Chapter 27
Measures Against Climatic Changes for Ghana's Volta River Basin

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27.1 Introduction

Climate change and variability are one of the most significant challenges this century and into the next. Developing countries in Sub-Saharan Africa (SSA) are particularly at risk in areas where temperatures will rise the fastest. They are also more vulnerable because they depend on agriculture, the most climate-sensitive sector. Despite uncertainty about the precision of climate science, there is now close agreement amongst climate scientists on several issues. Firstly, it has been firmly established that the earth is undergoing rapid changes due to significant greenhouse gas increases (GHGs) increases. For example, global GHG emissions have roughly doubled since the early 1970s and, on current policies, could rise by over 70% from 2008 to 2050. Atmospheric concentrations of carbon dioxide (CO_2) have increased by nearly 100 ppm (parts per million) compared to pre-industrial levels, reaching 379 ppm in 2005, and the Earth has warmed by 0.7 °C since 1900 (IPCC 2007; Brohan et al. 2006). Secondly, human activities, notably the burning of fossil fuels and deforestation, have been identified as prime causes of the changes observed in the 20th century and

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are likely to contribute to further changes in the 21st century (IPCC 2001). These atmospheric changes will likely alter temperatures, rainfall patterns, and sea levels. Furthermore, it increases the frequency of extreme weather events and climate-related aspects.

Even though Ghana has considerable surface and groundwater resources, climate change will negatively affect usable water resource availability. Due to changing climate, lower precipitation, expanded evaporation, and frequent droughts will decrease water availability in the Volta River Basin (VRBN). Furthermore, the Akosombo dam, which provides about 70% of the country's energy needs, produces only 30%t during dry low water levels. Such energy reduction affects industrialization and private-sector development. Since farmers rely on rain-fed agriculture, these factors also contribute to significant variations in agricultural productivity (Kabo-Bah et al. 2016).

Agricultural development in Ghana is highly dependent on water availability across the Volta River Basin (VRBN). Ghana is more vulnerable because agriculture is the most climate-sensitive sector. The contribution of the farming industry in Ghana was estimated to be 42% of the country's Gross Domestic Product (GDP)—Fig. 27.1. The predicted climatic changes will adversely affect human well-being and activities, food insecurity, reduce water availability within the Volta River basin, and primarily reduce the agricultural sector's contribution to the country's income. The variability of the growth in the agriculture sectors is illustrated in Fig. 27.2. In response to these climate changes, people will migrate, searching for better land and water resources. The migration and relocation of the population from rural to urban areas cause pressure and higher demand on municipal services (e.g., water supply and sanitation, public health, energy, transportation, and housing services), which necessitate better management of the water flow at the basin in response to climate changes.

Dembélé et al. (2022) showed that disparities are observed in the spatial patterns of hydroclimatic variables across climatic zones, with higher warming in the Sahelian zone at the Volta River Basin (VRB). Authors showed that climate change would have severe implications for future water availability with concerns for rain-fed agriculture, weakening the water–energy–food security nexus and amplifying the local population's vulnerability. The variability between climate models identifies the uncertainties in the projections and indicates a need to represent complex climate features in regional models better. These findings could serve as a guideline for the scientific community to improve climate change projections and for decision-makers to elaborate adaptation and mitigation strategies to cope with the consequences of climate change and strengthen regional socio-economic development. Similarly, this study's main objective is to study the climate change impacts and adaptations for the agricultural sector in Ghana's Volta River Basin.

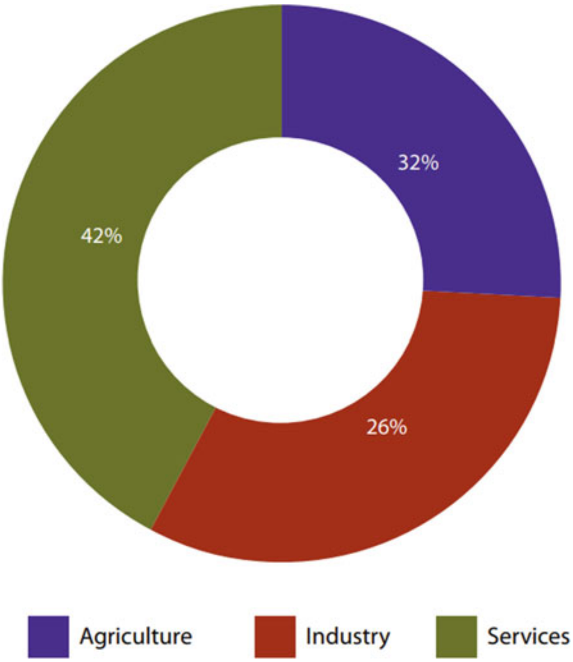

Fig. 27.1 Ghana's gross domestic product (GDP) contribution by sector

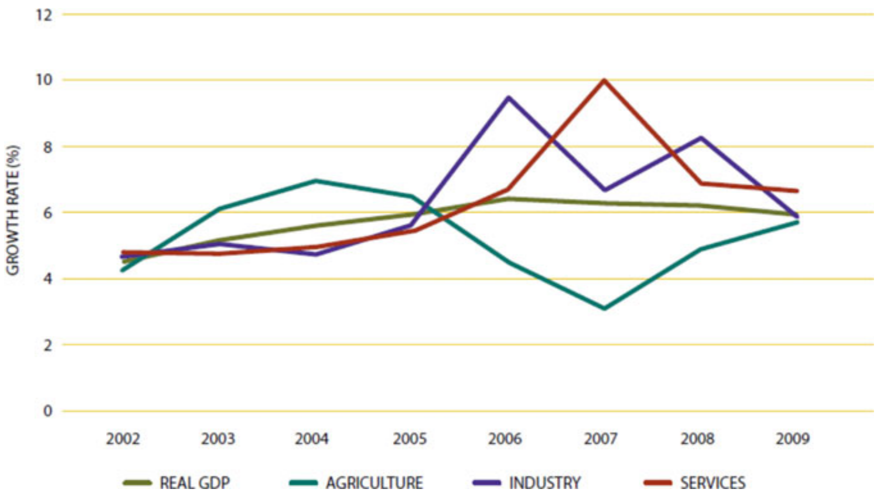

Fig. 27.2 Historical output growth trend (%)-agricultural sector contribution against the other sectors

27.2 Objectives

The two objectives of this study are:

Identifying proper River basin modeling of hydrology and Volta River basin to assess the hydrology and cropping systems vulnerability using CLI-Run (model for climate change simulations), Cli-Crop (model for crop yield impacts) and IMPEND (model for watershed optimization).

Investigate climate change (that include dry and wet climate change scenarios), economic impacts on the water and agricultural sectors in Ghana, and identify adaptation strategies that optimize resource use in the Vola River Basin (VRBN) by using if, then scenarios.

27.3 Methodology

To study the impact of climate changes on the agricultural sector and the Volta River Basin in Ghana, Volta River Basin, using the scenarios represented in Table 27.1. This study used the CLICROP Model. CLICROP is a crop model used to calculate the effect of changing daily precipitation patterns caused by increased CO_2 on crop yields and irrigation water demand—Eq. (27.1). The model was developed in response to the available crop models that use monthly average rainfall and temperature to produce crop yields. Model results serve as inputs to the Climate, Hydro, and Cost minimization models to produce the modeling outcomes/results—Figs. 27.3 and 27.4.

The following is the CLICROP yield equation.

$$\text{equation:}\left[1\frac{Y_a}{Y_m} = K_y^d \cdot \left[1 - \frac{ETC^d}{ETA^d}\right]\right] \tag{27.1}$$

where

Y_a = predicted actual yield

Y_m = maximum yield

K_y^d = yield coefficient, different for development stage d

ETC^d = sum of daily ET crop demand for development stage d

Table 27.1 General circulation models scenarios for global and country's specific study

Scenario	General circulation model (GCM)	SERIES	Climate moisture index (CMI) deviation (%)
Global wet	ncar_ccsm3_0	A2	− 17
Global dry	csiro_mk3_0	A2	9
Ghana wet	ncar_pcm1	A1b	49
Ghana dry	ipsl_cm4	B1	− 66

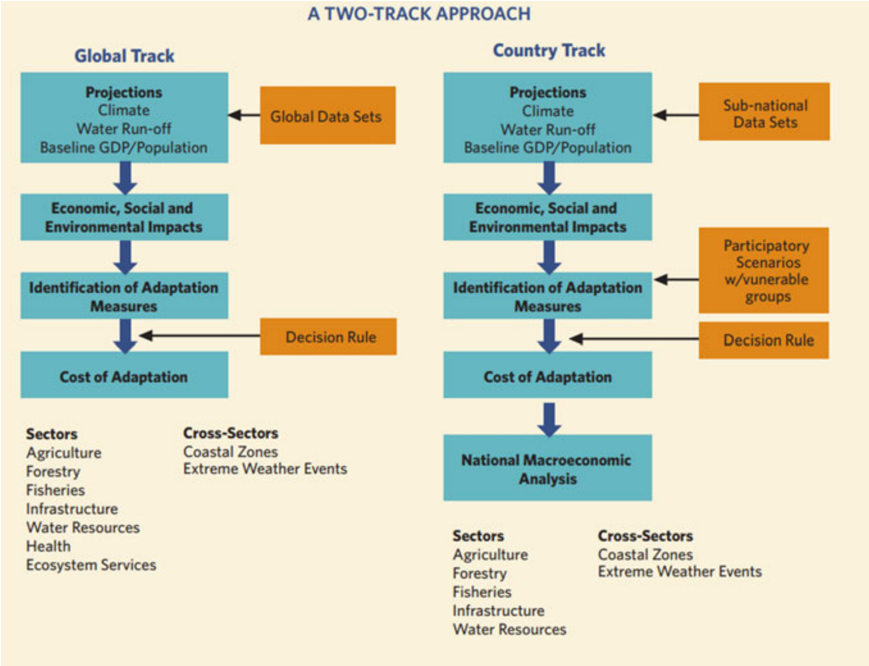

Fig. 27.3 Climate change scenarios applying the global and the country-specific tracks

ETA^d = sum of daily actual ET for development stage d

$\%Yield^d$ = ratio of actual yield over maximum yield, the value reported by CLICROP.

27.4 Results

The Volta River Basin (VRBN) is an essential transboundary basin in West Africa that covers more than 410 thousand square kilometers across six countries in western Africa. These countries include Benin, Burkina Faso, Côte d'Ivoire, Ghana, Mali, and Togo. The basin's natural resources sustain its population's living and contribute to economic development in Ghana and neighboring countries, Williams et al. (2019). Figure 27.5 compares the temperature range in the two and agroecological between the base scenario temperature range and the climate change scenario's range. The figure indicates a typical pattern of temperature changes across the various agroecological zones in Ghana. The Ghana Wet and Dry scenarios show higher temperature variability relative to the base scenario than the Global Wet and Global Dry scenarios.

The precipitation forecast reveals a cyclical pattern over 2010–2050 for all regions in Ghana, with high rainfall levels followed by a drought every decade. The wettest

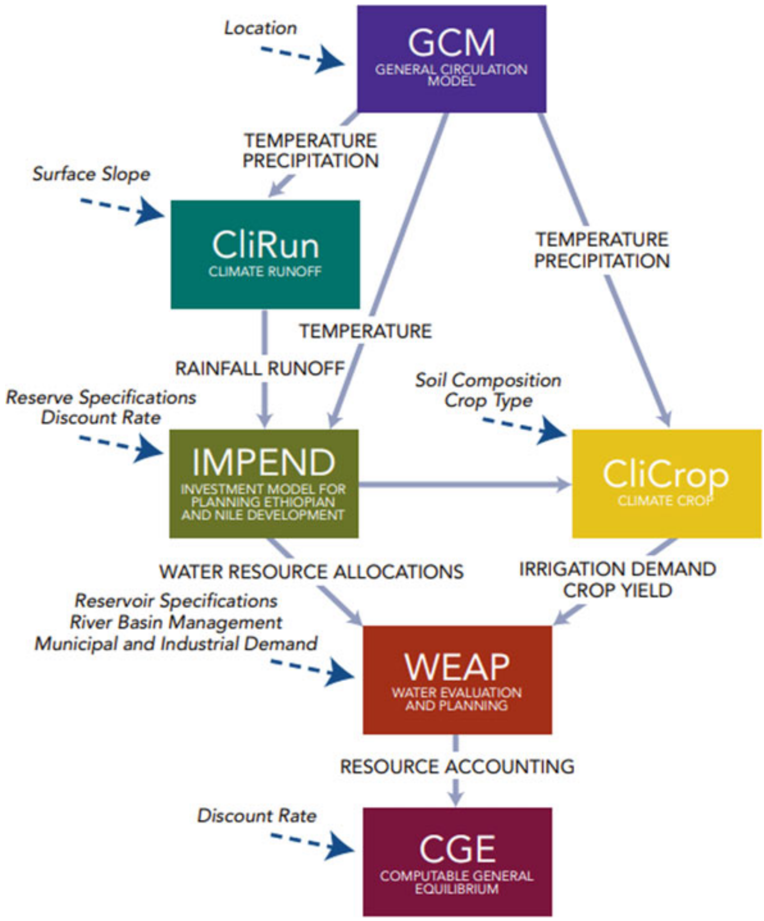

Fig. 27.4 Flowchart of the modules used to simulate climate change impacts and adaptation scenarios for the agricultural sector in Ghana's Volta River Basin (VRBN)

parts of the country are expected to be the Forest and Coastal agroecological zone. The Northern and Southern Savannah regions are expected to be relatively dry—Fig. 27.6.

As illustrated in Table 27.2, climate change economic in present value impacts (costs) in billion dollars result from global and Ghana-specific scenarios. The highest economic cost appears in the Ghana Global Dry scenario of 13.1 billion dollars or 31.5 dollars per capita per year. Meanwhile, the lowest costs are the outcome of the Ghana Dry country-specific scenario. The total economic costs are estimated to be 2.7 billion dollars and 9.7 dollars for the present value of lost welfare and the per capita annual income.

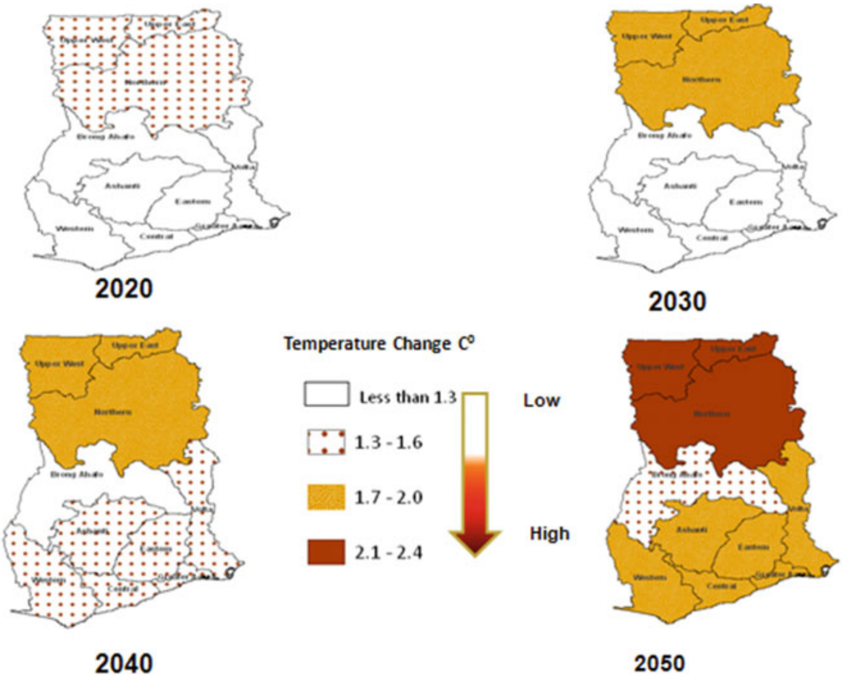

Fig. 27.5 Climate changes and temperature wet versus dry scenarios compared for every decade forecast from 2020 to 2050

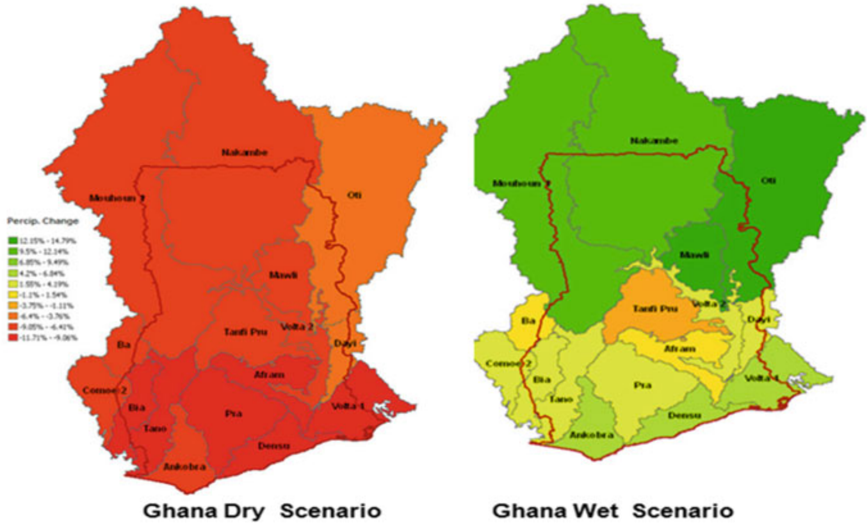

Fig. 27.6 Ghana's dry scenario and wet scenario precipitation changes compared to the base scenario, an average of 2010–2050

Table 27.2 Climate change results from global and Ghana-specific track scenarios

Scenario	Present value of lost welfare ($ billion)	Equivalent annual value ($ billion)	The annual equivalent per capita ($)
Global dry	13.118	764.5	31.46
Global wet	10.095	558.3	24.21
Ghana dry	2.709	157.9	6.5
Ghana wet	5.05	236	9.71

Source World Bank (2010). Economics of adaptation to climate change: country case studies, Ghana report

Table 27.3 and Fig. 27.5 and below show the climate change scenarios' adaptation costs at selected sectoral levels (traditional non-irrigated rain-fed Agriculture, Hydro/Agriculture, and education sectors). The cost with no climate change is expected to be between 13.1 billion dollars in the Global Dry scenario and 2.7 billion dollars at the national level. At the sectoral level of road design, adaptation costs can be as high as 10.3 billion dollars. Traditional agriculture and irrigated agriculture climate change adaptation costs are expected to be moderate compared to the infrastructural sectors (Fig. 27.7).

Table 27.3 Climate change scenarios' results at the national and sectoral levels (present value in $ billion)

Scenario	No adaptation	Road design	Traditional rain-fed agriculture	Hydro/agriculture	Education
Global dry	− 13.118	− 10.308	− 0.121	− 0.941	− 2.09
Global wet	− 10.095	− 5.854	− 2.973	2.116	0.584
Ghana dry	− 2.709	− 3.009	− 1.193	− 1.782	− 1.308
Ghana wet	− 4.05	− 0.766	1.936	1.358	1.795

Source World Bank (2010). Economics of adaptation to climate change: country case studies, Ghana report

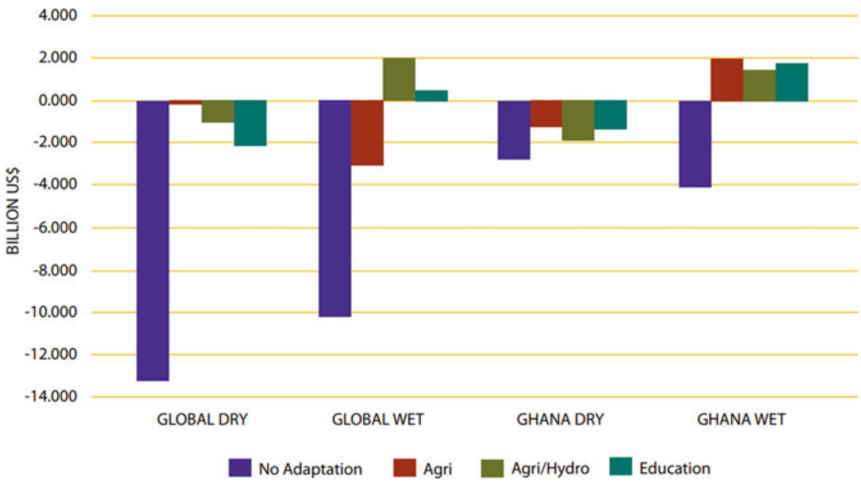

Fig. 27.7 Climate change costs of the scenarios on the traditional rain-fed agriculture, hydro-irrigated agriculture, roads sector, and education sector

27.5 Conclusion and Recommendations

The agricultural and hydro sectors' climate change adaptation measures in this study include investment in agricultural research and extension services, including transfer research and development findings (e.g., more drought-tolerant crop varieties and animal species) to the end-users (farmers and their inputs providers). Successful agricultural climate change adaptation measures must consider crops and livestock production and marketing activities from the farmers to the consumers' level (i.e., throughout the food supply chain). Climate change adaptation strategies also provide storage and better marketing capabilities for cash and non-cash crop producers. Agricultural climate change adaptation strategies should target both rain-fed as well irrigated lands. Climate change adaptation strategies may include programs and projects to enhance irrigation project efficiency in irrigated land. Analysis of agricultural sector climate change adaptation strategies will consider agroecological zones' production and crop compositions (cash crops versus food crops) and the possible economic implications of such classification.

Under the scenarios included in this study, part of the available resource envelope is spent on additional investments in hydropower relative to the baseline that eliminates negative climate change impacts on power generation. The remaining part of the resource envelope is spent on agricultural productivity improvements. An increase in agricultural productivity due to investment in infrastructure, R&D, and agricultural extension services has been widely reported in previous studies. For instance, Alston et al. (2000) showed that typically the return to investment in agricultural R&D generates 40–60% returns annually for each dollar invested. These returns include an increase in the productivity of crops and livestock products.

To be better prepared for floods and or droughts, there is a need for enhanced irrigation project efficiency. A higher level of irrigation efficiency significantly decreases water consumption and saves water for other sectors (Municipal and Industrial M&I). Climate change adaptation strategies may also provide the agricultural sector's stakeholders with modern climate forecasting capabilities. These forecasting capabilities may consist of climate monitoring stations and early warning systems. Low-income communities and households in Ghana are highly vulnerable and at risk of climate change. The agriculture climate change adaptation strategies work successfully in the presence of high-level coordination with the country's poverty reduction programs to optimize the outcome for the poor communities.

Climate change adaptations relevant to the agricultural and hydro sectors at the Volta River Basin (VB) include the need to improve water storage capacity to utilize excess water in wet years during dry years. It is recommended to improve agricultural and livestock extension services and marketing networks and construct small to mid-size irrigation facilities. Improve entrepreneurial skills to generate off-farm income. As well it was founded, improving access to loans and microcredit is essential. Other necessary measures include increasing water transfer from the Volta basin to meet the needs of a growing urban population. Finally, the study found that it is essential to construct efficient infrastructure and reduce the blocking of dry-stream channels to harvest rainwater to recharge the groundwater system, which serves as an alternative water supply during dry years and develop a program for afforestation initiatives to improve land-use practices, protection of river courses, and de-sedimentation of reservoirs.

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