number of very heavy rainfall days (greater than 95th percentile) per year

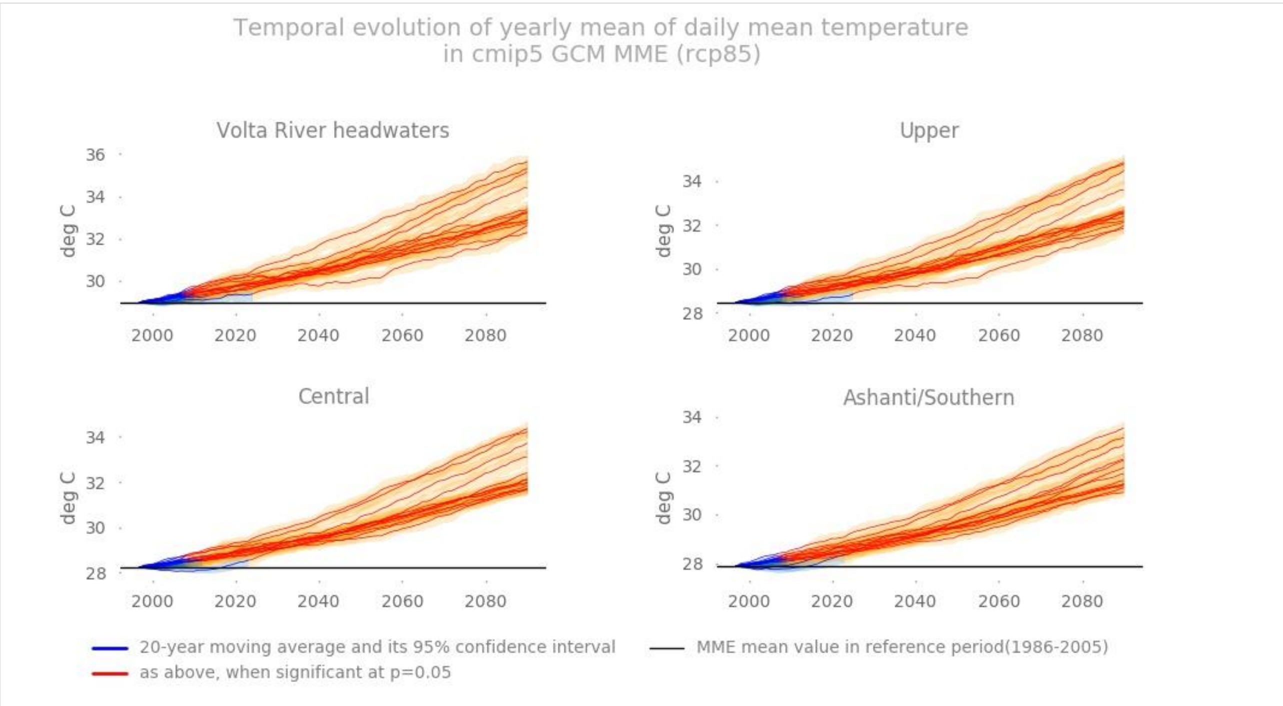


Figure A-8: Projected changes and emergence of changes annual mean daily mean temperatures

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