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Review article

Managing the challenges of climate change mitigation and adaptation strategies in Ghana

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ABSTRACT

Ghana's economy is climate sensitive as more than 80% of its agricultural production is rainfall dependent, with only 2% of irrigation potential used. This has consequences under changing climate, with the impact projected to intensify if things go in a business-as-usual scenario. The manifestation of climate change impact is evident in other sectors of the economy, which requires proactiveness to adapt and mitigate through the development and execution of national adaptation strategies. This research reviews the impact of climate change and some interventions made toward its management. The study explored peer-reviewed journals, policy documents, and technical reports for relevant materials that chronicle programmes and measures to address the challenges of climate change. The research revealed that Ghana had experienced about 1 °C rise in temperature over the past four decades and sea level rise with socioeconomic consequences including decreased agricultural productivity and inundation of coastal communities. Policy interventions have resulted in the introduction of several mitigative and adaptation programmes, such as building resilience in various economic sectors. The study highlighted the progress and challenges to climate change implementation programmes and future policy implementation plans. Inadequate funding of programmes and projects was identified as a critical challenge to achieving climate change policy goals and objectives. We recommend more political will from the government and stakeholders towards policy implementation and greater commitment to providing adequate funding for programmes and project implementation to ensure the success of local climate action for adaptation and mitigation, as well as for sustainable development.

1. Introduction

The climate change phenomenon has become a global challenge affecting human activities in multiple ways. Intense and extreme weather events such as floods, cyclones, tornadoes, forest fires, more frequent torrential rains, prolonged droughts, heatwaves, warmer and more humid winters with less snow, and high wind speeds continue to be experienced in various parts of the world [1–4,93]. This is attributed to increasing atmospheric temperature due to emissions of greenhouse gases (GHGs) from burning fossil fuels, clearing forests, and raising livestock [5]. According to the Organisation for Economic Cooperation and Development (OECD) [6], the world's

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GHGs emissions from various sectors have increased annually for the past decade (2010–2021): agriculture (8%), transport and storage (10.7%), manufacturing (14.6%), electricity (14.8%), construction (14.4%), mining (7%), water supply, sewerage, waste management and remediation activities (20.6%), total households (5.7%) and other service industries (11.7%).

Climate change affects different ecosystems and the services they provide to society. For example, increased infections by insects and fungi, tree mortality, high stress on the components of forest ecosystems, deteriorating and reducing biodiversity that affects production, supply, and other functions that forests provide to society [7,8], and sea-level rise (SLR) which also endanger life and properties in coastal areas that are attractive to human settlement. The global mean SLR increased by 200 mm between 1901 and 2018 [9] due to the evolving climate from the thermal expansion effect and the melting of ice sheets and glaciers. A third of the increase in global sea level happened in the last two and a half decades [10]. Comparing the ten-year annual averages, 1990–1999 to that of 2000–2009, the frequency of natural disasters has shown percentage increases in extreme temperature (143.5), flood (99.4), insect infestation (96.7), epidemics (55.8), wildfires (38), landslide (28), drought (26.3), volcanic activity (17.6) and storms (16.6) [11]. Even after 2010, the frequency of natural disasters is still ascending.

The economic costs and social consequences of climate change (and environmental degradation) disproportionately affect the vulnerable, often people experiencing poverty [1]. This is because three-quarters of people living in poverty rely heavily on ecosystem services or nature-based activities, particularly farming which is negatively impacted by climate change and resulting in decreasing agricultural yields [12]. Also, much of the impact of climate change, which results in chronic water shortages, rising sea levels, flooding, mass population displacement, and damage to productive infrastructure, affect the vulnerable and those impacted by inequalities. The plight of the vulnerable is worsened by erratic weather, limited water sources, and increased competition for resources to the level of life and death. Under the covid-19 pandemic, where millions were plunged into poverty in 2020, climate change is expected to worsen the situation if the pandemic is not mitigated [12]. In this regard, managing ecosystem services, including agriculture, soil, and water resources, is paramount in mitigating the adverse effects of climate change on the vulnerable.

There has been considerable attention on responses to climate change at the global, national, and local levels, which has resulted in two distinct responses [13]. The first relates to measures aimed at slowing down and moderating the pace of climate change which implies cutting down or lessening GHG emissions into the atmosphere, termed mitigation measures. The developed countries have been at the forefront of this drive which is in line with the United Nations Framework Convention on Climate Change (UNFCCC), signed in 1992, the Kyoto Protocol (1997), the EU Emissions Trading Scheme (2005), the Copenhagen Accord of 2009, the Paris Agreement (2015), and Sharm El-Sheikh Climate Change Conference, 2022 (COP 27). The second response to the impacts of climate change is described as adaptation. It includes measures that focus on the capacities of individuals, communities, and nations to handle the effects of changed conditions and take advantage of the opportunities they offer [13]. This need for adaptation has also been highlighted in the agreements, as mentioned earlier, and given a further boost at COP 27 with the creation of funding mechanisms for loss and damage, especially for developing countries that are particularly vulnerable to the effects of climate change [14]. However, responding to climate change through multilateral processes like the UNFCCC could be challenging since it requires consensus among countries with different development agendas on the approach and strategies for reducing GHG emissions and adapting to adverse effects. The challenges include securing the climate financing required for adaptation and mitigation plans to transition developing economies, political will and commitment to policy implementation [15], and knowledge gaps, which require increased cooperation between scientists, researchers, businesses, and public authorities [16].

The impact of climate change is evident to the extent that the United Nations Environment Programme (UNEP) has ranked it as 7th among 21 Emerging Environmental Issues for the 21st century [17]. As a result, countries have reaffirmed their commitment to limit global temperature rise to 1.5 °C above pre-industrial levels through mitigation measures and to adapt by boosting financial support, technology, and capacity building, especially in developing countries [14]. Ghana is in a climate-sensitive zone in west Africa (bordered by the Republic of Togo, Burkina Faso, and Cote d'Ivoire), with climate impacts on the overall economic growth largely negative [10]. With several water bodies and two broad ecological zones: the southern forest zone (30%), the transition belt and Northern Savannah Zone (70%), the country relies heavily on agriculture, forestry, hydroelectricity, and other natural resources [10,18]. As a lower middle-income developing economy with a population of over 30 million with a projected growth rate of about 2% and a GDP of US$77.59 billion (2021) [10,19], the negative impact of climate change on the future GDP is expected to become intense by 2050 [20]. This could result from the multiplicity of factors due to the changing climate and increased resource use due to population growth. The challenges could be dire, notwithstanding recent economic growth facilitated by industry and services due to the developed offshore oil and gas resources. The adverse effects of climate change have been highlighted in national policy documents such as Ghana's National Climate Change Policy [21], National Climate Change Adaptation Strategy [22] and Ghana Nationally Determined Contributions (NDC), which stress the country's urgency to adapt, mitigate and reduce vulnerability in critical sectors for socioeconomic development. Therefore, the government needs to enforce and implement these policies and be proactive in preparing to manage the impacts of climate change by taking advantage of the opportunities outlined in multilateral climate agreements such as COP 27. One of these agreements, known as REDD+ (Reducing Emissions from Deforestation and Forest Degradation), was adopted at the 21st Conference of the Parties (COP 21) to the United Nations Framework Convention on Climate Change (UNFCCC) to manage forests sustainably, conserve, and enhance forest carbon reserves to mitigate climate change and maintain livelihoods in the signatory countries.

This research paper reviews the impact of climate change on critical sectors of the economy, emission levels, and attempts at mitigating and adapting through the development of national policies, strategies, plans, and climate-related projects in Ghana. The critical sectors of Ghana's economy are services, industry, and agriculture. Agriculture, which contributes about 19.1% to the GDP and provides direct employment to 33% [23] of the working population, is mostly affected by climate change. Low and unpredictable precipitation and rising temperature significantly affect agriculture because more than 80% of Ghana's agricultural production is

rainfall dependent. The country's energy sector also depends on rainfall to generate power for both industry and agriculture. For example, poor rainfall between 2014 and 2016 resulted in low power generation, which led to power rationing. This was because the hydropower dams could not generate enough electricity due to inadequate water. The period witnessed a significant closure of industries and a reduction in agricultural and industrial output [24]. Since most people in northern Ghana depend on agriculture for their livelihood, this also impacted their crop production and livestock watering. As a result, a significant number of people migrated to the south for livelihood opportunities [25], and many have become destitute.

The remaining sections of this paper are structured as follows. Section 2 describes the methodology employed in answering the research questions on the impact of climate change in Ghana. Section 3 provides the dimensions of climate change impact in Ghana with subsections detailing the impact on water supply, health, agriculture, forestry, and natural resources. Section 4 details the GHG emissions levels, mitigation and adaptation policies, strategies employed, and the progress and challenges with implementation and sectoral adaptation options in the water, health, and agriculture sectors. Section 5 concludes the paper by summarising the impact of climate change in Ghana and recommendations.

2. Methodology

The study is more of a qualitative investigation of current and developing challenges regarding the effects of climate change, with a focus on Ghana, rather than a systematic review or meta-analysis. This research paper sought to address the following questions: what are the impacts of climate change and its manifestation on the critical sectors of the economy of Ghana? What are the policies, strategies, and plans aiding Ghana's management of climate impacts through adaptation and mitigation? An extensive literature review was conducted to answer these research questions and obtain information on crucial life-supporting sectors such as agriculture, forestry, ecosystem services, water, and health. These sectors were selected because they were considered relevant to meeting the challenges associated with the impact of climate change, as emphasised in the Ghana National Climate Change Policy [21] and Adaptation Strategy.

To answer the first and the second research questions, an online literature search was conducted on Google Scholar and Google search engines, providing a wide range of information that cuts across various journals [26] and national and multilateral climate change documents. Examples include Nature, Scientific African, Land use policy, Climate risk management, Ecosystem and echography, and Environmental sciences. The multilateral includes documents from the UNFCCC and the World Bank Group. The search focused on the impact of climate change in general and then zeroed in on national and sub-national levels for information on mitigation and adaptation strategies in Ghana. The search was done without a specific time interval to obtain as much information as possible [26]. Numerous keywords and phrases were used in the search about the subject area of the research topic, including "impact of climate change", "climate impact in Ghana", "climate change + policy + Ghana", and "climate change + adaptation + mitigation + strategy". Other documents were retrieved, which were numerous to be mentioned and helped answer the second research question. Examples include the National Climate Change Policy (2013), National Climate Change Master Plan Action Programmes for Implementation (2015–2020), National Climate Change Adaptation Strategy (2012), Nationally Determined Contributions (NDC) on climate change (2015), Updated NDC 2020–2030, the Fourth and Fifth Greenhouse Gas Inventory Reports of Ghana (2019 and 2022, respectively), The World Bank's Climate Risk Country Profile of Ghana (2021), Ghana's Fourth National Communication to the UNFCCC (2020), Ghana's Adaptation Communication to the UNFCCC (2021).

In addition, the International Monetary Fund (IMF) and the United Nations Children's Fund (UNICEF) datasets https://climatedata.imf.org/pages/climatechange-data and https://data.unicef.org/resources/resource-type/datasets/, respectively provided data for this research paper.

3. Dimensions of climate change impact in Ghana

Climate change impacts are varied and include adverse weather conditions, such as increases in extreme weather events, which could limit human actions and responses [27]. The impacts of climate change could also present developmental opportunities or gains by building a climate-resilient economy [28]. There has been a progressive rise in temperature, which will continue even if there is a significant reduction in GHGs emissions [9]. In Ghana, it was found that the observed mean annual temperature has risen more than 1 °C in the past decades [10,29,30]. The impact of climate change also manifests in reducing rainfall in the forest, forest-savanna (transition zone), and savanna zones of Ghana. Since the 1960s, an overall reduction in cumulative rainfall of 2.4% per decade has been observed in Ghana [30], with a decline in the middle belt and high intensity in the north and south of the country and the possibility of increased dry spell durations. Even with this increase, the temperature is expected to rise further in a business-as-usual scenario when efforts are not made to reduce GHG emissions. For instance, in Accra, the wet season is expected to have a rise in the

Table 1
CMIP5 ensemble projection of climate change.

CMIP5 Ensemble projection	2020–2039	2040–2059	2060–2079	2080–2099
Annual temperature anomaly (^{O}C)	+0.6 to +1.5 (+0.9 °C)	+1.2 to +2.7 (+1.7 °C)	+1.7 to +3.8 (+2.7 °C)	+2.3 to +5.3 (+3.6 °C)
Annual precipitation anomaly (mm)	−16.7 to +22.0 (+0.9 mm)	−22.2 to +30.4 (+0.3 mm)	−22.9 to +38.9 (+2.9 mm)	−29.7 to +45.2 (+1.6 mm)

The range values (10th–90th Percentile) and values in parentheses show the median (or 50th Percentile).
Source: The World Bank Group (2021): Climate Risk Profile of Ghana

average temperatures of 1.68 ± 0.38 °C by 2050 and 2.54 ± 0.75 °C by 2080; the dry season was projected to have 1.74 ± 0.60 °C by 2050 and 2.71 ± 0.91 °C by 2080 [31]. Similar temperature projections have been recorded in all agroecological zones across the country [10,32]. These observed and projected increases have a consequential impact on ecosystem services and a domino effect on society's well-being.

Table 1 shows the CMIP5 (Coupled Inter-comparison Project No.5) of the Fifth Assessment Report (AR5) of the Intergovernmental Panel on Climate Change data ensemble obtained from the World Bank Group's Climate Change Knowledge Portal (CCKP), which provides annual temperature and precipitation change projections under different emission scenarios or representative concentration pathways (RCP) (low = RCP 2.6; medium = RCP 4.5; and high = RCP 8.5) [33]. This research paper highlights the high emission scenario (RCP 8.5) situation over four different time horizons [10]. The projection under RCP 8.5, where GHG emissions follow the business-as-usual scenario without mitigation measures, shows that the mean annual temperatures will increase by 0.6 °C–1.5 °C around the 2030s, 1.0 °C–3.0 °C around 2050s and by 2.3 °C–5.3 °C by 2099 (Table 1). These projected temperature increases are expected to cause rapid warming in the northern and inland parts of Ghana. The positive temperature anomalies (change) in the ensemble projections (Table 1) show that the observed annual temperatures will be warmer than the baseline in all emission scenarios of the different time horizons. Some manifestations of temperature increases are expected to be seen in the frequency of hot days and

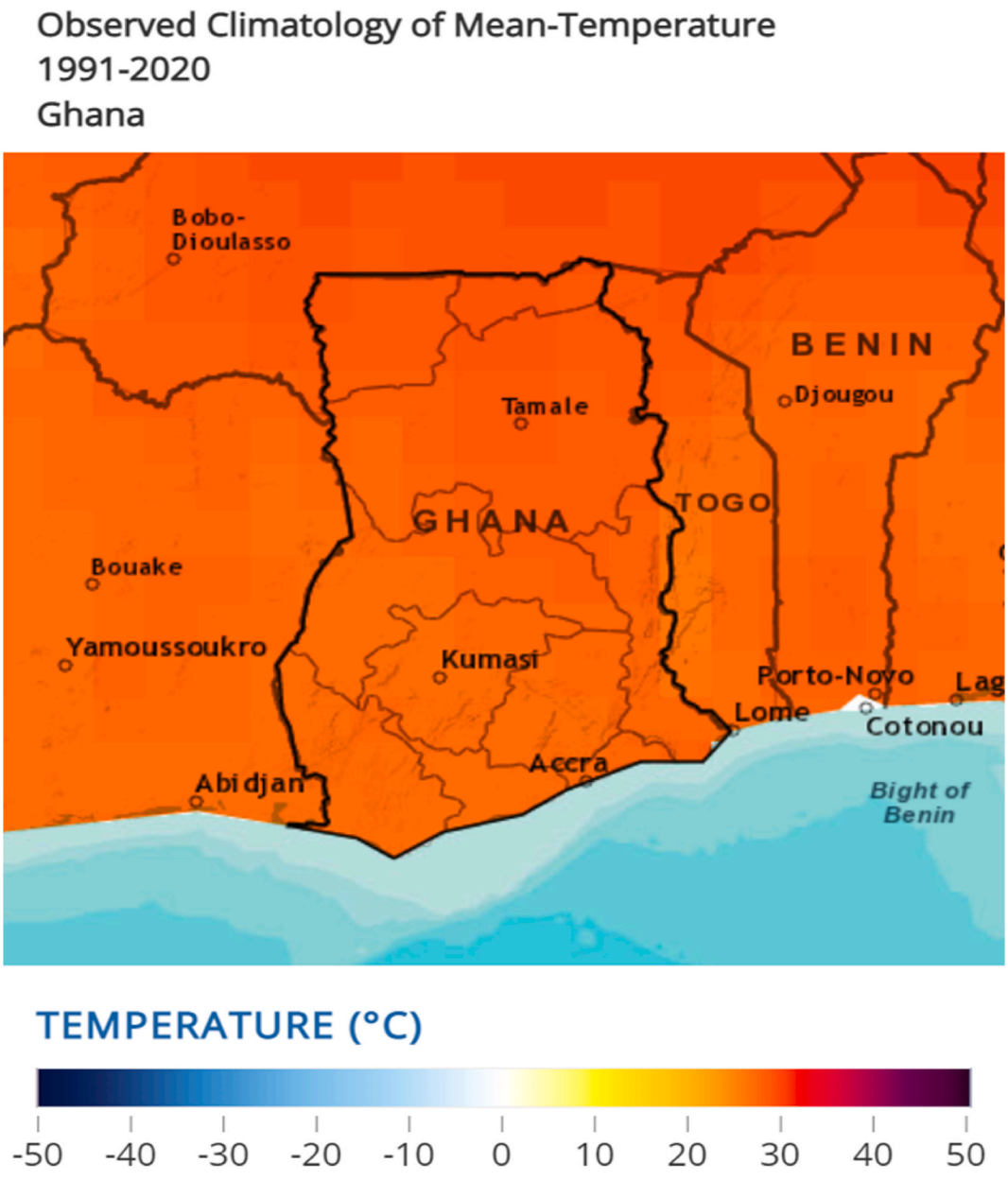

Fig. 1. Observed mean temperature over the period 1991–2020. Source: Climate change knowledge portal: World Bank Group, 2021.

nights and a decrease in the number of cold days [10,30]. Within the same time horizon, the projections show anomalies in precipitation of −22.2 mm to +30.4 mm around 2050 and -29.7 mm to +45.2 mm by the end of the century. This translates into decreasing and increasing rainfall events in the wet season and lower levels during the dry season. The negative and the positive anomalies in precipitation have implications of expected drought and flooding, which have consequences on important sectors such as agriculture and water resources. The northern zones, especially, are expected to experience lower rainfall than the southern zone. These projections of the changes in the annual temperatures and precipitations have consequential effects on crop production [25,29], where the growth of crops such as sorghum, maise, millet, cowpeas, yam, and groundnuts are likely to be negatively affected. Figs. 1 and 2 further shed light on changes in observed mean temperature and the annual average temperature in Ghana from 1991 to 2020 and 1901–2021, respectively, due to climate change. Fig. 2 shows that temperatures have increased by approximately 1 °C above the baseline since the 1960s.

In recent years, extreme weather events have also been experienced in almost the entire country, exposing its vulnerabilities to these occurrences and raising questions about its preparedness to cope. Several studies [33–37] have also revealed the impact of climate change on hydroelectric power generation in Ghana. These studies have further indicated that both drought and flood negatively affected the operational water level of the country's main hydroelectric dam (Akosombo) on Volta Lake. The drought reduced the agricultural production around the lake's catchment area and water level for power generation. Flooding posed structural problems to the dam and horizontal displacement of many settlement structures and farmlands, given the low-lying nature of most parts of the lakeshore. Usually, devastation of this nature results in high mitigation and resettlement costs [35]. Therefore, low water levels and the displacement of settlements due to climate change significantly impact the country's socioeconomic activities. With the prediction that extreme events will be on the rise, hydroelectricity generation must be augmented with renewable energy sources (solar, wind, tidal waves) and enhancement of early warning systems.

Several studies have also indicated the impact of SLR along the coastal areas of Ghana [10,30,38–43]. Some of these studies have indicated variable sea levels with varying intensities and impacts along the coast. According to Appeaning Addo, the sea rose by about 2 mm per year in 2008, with average coastal erosion of about 1.13 m per year along the coast of Accra [38,39], and is expected to increase further between 2 and 6 mm per year in the future [92]. The expected increase in the future will cause a recession at varying degrees, with much of the coastal lands lost [39]. Follow-up studies by Evadzi et al. [41] reported that Ghana's average sea level rose by about 53 mm from 1996 to 2017, accounting for ~31% of the observed annual coastal erosion. However recent average annual rise rate is about 3 mm per year [10], showing a 50% increase within a decade and a half. The rising sea level is therefore inching closer to the global average of 3.7 [3.2–4.2] mm per year (2006–2018) [9]. Evadzi et al. [41], in their research using IPCC AR5 (RCPs 2.6, 4.5, and 8.5 scenarios), projected future increases of SLRs of 146.2 mm, 206.4 mm, and 335.4 mm by 2100, respectively. The study further projected a high risk of inundation of 2.66 km^2–3.24 km^2 of settlements, 2.10 km^2–2.58 km^2 of lagoons and 1.39 km^2–1.71 km^2 of wetlands by mid-century for low and high-emission scenarios, respectively, and likely to worsen by the end of the century without effective mitigation [40]. These research findings confirm predictions and the implications of SLR in IPCC's special report on the ocean and cryosphere, emphasising increasing global mean sea level and related challenges [44]. In Ghana, communities on the eastern coast are affected mainly by SLRs, such as in Ada, Keta, Ningo, and Prampram, and with attendant impact on mangrove forests, erosion,

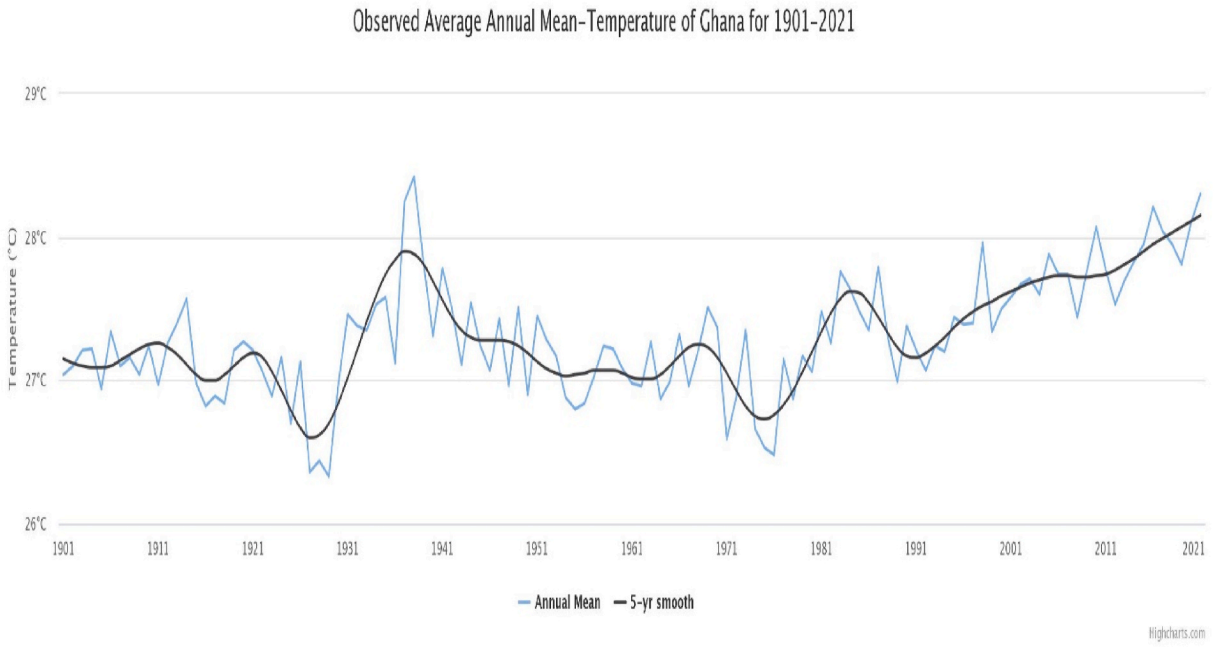

Fig. 2. Observed annual average temperature over the period 1901–2021. Source: Climate change knowledge portal: World Bank Group, 2021.

agriculture, loss of houses, and other infrastructure such as fish landing sites, and beach resorts.

3.1. Impact of climate change on water supply

According to the UNFCCC [45], more than 2 billion people are experiencing severe water security threats, likely to worsen due to climate change and increased population and water demand. The UNFCCC Report further affirmed that by 2030 water scarcity in some arid and semi-arid places would displace between 24 million and 700 million people in the current climate change scenario. This is expected to worsen due to increasing pollution, as 12% of the world's population drinks water from unreliable and unsafe sources [45]. In Africa, the impact is projected to be severe on water supply and sanitation infrastructure [46]. The projection for Ghana indicates that by 2050, the demand for water, hydropower, and municipal and agricultural uses in and around the Volta basin cannot be achieved. McCartney et al. [47] further confirm a reduction in water flow in the Volta Basin by 24% by 2050 and 45% by 2100 because of an expected reduction in rainfall, high temperature, and evaporation rates [30]. Ghana's hydropower (from the Akosombo, Kpong and Bui dams) which provides about 54% of national generation capacity, is projected to suffer a reduction in power generation by 50% by 2050 [30]. Studies by Amisigo et al. [34] further corroborate the impact on water resources in Ghana in terms of water availability and quality in the Volta basin.

According to Kankam-Yeboah, referenced in Owusu et al. [48], Ghana will experience water stress even without climate change considerations by 2025. The impact of water insecurity is being felt, with an estimated 25% of communities lacking access to clean water and sanitation, a situation that could be exacerbated by climate change [10]. Other effects of climate change on water availability are rising sea levels in the southeastern coastal areas that infiltrate underground aquifers and the increasing salinisation of surface and subsurface waters [30,49]. This reduces access to quality water, and the situation is also exacerbated by anthropogenic activities such as illegal mining and inappropriate use of agrochemicals that pollute water bodies [50,51]. Therefore, the increase in water pollution and its impoundment for potable water production requires a high water treatment cost by utility companies.

Since water remains an essential resource for sustaining life and development, climate impact significantly affects socioeconomic conditions and the livelihood of the populace. The effects of dwindling water supply include health and sanitation problems such as increased incidence of waterborne diseases, decreasing hydroelectric power, negatively impacting energy for industrialisation drive, job creation, domestic consumption, and quality of life. The need for hydropower will likely increase future conflict and political tensions with neighbouring countries [30] (e.g., Burkina Faso, Benin, Côte d'Ivoire, and Togo) that depend on transboundary water sources such as the Volta River Basin for damming and hydroelectricity. This also has the attendant risk of increased business costs, likely due to the high cost of electric power. Dwindling water supply for agriculture also has food insecurity implications and the livelihoods of riparian communities. Climate-induced water scarcity will require extra time, resources and efforts to search and collect water, with a greater impact on women and children.

3.2. Impact of climate change on health

Climate change has multiple influences on human health due to heat stress [52]. Both direct and indirect impacts are expected due to this phenomenon. These include alterations in the geographic range and intensity of transmission of disease vectors (insect, tick, and rodent), food and waterborne diseases, and the prevalence of diseases associated with air pollutants and aeroallergens [53]. Dengue, yellow, and malaria fevers are expected to become more prevalent under changing climates, including communicable diseases such as HIV/AIDS, cholera, and tuberculosis [10]. Non-communicable diseases (NCDs) and acute and chronic respiratory conditions like chronic obstructive pulmonary disease and asthma, diabetes, cardiovascular disease, cancers, and malnutrition can be exacerbated by climate change [52,54].

The incidences of direct and indirect impacts, such as deaths from heatwaves and floods, can increase. Studies by Rodgers et al. [55] estimated that climate change may already be causing over 150,000 deaths per year, with the fear that the number could double globally by 2030 [55]. Further, the World Health Organisation (WHO) [56] has also shown that heat-related death in the elderly (65+ years) is projected to increase under high emission scenario to 70 deaths per 100,000 by 2080 compared to the estimated baseline of approximately two deaths per 100,000 annually between 1961 and 1990 in Ghana. The situation is alarming as another study by Monash University, seen as the world's most extensive survey, further attributes 5 million deaths annually to extreme temperatures [57].

Ghana is among the countries at risk of direct exposure to climate change and its impacts on waterborne diseases [58]. It is the 64th most vulnerable and the 124th most ready country in the world, ranking 111th out of 182 countries for climate vulnerability, indicating that it is both vulnerable to and only moderately prepared to deal with the effects of climate change [59]. This requires significant investment and innovation to improve preparedness with urgency. With climate change, measles and guinea worm infestation cases are projected to increase due to rising temperatures and reduced rainfall [32]. The relative risks of diarrhoea are projected to increase by 8–11% (2010–2039) and 22–29% by the end of the century [60]. The resilience of invasive aquatic weeds and their increased spread due to climate change also facilitates the prevalence of water-dependent disease vectors. This includes mosquitoes and water snails that spread malaria, yellow fever, encephalitis, and schistosomiasis. There is a risk of increased exposure to dusty harmattan winds resulting in the severity of respiratory diseases such as asthma and meningitis [30]. Food insecurity due to climate change is further aggravating the impact on health. For instance, food insecurity can lead to hunger and malnutrition in vulnerable groups and negatively impact their health. By 2050, the risk of hunger and malnutrition is predicted to rise by up to 20% globally, necessitating the development of resilience to deal with the effects [10]. In Ghana, 13.4% of children under five are malnourished [61], which suggests that food insecurity may worsen malnutrition under climate change.

3.3. Impact of climate change on agriculture

The importance of agriculture to the economy of Ghana cannot be over-emphasised because of its contribution to economic growth, livelihoods, and food security. Before 2010, agriculture was the most significant contributor to Ghana's GDP. However, this has been overtaken by the industry (36.3%) and services (44.6%) sectors between 2010 and 2020, with agriculture at 19.1% of GDP [62]. This is attributed to the discovery and production of crude oil in commercial quantities, which is impacting the growth of industry and services. Notwithstanding the position of agriculture as the third contributor to GDP, it is an important sector for the Ghanaian economy and employs a great number of the country's labour force, as indicated earlier.

Climate change and variability influence rainfall patterns, resulting in early or late rainfall, increased rainfall intensity and flooding, and persistent drought that destroys crops. These have been attributed to inadequate adaptation and mitigation practices, over-reliance on rainfall, and limited irrigation capacity for all-year-round farming [63]. As a result, the country has to contend with low precipitation and drought that lead to low crop production, as only 2% of the country's irrigation potential is used [10]. The impact on cash crops such as cocoa could be dire because it is temperature and drought sensitive. Moreover, cocoa-producing areas along the coast of Ghana are also negatively impacted due to increasing floods, erosion, and soil salinisation, which affect cocoa production [30].

Rising temperatures are projected to lower the yields of major staple crops such as cassava, yams, plantains, maise, and rice. It has been projected that maise and other cereal crops will reduce by 7% by 2050 and cassava by 29.6% by 2080 [64]. A study by Kyei-Mensah et al. [65] has also indicated an average decline of 16% in the yield of cassava, cocoyam, and plantain in the Fanteakwa District of Ghana due to climate variability. The risk of total crop failure in northern Ghana is projected to occur about once every five years due to reduced or delayed rainfall [10]. Crop failures also threaten the northern sector, which mostly sustains the nation with food due to increased temperature. Therefore, food crops such as sorghum, maise, millet, cowpeas, yam, and groundnuts are experiencing declining production [29]. Also, a temperature rise and reduced rainfall could shorten the growing season, leading to the desertification of agricultural land by unsustainable farming practices [66].

Furthermore, the increased prevalence of pests and diseases exacerbates crop yields [10], such as the outbreak and incidence of fall armyworms that have become a major threat to maise production in Ghana [67]. The fisheries sector is projected to be impacted since rising sea surface temperatures will negatively affect the availability of some critical fish species' and alteration of their reproductive cycles and migratory patterns (e.g. anchovies, sardines, tilapia, shrimp and catfish). The projection of a rise in sea surface temperatures ranging from 2 to 4 °C by the end of the century [30] could aggravate the situation and cause a further decline in fish availability. Climate change could further worsen the spread of invasive aquatic weeds (such as water hyacinth, *Salvinia,* and *Pistia*) that can adversely affect fishing and the livelihoods of riparian communities in the country. Therefore, the over 200 million spent annually on importing seafood could be attributed to declining fish stocks due to climate change [30]. These challenges in declining agriculture production due to climate change are likely to jeopardise the employment of about 60% of the active population [65] and are also likely to increase food prices in major cities. Decreasing agricultural yield due to climate change is projected to cause a decline in Ghana's GDP, with great implications for food security, protein nutrition deficits, income, and livelihoods.

3.4. Impact of climate change on forestry and natural resources

The forest and its resources are critical to the economic growth and sustenance of the livelihoods of many of the rural populations in Ghana. Approximately 71% of the people are employed in forestry, agriculture, and fishing in rural areas [10]. The sector is a primary source of employment for the 300,000–350,000 new workers who enter the labour force each year [10]. Apart from this vital role, the forest also serves as a carbon sink to help regulate the climate. It has been estimated that tropical forests store between 120 and 400 tons of carbon per hectare or up to 3000–6000 tons per hectare for carbon-rich peat forests [68].

At the beginning of the 20th century, Ghana had a high forest of 8.2 million hectares and 1.1 million hectares of forest-savannah transition. By the early 1990s, about 80% of the high forest had been lost for various uses [69]. As a result, Ghana has been cited as one of the highest net losers of forest cover in the humid tropics because of widespread bush fallowing farming, timber exploitation, fuelwood harvesting, and wildfires. Deforestation contributes about 17.4% of anthropogenic GHG emissions [70], and tropical forest degradation accounts for 25% of emissions [71]. High temperatures and prolonged drought due to climate change result in wildfires which in turn cause habitat destruction and loss of biodiversity. This challenge is compounded by unsustainable logging and hunting practices, causing loss of biodiversity, ecosystem services, and species extinction [1] and could negatively impact reforestation and afforestation efforts.

4. Emissions, mitigation, adaptation policies, and strategies in Ghana

4.1. Greenhouse gas emissions

Ghana's greenhouse gas (GHG) emissions are relatively low (59.80 $MtCO_2e$) compared to global estimated emission levels of approximately 50 billion metric tons of carbon dioxide equivalent (GtCO2e) as of 2019 [72,73]. The most recent GHG emission estimate of 59.8 million tonnes (Mt) of CO_2-equivalent (CO_2e) [72] was mainly emitted from agriculture, land use and land use change and forestry (LULUCF), industrial processes and product use (IPPU), energy, and waste sectors. The emission trend in Ghana shows increased GHGs (Table 2) from 1990 to 2019. The energy sector was the major source of emissions accounting for 45.7% of total emissions. The second largest source was agriculture, forestry, and land use (AFOLU), constituting 44.6%, followed by the waste sector

at 6.9% and then the IPPU sector at 2.9%. Except for IPPU, which recorded a decline of about 11.8% from 1990 to 2019, all the sectors recorded emission increases. The general trend was attributed to economic expansion with increased production and a corresponding increase in GHG emissions. Increased emissions from road transportation, fossil-fueled electrical generation, biomass, and deforestation occurred concurrently with population growth [72].

4.2. Mitigation, adaptation strategies and national policy initiatives

Notwithstanding the emission increase from 1990 to 2019, some mitigation strategies have supported emission removals in response to the fight against climate change. They include the implementation of a forest plantation development program targeted at planting trees on degraded forest lands and the establishment of a plantation development fund to encourage private-sector plantation development, and a government policy banning the export of round logs for enhancing local timber processing [72]. Others are the GHG emission control in the industry, such as in the IPPU sector, which has resulted in the decline of emissions by about 11.8% between 1990 and 2019 [72]; natural gas recovery and utilisation and restriction of gas flaring in the oil and gas industry; scaling-up renewable energy; clean cooking and lighting; energy efficiency in households, commerce, and industry; and innovative waste management through waste reduction, recycling and reuse.

Because of the development opportunities that come with adaptation and mitigation, the global community aligns positively with climate change as a sustainable development issue. The IPCC's Fourth Assessment Report corroborated the development angle, underscoring the need to integrate GHG emission reduction in its development trajectory [74]. Against this backdrop, Ghana's National Climate Change Adaptation Strategy [22] was developed to stress the country's urgency to adapt to climate change. The NCCAS aims to reduce vulnerability in critical sectors and socioeconomic development areas. Another strategic document, the Ghana National Climate Change Policy [21], highlights four thematic focus areas concerning climate change adaptation. These include agriculture and food security; natural resources; infrastructure; and disaster preparedness and response. Since the passing of the strategy and the policy, adaptation strategies have been pursued at various levels relating to policy direction, such as capacity building and project implementations. These range from large-scale national programmes to small-scale community-level and individual initiatives.

The priority areas of the NCCP include increasing national awareness, mainstreaming climate change impacts and adaptation into sectoral policies, plans, and programs, addressing long-term investment risks, dealing with extreme weather events, improving observation and early warning systems, strengthening the research and development base, and fostering partnerships and international cooperation. Several other policy initiatives have been undertaken to translate these priority areas into action programmes and integrate them into national and local development plans. These include the development of a guidebook on integrating disaster risk mitigation and climate change into national development programmes, policies and plans in 2010; Ghana National Climate Change Master Plan Action Programmes for implementation (2015–2020); mainstreaming climate change in district medium-term development plans, as well as the National Adaptation Policy Framework, a crucial tool for enhancing the emphasis on adaption. Table 3 highlights some policy-related project initiatives for Ghana's climate change adaptation and mitigation.

On the part of climate change mitigation, Ghana has submitted a set of fifty-five (55) Nationally Appropriate Mitigation Actions (NAMA) in response to the Copenhagen Accord [75] and Ghana Nationally Determined Contributions (NDC) for Climate Change Adaptation and Mitigation [28]. The NDC reaffirms Ghana's commitment to the Paris Agreement. It highlights the country's long-term mitigation and adaptation goals and ways to build resilience, synergy and reduce vulnerabilities, and enhance efforts at building a green economy. The NDC also addresses the priorities for sustainability in other national policy documents, including the Ghana @ 100 development frameworks, the National Infrastructure Plan (2018–2047), the Coordinated Programme of Economic and Social Development Policy, the Medium-Term Development Policy Framework (2022–2025), the Ghana Beyond Aid Charter Strategy and the COVID-19 Alleviation and Revitalisation of Enterprises Support [28]. As indicated in the NDC, the sectors with the highest priority for adaptation and mitigation of greenhouse gases include agriculture, transport, promotion of energy efficiency, renewable energy, and

Table 2
National GHG emissions by sector contributions in 1990, 2000, 2016 and 2019 and the percentage changes for 1990–2019 and 2016–2019, compared to the population and GDP.

Sectors/Categories	Total Emissions ($MtCO_2e$)				Percentage change	
	1990	2000	2016	2019	2016–2019	1990–2019
National Emissions with LULUCF	25.0	26.2	51.4	59.8	16.3	139.2
National Emissions without LULUCF	10.7	12.8	38.0	45.3	19.2	323.4
Energy	2.86	4.07	22.4	27.3	21.9	854.5
Industrial Processes and Product Use	1.96	0.90	1.68	1.73	3.0	−13
Agriculture, Forestry, and Other Land Use	19.0	19.53	23.73	26.64	12.3	40.2
Waste	1.1	1.6	3.6	4.1	14	265.1
Population (million)	14.43	18.91	28.21	30.42	7.8	110.8
GDP (Constant 2015 USD billion)	13.17	20.01	51.07	62.47	22.3	374.3
GHG emissions per capita (tCO_2e)	1.73	1.39	1.82	1.97	8.2	13.9
CO_2 emission per capita (tCO_2)	1.18	0.91	1.25	1.38	10.4	16.9

Source: EPA, 2022: National Greenhouse Gas Emissions Report, 2021
Source: Environmental Protection Agency (EPA, 2022). Ghana's Fifth National Greenhouse Gas Inventory Report to the United Nations Framework Convention on Climate Change (UNFCCC).

Table 3
Some policy-related project implementations on climate change adaptation and mitigation.

Project title, location, and duration	Activity	Development partners; Government partners; Funding amount
Ghana Forest Investment Program, HFZ, (GFIP) (2015–2023)	This project seeks to (1) improve forest and landscape management with communities, (2) implement institutional reforms and policy strengthening, (3) enhance trees and agroforestry practices in cocoa forests (4) make on-reserve investments for REDD+ and plantations.	World Bank; Ministry of Lands and Natural Resources (MLNR)/Forestry Commission (FC); US $50 million program
Ghana Cocoa Forest REDD + Program, HFZ, (GCFRP) (2019–2025)	The project covers 5.9 million ha of the high forest zone (HFZ). It is being implemented in identified hotspot intervention areas (HIAs) through five main pillars of activities that require concerted actions by stakeholders: **(1)** institutional coordination and monitoring, (2) landscape-level land-use planning, (3) climate-smart cocoa production, (4) risk management and finance, and (5) legislative and policy reforms.	World Bank; MLNR/FC, Ministry of Food and Agriculture (MoFA)/Ghana Cocoa Board (Cocobod); US$230million, US$50 million performance-based payments
Cocoa and forests Initiative (CFI), cocoa areas, (2019-)	This project is committed to a no-deforestation supply chain from Ghana (and Cote d'Ivoire), partnering with the GoG. Companies in the cocoa sector are taking concrete steps and investing to end cocoa-related deforestation and support reforestation. The main actions were focused on forest protection and restoration, sustainable cocoa production and farmers' livelihoods, and community engagement and social inclusion.	World Cocoa Foundation, Dutch Sustainable Trade Initiative; MLNR/FC, MoFA/Cocobod
Form Ghana Reforestation Project, Ashanti Region (2017-)	This project aimed to restore 11,700 ha of degraded forest reserves by establishing a large-scale sustainable commercial forest plantation with the Government of Ghana (GoG). It also focuses on producing billets, poles, and round logs for local and export markets.	African Development Bank, Forest Investment Program; MLNR/FC; US$24million
Community Resource Management Area (CREMA), nationwide	The CREMA mechanism is Ghana's natural resource management and landscape- level planning tool for community initiatives. The FC's Wildlife Division developed it to enable community-based natural resource management in off-reserve lands. CREMAs fill a critical policy gap by giving communities the right to govern, manage, and benefit economically from their natural resources (Kasanga, 2003; Sarpong, 2006). At least 30 CREMAs across Ghana, with an estimated 500,000 + ha under management. CREMA now supports eco-tourism, NTFP value chains, climate-smart cocoa production, REDD+, etc.	MLNR/FC (Wildlife Division)
Increased Resilience to Climate Change in Northern Ghana (2016–2020)	The project sought to achieve climate change resilience and adaptive capacity by managing water resources and diversifying rural livelihoods in the Upper East, Upper West, and Northern Regions. Results centre on improved water access and increased institutional capacity and coordination.	UN Development Programme; MESTI; US $8.3million
Program on Affirmative Finance Action for Women in Africa (AFAWA): Financing Climate-Resilient Agricultural Practices in Ghana, NSEZ (2019–2024)	This project aims to empower women groups in the climate-vulnerable NSEZ to participate in low-emission, climate-resilient agricultural practices. The project provides concessional loans and technical assistance to women-led enterprises and farmer-based associations.	African Development Bank, Green Climate Fund; MoF, MoFA; US$20 million
Sustainable Land and Water Management Project (SLWMP), Northern Savannah, (2014–2020)	The project aims to expand the area under SLWM practices in selected watersheds. The specific goals are to (a) improve SLWM practices to reduce land degradation and enhance the maintenance of biodiversity in selected micro-watersheds and (b) strengthen spatial planning to identify linked watershed investments in the Northern Savannah region. SLWM activities are ongoing in 174 communities within 12 districts across northern Ghana.	GEF, World Bank; MESTI; US$28 M project (which includes US$14.77 M in additional financing)
Urban Health and Short-Lived Climate Pollution (SLCP) Reduction Project, Accra (2017 -)	The initiative aims to mobilise the health sector to support policy action to mitigate climate change and air pollution. It emphasises the health risks of air	WHO; MESTI/EPA, Ministry of Health/Ghana Health Service

(*continued on next page*)

Table 3 (*continued*)

Project title, location, and duration	Activity	Development partners; Government partners; Funding amount
	pollution and climate change to the public and other economic sectors, hoping to compel constituencies and policymakers to act.	

Source: World Bank, 2020: Ghana Country Environmental Analysis

waste management with a focus on REDD+ and the Low-carbon Emission Road map.

4.3. Forests protection

Since 2001 Ghana has been implementing the National Forest Plantation Development Programme (NFPDP) to expand its forest resource base to satisfy wood demand and enhance environmental quality. This was accomplished through the reforestation of degraded forest lands, with a yearly planting target of 20,000 ha [76]. The extent of deforestation in the nation led to an increase in the most recent replanting efforts spearheaded by the Forestry Commission [69]. Even so, the reforestation efforts suffer challenges such as poor management of plantations, widespread illegal logging, deviation from management prescription, and the low quality of residual production forests [76]. Other challenges include inadequate funding, the destruction of young trees by activities of cattle herders, and fire outbreaks. Therefore, to help maintain the forests, the Government of Ghana provided portions of the degraded forest to forest-dependent communities to use farmers to simultaneously maintain forest plantations while farming to address food security and livelihood issues [77]. However, the challenge for this project has been the negative impact of illegal small-scale mining (locally termed "Galamsey") on agriculture and forest ecosystem services [78] and the lack of formalisation and regulation of the sector [79]. Illegal small-scale mining causes deforestation and therefore thwarts afforestation efforts to mitigate climate change.

Another effort to protect the forest is by reducing emissions from deforestation and degradation (REDD+) project. The National REDD + Readiness Project was launched in April 2012 by the Ministry of Land and Natural Resources and the Forestry Commission under the World Bank's Forest Carbon Partnership Fund [80]. Since its inception, it has helped reduce forest degradation and deforestation by placing an economic value on carbon, ecosystem services, and non-carbon benefits. It has ensured the maintenance of forests and introduced a performance-based payment system to beneficiaries, who are mainly farmers, thereby supporting livelihoods [10]. Maintenance of forests, including cocoa agroforestry, is encouraged in the high forest zones to support carbon sequestration, micro-climate regulation, and attainment of the REDD + goals. The challenge has mainly been limited funding and political power dynamics that slow the disbursement of funds for effective implementation [81].

4.4. Sectoral adaptations

Water: The water sector is one of the critical sectors to consider in developing adaptation strategies, such as relying on underground water recharge to sustain livelihood. Others include water resource management, such as irrigation, improvement in water supply, and sanitation [10]. Water harvesting from rainwater and other sources is essential for community and household use [82]. Flood retention developments and post-construction support for dams, such as water retention ponds and dams' desilting, can help sustainable water supply [10,83]. Sustainability in the water supply can be achieved through sectoral policies such as the Water Sector Strategic Development Plan (2012–2025) and the National Irrigation Policy (2011) and other government flagship projects such as the construction of water retention small dams in villages- One-Village-One-Dam (1V1D) which are aimed at promoting water security and resilience to climate change.

Health: Relevant adaptation strategies such as immediate policy responses, including investments in healthcare infrastructure, are needed to build resilience to climate impact on health. This will include effective management of the environment and ecosystems to help reduce disease vectors, waterborne pathogens, and contaminants. The Ghana Government has shown some commitment to adapting to adverse impacts in the health sector by approving a national health adaptation strategy to help address the risk of climate change [49]. However, the challenge has been the need for more effective implementation of strategies, policies, and measures such as national assessment of climate change impacts, vulnerability, and adaptation for the health sector. Nonetheless, some action has been taken to build resilient climate health infrastructure capacities. Strategies should include developing adequate early warning systems for climate-related diseases through improved monitoring and surveillance systems [84] and climate health adaptation research to study the relationship between climate change and health [49].

Agriculture: Adaptation strategies in Ghana have prioritised technology needs in the agriculture sector [85], such as cereal-legume integration, climate-smart cocoa production, poultry feed improvement and genetic resource enhancement, climate-resilient ruminant production and genetic resource conservation, sustainable fisheries and aquaculture, diversified tree crop production, roots-tubers-livestock integration, knowledge system and advisory services, water harvesting technologies and irrigation management [10]. Other adaptations in the agricultural sector include strengthening insurance programmes to cover the impact of climate change on crop yields, particularly in northern Ghana. This is important because of inadequate insurance packages targeting farmers [86].

4.5. Progress, challenges, and plans for future climate change policy implementation

Ghana has achieved considerable progress through policies, programmes, and planning processes to build resilience to the harmful impacts of climate change. One of these is the establishment of the National Climate Change Committee (NCCC), which serves as a platform for strategic engagement, communication, and coordination support systems across the government ministries in charge of energy, forestry, agriculture, health, and gender. Under these ministries, Climate Change Units have been established to handle specific climate change challenges in various sectors.

Even though there is ample evidence of growing climate financing in the past decade, it is not equally distributed across the various climate actions [83,87]. However, some successes have been achieved. For instance, about US$ 1.3 billion has been committed to climate finance projects between 2011 and 2019, excluding investments in climate-related projects in the development of the oil and gas fields, which amounts to about US$ 14.2 billion [88]. Development partners provided a greater portion of the financing through grants (72.1%), loans constituted about 19.1% and government budgetary support and results-based payments over 8% [88]. The funds were channelled to energy, forestry and agriculture, with energy receiving the greatest US$ 758.8 million (57.8%), followed by forestry (25.7%) and agriculture, the recipient of the remainder from 2011 to 2019. The main channels of financial support within the period were bilateral, constituting the largest (45.1%), followed by multilateral (29%), global projects (11.6%), national funds (7.1%), and Global Environment Facility (GEF, 4.4%). Other channels include private foundations, the private sector and technical cooperation, constituting 1.3%, 0.13%, and 0.02%, respectively [88].

Some key projects implemented over the years on adaptation and mitigation include, investment in sea defence projects (adaptation measures) to the tune of about US$ 670 million along the coastline over the last decade [88]; over US$ 100 million invested in the savanna zone of the north to support the building of resilience of farmers and improve their livelihood [88]; €3.8 million invested in climate risk transfer (drought index insurance); US$ 200 million World Bank funding for resilient city infrastructure planning, such as the Greater Accra Resilient Integrated Development Project to reduce flood risk and improve solid waste management in the Odaw River [88]; enactment of Act 919, the Petroleum Exploration and Development Act of 2016, which limits gas flaring during petroleum exploration and development; reduction of GHG emissions by six million tonnes under the Ghana Cocoa Forest REDD + Programme by the Forestry Commission of Ghana with support from the World Bank in 2019 [89]; rehabilitation of irrigation projects; control of climate-induced and gender-related health risks; improvement of climate services and education; and management of early warning systems and disaster risk; and integrated water resources management.

However, several challenges and gaps were identified in implementing these climate change interventions. The most important of them was limited financing, which constraints efforts to adapt to climate impacts, including droughts, floods, and sea level rise, because funds do not reach the subnational (district) level as envisaged. Also, there is more focus on mitigation activities (such as in energy and forestry) than local climate adaptation initiatives, especially in agriculture, with less funding. According to the updated nationally determined contributions [28], effective adaptation will require between US$ 9.3 and US$ 15.5 billion investment for implementation activities from 2020 to 2030. These are anticipated to be mobilised from global, private sector, public, and carbon markets sources. Of the total amount, the unconditional programmes of action will require US$ 3.9 billion, while the conditional programmes require the remaining US$ 5.4 billion for implementation until 2030 [28]. Even with the limited financing, there is a challenge in tracking financial inflows because numerous organisations in the country receive funding for climate change from various sources that only sometimes pass through a centralised location like the Ministry of Finance [88]. For example, funding to NGOs and civil society organisations working on climate change projects is not reported to a centralised agency for tracking. Also, the communication between the government, donors, and other civil society organisations is not well coordinated, leading to the duplication of climate change interventions.

Aside from the financial limitations, there are other ways that adaptation is hindered, such as limited knowledge about the numerous alternatives available to different vulnerable groups on the various manifestations of climate impacts [89]. Others include inadequate climate information and capacity development through education and early warning systems to enhance adaptation. The generally top-down approach to climate change decision-making hinders the adoption of ideas from local communities already experiencing the effects of climate impacts, limiting adaptation and mitigation efforts at learning from local knowledge [90]. Notwithstanding these challenges, among others, important lessons could be learned that could be used to create future successful paths towards improved adaptation. Policymakers will need to pay more attention to this to solve the challenges in policy implementation and to design efficient and sustainable paths for adaptation projects. Ghana expects the revised NDC to be crucial to fulfilling her international commitments and achieving long-term national development plans and global sustainable development goals. This could be accomplished through capacity building on climate financing skills and competencies to mobilise the needed funds for local climate action.

Even though financial support from the private sector in the implementation of climate change projects was inadequate over the years [88], the Government of Ghana's collaboration with the private sector through the Private Enterprise Federation (PEF) in the effective implementation of the SDGs is a step in the right direction. According to the Voluntary National Review (VNR) Report on the Implementation of the 2030 Agenda for Sustainable Development [91], in order to actively contribute to the achievement of SDGs targets, including those for sustainable production and consumption and climate change mitigation and adaptation, the private sector must actively integrate sustainability concepts into their business operations. As a result of this vision, the Private Enterprise Federation (PEF) collaborates with Ghana's SDGs implementation processes and the Green Economy and Climate Change steering committees at the national level. The partnership has resulted in the creation of some resources to assist the private sector's involvement, such as a green employment guide (to achieve Goals 1, 2, and 8); interventions in renewable energy to give Goals 7 and 9 a boost; and the creation of an investor guide to drawing the attention of available opportunities (thereby working towards Goals 9, 13

and 17) [91].

5. Conclusion and recommendations

This research paper portrays the effect of climate change across critical developmental sectors and the corresponding adaptation and mitigation measures. The effects of climate change are varied, with different manifestations due to adverse weather conditions. Even though it depicts that the effects could be dire, they could also present developmental opportunities or gains by building a climate-resilient economy. Ghana has experienced about 1 °C rise in temperature over the past four decades and SLR with socio-economic consequences including decreased agricultural productivity and inundation of coastal communities. The projected mean annual temperatures in the 2030s, 2050s and 2100 are expected to cause rapid warming in the northern and inland parts of Ghana and decrease the number of cold days. Within the same time horizon (the 2030s, 2050s and 2100), variations in precipitation are expected, which could translate into decreasing and increasing rainfall events in the wet season and lower levels during the dry season. These projections and future sea-level recession rates will have severe socioeconomic consequences without effective adaptation and mitigation measures. Both direct and indirect climate impacts on health are expected, such as increased incidences of communicable and non-communicable diseases.

GHGs emissions in Ghana increased to 59.8 million tonnes (Mt) of CO_2-equivalent (CO_2e) by 2019 due to increased production and economic expansion but is relatively low compared to the global emission level of about 50 billion metric tons of carbon dioxide equivalent (GtCO2e) as of 2019. The implementation of mitigation policies and strategies is expected to reduce GHG emissions to adapt and mitigate the adverse impacts of climate change. Progress and challenges to climate change policies implementation and future implementation plans were identified, such as building resilience through various project implementations in critical sectors and challenges of inadequate funding and strict policy implementation.

Based on these research findings of the impacts and projected future outcomes, we recommended the political will to strictly enforce policies (both national and multilateral), to carry out programmes and plans at the national and sub-national levels. This could be addressed by passing legislation to make climate change a national priority to change perceptions and attitudes toward climate change, as emphasised in Ghana's Adaptation Communication to the UNFCCC, 2021. Also, the government could seek innovative ways to mobilise funds for local climate action to complement the existing funding streams, such as private sector investment in more sustainable projects because businesses must adapt to the changing needs of the environment. For example, using public-private partnerships to mobilise capital, including foreign direct investments (FDIs) for climate-resilient infrastructure projects for mutual benefit. Finally, this study employed a qualitative content analysis which allowed for a broader range of data sources. The research also provided an opportunity to explore the context in which different research was conducted and helped to gain insights into how different factors influenced research outcomes or results. However, this review needs more quantitative information and could benefit from further investigation through a systematic review to broaden the literature.

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Data availability statement

Data used in this article are duly referenced.

Declaration of competing interest

The authors reported no potential conflict of interest.

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