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Modeling impact of climate change on water resources and agriculture demand in the Volta Basin and other basin systems in Ghana

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Abstract: An assessment of the impacts of projected climate change on water availability and crop production in the Volta Basin and the southwestern and coastal basin systems of Ghana has been undertaken as a component of the impacts and adaptation study for Ghana by UNU-WIDER and the University of Ghana. Four climate change scenarios were considered in addition to a reference (no change) scenario – two dry and two wet scenarios. The CliRun water balance model was used to simulate catchment runoffs using projected rainfall and temperature under the scenarios. The water evaluation and planning software was used for the water allocation modeling. The climate impacts on yields of many of the economically important Ghana crops were modeled using the AquaCrop software. The results show that all water demands (municipal, hydropower, and agriculture) cannot be simultaneously met under any of the scenarios used, including the wet scenarios. This calls for an evaluation of groundwater as an additional source of water supply and an integrated water resources management in the catchments to balance demand with supply and ensure sustainable socio-economic development. In addition, the AquaCrop model forecasts negative impacts for the crop yields studied, with some crops and regions seeing larger impacts than others.

Keywords: Ghana, water resources, agriculture, climate change
JEL classification: O55, Q54

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1 Introduction

The water resources of the Volta Basin of West Africa are under severe stress due to poor climatic conditions and competing demands on the resources by the riparian countries (van de Giesen et al. 2001). Climatic conditions in the region are such that there is high variability in both temporal and spatial distribution of rainfall over the basin causing a corresponding high variability in streamflow. The effect of this is that most streamflow, particularly in the northern parts of the basin, occur in just a few months of the year with little or no flow for much of the year (Amisigo 2005). In addition, the agricultural sector is highly vulnerable because it is largely rainfed and has a low level of irrigation development (Kristensen, Means, et al. 2010). The agriculture sector comprises approximately 30 percent of the country's GDP to date and employs about 50 percent of the population. Though agricultural may have the potential to grow by as much as 6 percent, climate change could inhibit such progress in the long run, given the sector's vulnerability (De Pinto et al. 2012).

This, coupled with non-climatic factors such as population growth and increased economic activity, has led to the widespread construction of hydraulic infrastructure of various types and sizes for water mobilization throughout the basin, particularly in Burkina Faso and Ghana that together cover about 85 percent of the basin area. These hydraulic facilities include numerous small-scale reservoirs in Burkina Faso and northern Ghana mainly for agricultural purposes in the long dry season, large-scale irrigation systems such as those in Tono, Vea, and Botanga in northern Ghana, and Bagre and Kompienga (both also used for hydropower generation) in Burkina Faso. There is also the huge Volta Lake in Ghana powering the nearly 1,200 MW hydropower generation facilities at Akosombo and Kpong in the Lower Volta with turbine flow of up to 1,200 m^3/s. A 400 MW plant on the Black Volta in Ghana is due to be fully operational in 2014 with several relatively smaller ones planned for the future in both Burkina Faso and Ghana.

Thus the riparian countries of the Volta Basin rely heavily on its water resources for their socio-economic sustenance. However, the improper exploitation of these resources in the past has caused serious environmental problems in the basin, key among which is diminishing resources (GEF 2003). To avoid or reduce these problems in the basin, institutional mechanisms such as the establishment of the Volta Basin Authority (VBA), have been put in place to drive and co-ordinate the proper water resources management in the basin. Unfortunately, climatic factors may have the upper hand in determining the availability of water resources in the basin. Climate change, in particular, could be a serious problem. It is projected to exacerbate the problem of diminishing basin water resources (de Condappa et al. 2008; McCartney et al. 2012).

The river basins in Ghana but outside the Volta systems are the southwestern and coastal (SWC) systems, as they are called in Ghana. These systems are also under stress from both climatic and non-climatic factors and studies have shown that climate change is likely to have adverse impacts on the water resources (EPA 2008; Obuobie et al. 2012)

This study, therefore, seeks to determine the levels at which projected climate change could impact water availability to meet municipal, hydropower, and agricultural demands in the Volta Basin and the rest of the river basins in Ghana. It is the water resources component of the impacts and adaptation study for Ghana undertaken by UNU-WIDER and the University of Ghana (UG) with a focus on climate change impacts and adaptations using the Strategic Analysis of Climate Resilient Development (SACReD) framework.

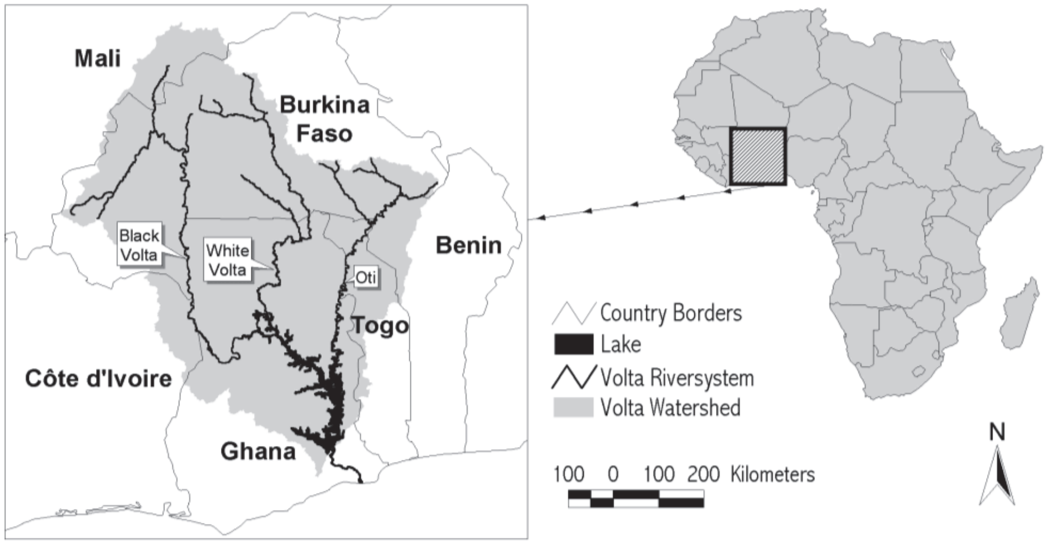
The study used the Water Evaluation and Planning software, WEAP, of the Stockholm Environment Institute (SEI) to model the water availability and allocation to the various water demands in the Volta and SWC basin systems. A separate water balance model, CliRun, was used to simulate surface water runoff as the supply input to WEAP and the Food and Agriculture Organization of the United Nations's (FAO) AquaCrop model was used to determine irrigation demands.

The following sections start with a brief description of the drainage, hydrology, and agriculture in the study area. Then the WEAP setup and the input data used to run WEAP are described. This is followed by the results obtained from the WEAP runs, the analyses and discussion of these results and the conclusions and recommendations derived from them.

2 Study area

The study area for this analysis covers the entire Volta Basin and the rest of Ghana river basins – the SWC basins. The Volta Basin (Figure 1) spans various sections of the six West African countries of Benin, Burkina Faso, Ghana, Côte d'Ivoire, Mali, and Togo. The areas of each country within the basin are indicated in Table 1. As the table shows, more than 84 percent of the basin area lies in Burkina Faso and Ghana.

Figure 1: Volta basin



Source: van de Giesen et al. (2001).

Table 1: Volta basin areas by country

Country	Area of basin (km^2)	% of basin area	% of country area
Benin	13,590	3.41	12.1
Burkina Faso	171,105	42.95	62.4
Côte d'Ivoire	9,890	2.48	3.1
Ghana	165,830	41.63	70.1
Mali	12,430	3.12	1.0
Togo	25,545	6.41	45.0
Total	398,390	100.00	

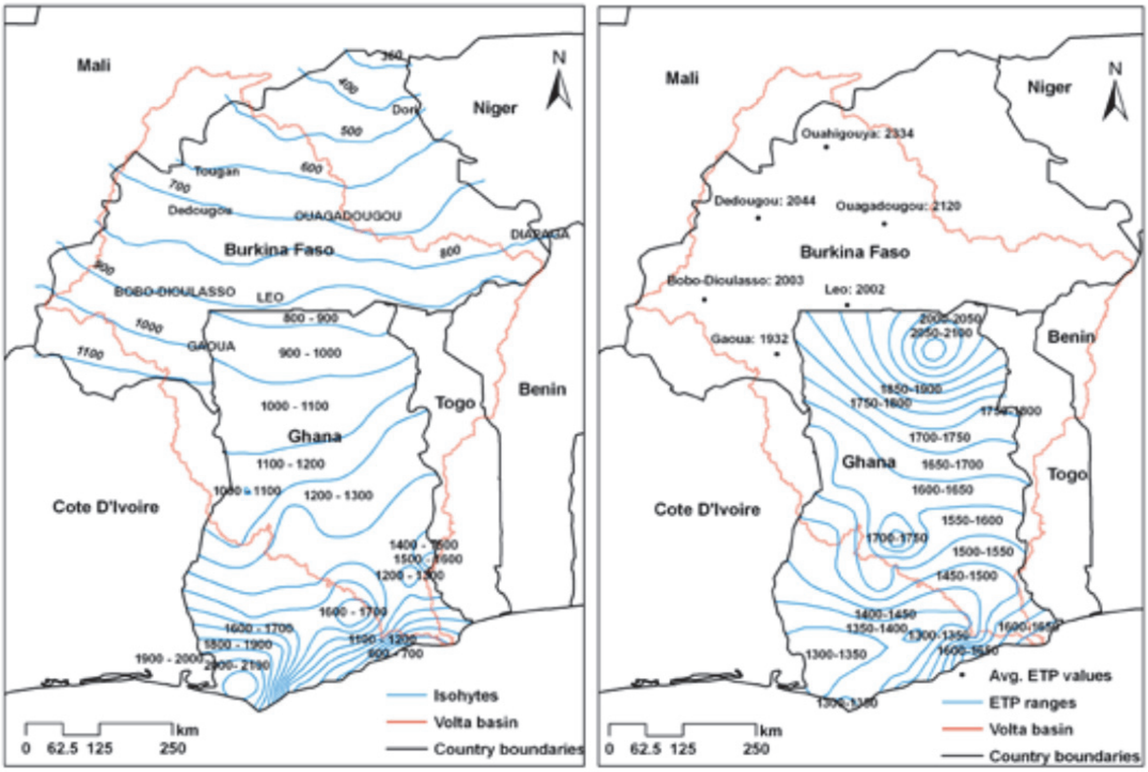
Source: based on Biney (2013a).

The basin is drained by the Black Volta, White Volta (with a major tributary of the Red Volta), the Main Volta (formed below the confluence of the Black and White Volta), the Oti and the Lower Volta below the Akosombo and Kpong hydropower facilities in Ghana. The major landmark in the basin is the 8,500 km^2 Volta Lake formed from the damming of the Main Volta at Akosombo for hydropower production in Ghana (VRA 2012).

Rainfall increases from less than 500 mm per annum in the northernmost parts of the basin in Mali to about 1,600 mm per annum in the southernmost part (Figure 2a). Potential evapotranspiration on the other hand, increases northwards (Figure 2b). Rainfall is unimodal in the northern and middle sections of the basin but becomes bi-modal further south in southern Ghana. Thus the drainage system of the basin moves water from more arid regions in the north to wetter regions in the south of the basin. Mean annual observed streamflows for the main sub-basins of the Volta are shown in Table 2. Maximum annual flow through the turbines at Akosombo (maximum turbine flow) is 1,200 m^3 or 38 x 10^9 m^3 (VRA 2012) and constitutes the Lower Volta streamflow.

The SWC basins are the river basins in Ghana outside the Volta system and cover about 30 percent of the country. The southwestern river system comprising the Pra, Ankobra, Tano, and Bia is the wettest in the country (Figure 2). Kakum, Amissa, Nakwa, Densu, and Ayensu, form the coastal system and are drier in average terms than even the part of the Volta system in Ghana. Estimated mean annual streamflows for sub-basins in this basin system are also shown in Table 2. All the nine sub-basins in the SWC basin system are stand-alone basins as each discharges directly to the sea.

Figure 2: Annual rainfall (a) and potential evapotranspiration (b) distributions in the Volta and SWC basin systems of Ghana



(a) (b)

Source: Johnston and McCartney (2010).

Table 2: Observed mean flows in the main sub-basins of the Volta and SWC basin systems

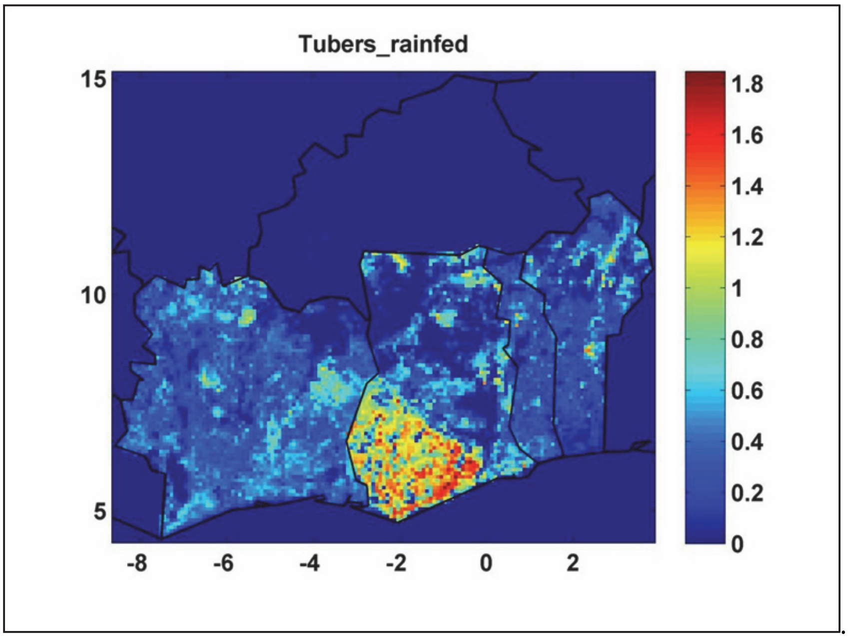
Main sub-basin	Observed mean annual flow (m^3/s)
Black Volta	200
White Volta	220
Oti	280
Main Volta	500
Lower Volta (turbine flow)	1,200
Kakum	5.8
Amisa	12.8
Nakwa	8.3
Densu	13.4
Ayensu	9.3
Bia	54.4
Tano	122.7
Ankobra	70.5
Pra	190

Source: Biney (2013b); VRA (2012); Opoku-Ankomah and Forson (1998), and computed for the Main Volta.

The most agriculturally productive area of Ghana is the southwest corner of the nation and includes the western, eastern, Ashanti and central administrative districts. Tubers, such as cassava, are especially prominent in this area, as Figure 3 below illustrates. Most other crops are also present in this region. Cropping areas for grains such as maize and sorghum extend further north, into the central area of the country. The far north, along the border with Burkina Faso, contains productive pockets also, but does not attain the yields of the southern region.

The most economically important crops in Ghana include yams, cassava, cocoa, rice, maize and tomatoes. Table 3 shows the top ten agricultural commodity crops for Ghana by production value and quantity, according to the FAO.

Figure 3: Tubers yield by location (metric tons per hectare)



Source: Authors' compilation.

Table 3: Ghana's top commodity crops (2011)

Rank	Commodity	Production (Int'l $1000)	Production (MT)
1	Yams	1,605,618	6,295,453
2	Cassava	1,487,644	14,240,867
3	Plantains	747,344	3,619,834
4	Cocoa beans	726,962	700,020
5	Taro	275,638	1,299,645
6	Groundnuts	197,370	465,103
7	Rice, paddy	126,387	463,975
8	Maize	126,063	1,683,984
9	Tomatoes	118,445	320,500
10	Oranges	115,955	600,000

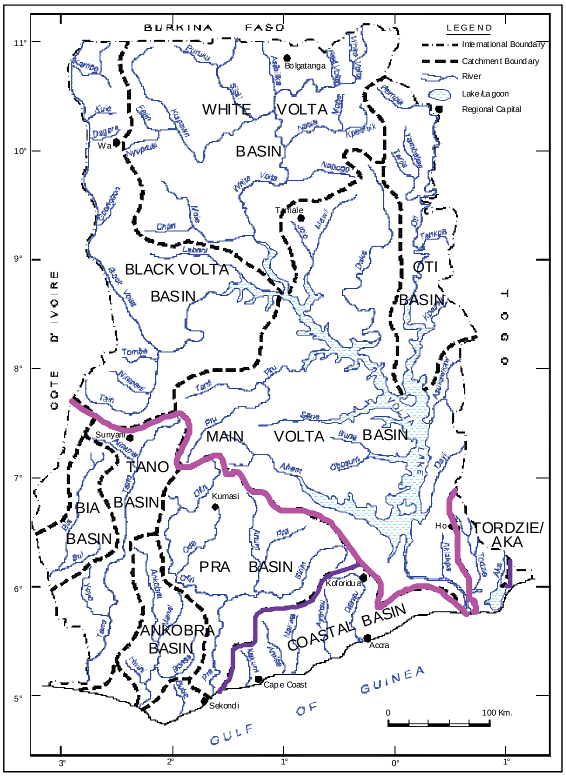
Source: FAOSTAT (2013).

3 Methodology

3.1 Catchment delineations

In all 29 catchments were delineated – 19 in the entire Volta Basin and ten in the SWC basins of Ghana. The SWC basins cover about 30 percent of the land area of the country and are the basins outside of the Volta system. The shape files for the Volta Basin catchment delineation were the same used in de Condappa et al. (2008) and McCartney et al. (2012). Those for the SWC sub-basins were obtained from the Council for Scientific and Industrial Research – Water Research Institute (CSIR-WRI), Accra. The catchment delineations are shown in Figure 4.

Figure 4: River basin systems in Ghana



Source: CSIR-Water Research Institute, Surface Water Division, Ghana.

3.2 Climate change scenarios

Four future climate scenarios were used in this analysis: Global Wet, Global Dry, Ghana Wet and Ghana Dry (Table 4). These were compared to a baseline, which was generated from historical conditions from 1950 to 2000. The time period for the projections was 2010-50. Climate projections from the National Center for Atmospheric Research (NCAR) and Commonwealth Scientific and Industrial Research Organisation (CSIRO) models were used to generate the Global Wet and Global Dry scenarios. To generate the Ghana Wet and Ghana Dry scenarios, climate projections from the two global circulations models/socio-economic (GCM/SRES) data and scnenarios combinations with the lowest and highest climate moisture index (CMI) for Ghana were used. It is important to note that in the case of Ghana, the globally 'wettest' GCM actually projects a drier future climate for Ghana than the globally 'driest' scenario (Kristensen, Means, et al. 2010). These scenarios include projections for both temperature and precipitation. All climate data, including historical data used to generate the baseline, came from the Princeton data source (See, http://www.princetondatasource.com).

Table 4: GCM scenarios for analysis

GCM Scenarios used for Ghana study			
Scenario	GCM	SRES	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%

Source: Kristensen, Means, et al. (2010).

3.3 Runoff (CliRun)

The CliRun model was used to model changes in runoff. It is a two-layer, one-dimensional infiltration and runoff estimation tool that uses historic runoff as a means to estimate soil characteristics (Strzepek et. al 2011). CliRun was calibrated using historical gauged flow in the Volta and Ghana Basins. There were only a few basins that had decent historical data which made calibration difficult. The runoffs as output from CliRun were observed to be too low for the catchments. Therefore, they were scaled up so the mean annual flows for the 2011-50 reference (base) period matched those observed for the main sub-basins as contained in Table 2. The factors used for this upscaling for the reference period were then applied to the CliRun flows for the other four climate change scenarios. The scaling factor for a main sub-basin was computed as:

$$SF = MAOR/MAPR \qquad (1)$$

where SF is the scaling factor, MAOR is the mean annual observed runoff and MAPR is the mean annual predicted runoff for the reference period. Where modelled runoff was higher than observed, no changes were made to the modelled flows. The observed flows exclude both upstream and within catchment water abstractions such as for municipal supply or irrigation. Therefore, they should be lower than modelled runoff that includes these abstractions.

CliRun's generated monthly runoff from 2011-50 for each catchment and climate change are inputs to WEAP. There were difficulties simulating flows for the last sub-basin in the SWC, Tordzie, so it was left out in the WEAP modeling and analysis.

3.4 Irrigation demand (AquaCrop)

The FAO's modeling tool AquaCrop (FAO 2013) was used to model crop yield and water needs under various climate conditions and in different parts of Ghana. The primary data components for AquaCrop's crop-grown calculations are: climate, crop, soil, and management (which includes irrigation and field management). While AquaCrop can model the effects of CO_2 fertilization, that feature was not used in this analysis. Adjustments were made to the characteristics of AquaCrop's preset crops (i.e. planting calendar, flowering, senescence, plant maturity, etc.) to reflect local conditions and farming practices in Ghana. The analysis used soil information from the FAO Soil Map of the World.

Management components include both irrigation and field management. Adjustments were made to the irrigation component to approximate conditions under which irrigation water might be used. AquaCrop contains no geographic scale data; therefore adding total area under irrigation is a post-process step. To model irrigation, the irrigated area was added slowly over time, assuming that infrastructure may be built incrementally. There was some discrepancy in the literature as to the amount of land under irrigation. The starting number selected was 40,000 hectares. A 2011

IFPRI report placed total current area at 33,000 hectares in 2007, with government schemes making up 9,000; the rest is assumed to be private sector irrigation (Namara et al. 2011). The analysis added irrigation over time from the current baseline. Official documents indicate plans to increase irrigation area to over 500,000 hectares, our model accounts for half that number, or 250,000 hectares. The field management default components within AquaCrop were left mostly unchanged for the analysis.

Cocoa is a significant crop in Ghana, but AquaCrop does not include it. The analysis therefore used data from Zuidema et al. (2005). This data was extrapolated to build the Ghana model. Once the output was generated, the data was checked to ensure it reflected actual irrigation and yields. Where the numbers were in conflict, adjustments were made either in the AquaCrop production input (as a calibration step) or as a coefficient for yield or water demand after the run. The projections of AquaCrop's monthly irrigation water demand from 2011-50 for each of the 29 catchments and each climate change scenario are inputs to WEAP.

3.5 Municipal demand

Municipal water demands are driven by population. Catchment level population data for 2000 and 2010 for all 29 catchments was compiled from the Gridded Population of the World version 3 (CIESIN 2005). For the population data, the growth rate from 2000 to 2010 for each catchment was computed and used to interpolate exponentially for annual catchment populations from 2011 to 2050. The Pra basin had the highest 2010 population of more than 5.9 million while Arly, the upper most catchment of the Oti sub-basin, is the least populated with a 2010 population of a little over 180,000. The assumed per capita daily water demands used to estimate municipal water demand which covers domestic, industrial, and mining demands are presented in Table 5. These demands are applicable at the catchment level, i.e. they apply to all 29 delineated catchments.

Table 5: Assumed per capita water demand used in WEAP

Year	Litres per capita per day (lpcd) demand
2010	60
2015	70
2020	80
2025	90
2030	100
2035	105
2040	110
2045	115
2050	120

Source: Authors' compilation.

A linear interpolation was then used to estimate for the years in between. These were then converted to m^3/yr and input into WEAP for the computation of municipal (domestic and industrial) water demand. Currently, municipal water supply in Ghana meets just a little over 60 percent of demand due to poor and inadequate water treatment and delivery infrastructure and not due to lack of availability of water (GWF 2011). According to FAO (2005), Ghana's current water availability of more than 2000 m^3/person means the country has adequate water resources to meet at least municipal demand. For Accra it is estimated that current supply is equivalent to only about 80 lpcd. For rural supply, 20-40 lpcd is usually considered by the Community Water and Sanitation Agency (CWSA) in its water delivery programs, but in the WEAP setup no distinction has been made between urban and rural demand.

3.6 Hydropower

Hydropower characteristics for current and planned facilities were obtained from literature (VRA 2012; McCartney et al. 2012; de Condappa et al. 2008; ERM 2007; MWH 1998). Hydropower demand is taken as the maximum capacity, in terms of both energy production and turbine flow. Current facilities are the Bagre (Wayen catchment) and Kompienga facilities in Burkina Faso and the Akosombo-Kpong (Main Volta or Senchi catchment) in Ghana. Four planned facilities (all in Ghana) are included in the schematic. These are Bui (Bamboi catchment of the Black Volta Basin), Pwalugu (Pwalugu catchment of the White Volta Basin), Juale (Sabari catchment of the Oti Basin) and Hermang (Pra sub-basin of the SWC Basins). Bui is due to be fully operational in 2014. When the remaining three planned facilities will come on stream is still unknown – 2025 was assumed as the start year for these and input in WEAP. The maximum power generating capacities of the facilities are shown in Table 6. It can be seen from the table that the Akosombo/Kpong and the Bui are the largest among the seven facilities.

Table 6: Installed capacities of the hydropower generating facilities

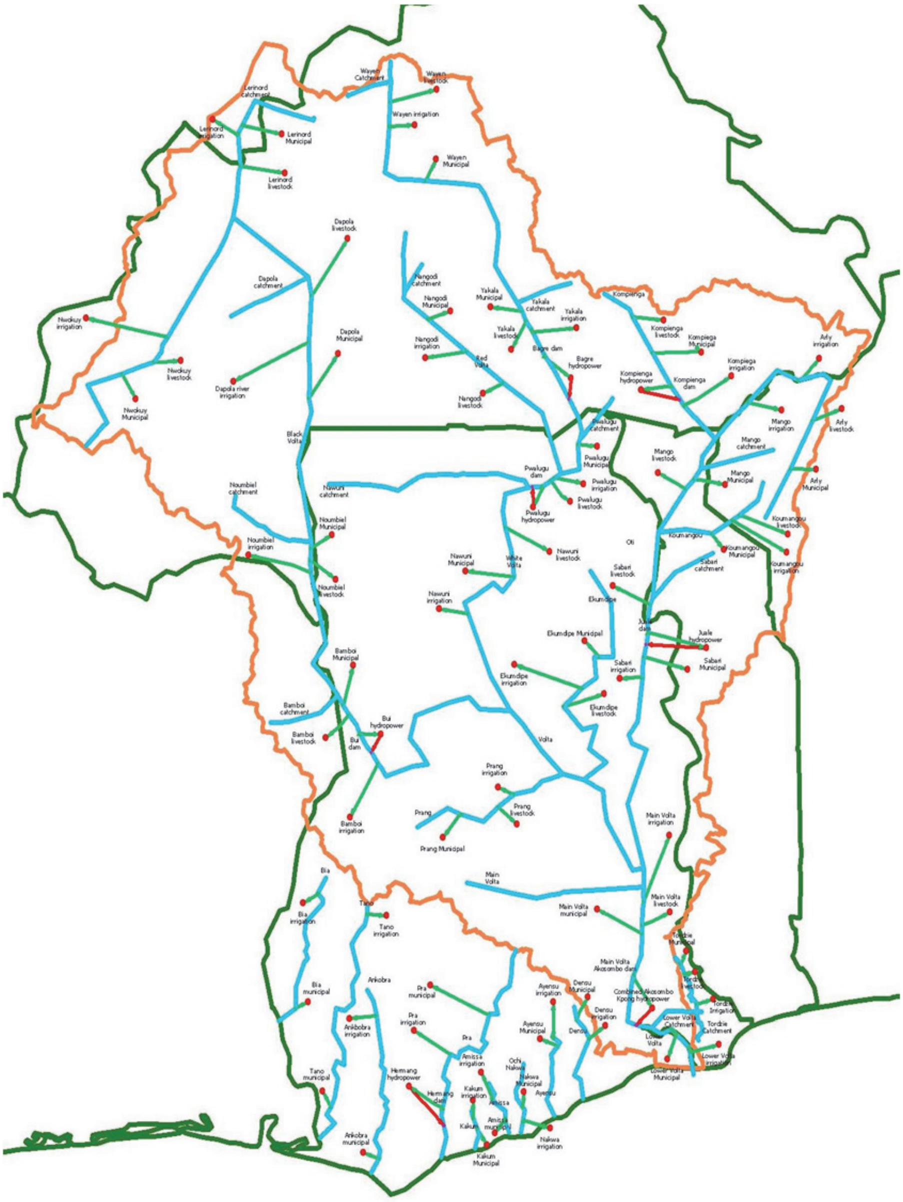
Hydropower facility	Country	Capacity (MW)
Main Volta Akosombo and Kpong dams	Ghana	1,180
Bui dam	Ghana	400
Pwalugu dam	Ghana	48
Sabari Juale dam	Ghana	87
Kompienga dam	Burkina Faso	14
Bagre dam	Burkina Faso	10
Pra Hermang dam	Ghana	93

Source: VRA (2012); McCartney et al. (2012); ERM (2007); MHW (1998).

3.7 Water infrastructure (WEAP21)

The WEAP model (SEI 2013) was used to evaluate water availability and allocation to the various water demands in the Volta and SWC basin system. A WEAP schematic representing all catchments and establishing water supply and demand nodes was first created before inputting the necessary data and running the model. The input catchment runoffs, agriculture water demands and populations (for municipal water demand computations) were obtained at the catchment level as described in the previous sections. The model was run on a monthly time step from 2011-50. Municipal was given highest priority to meet its demand with the available supply followed by agriculture, then hydropower. All local irrigation and water supply infrastructure currently existing in the study area were excluded from the WEAP schematic. This also applied to all local dams except those for hydropower purposes. The WEAP schematic thus developed is shown in Figure 5.

Figure 5: WEAP Schematic for the entire Volta basin and the southwestern and coastal basins of Ghana



Source: Authors' compilation.

4 Results and discussion

4.1 Impact of climate change on catchment runoff

Mean annual catchment runoff relative to reference scenario for all catchments and also at sub-basin level are presented in Table 7 for the other four climate change scenarios. Mean flows are taken over the 40-year simulation period of 2011-50 before computing the changes. At the sub-basin level for the Volta basin, the sum of the runoffs for all catchments in the sub-basin is used to compute the change. The changes are computed as:

$$pc = (MSR\text{-}MRR) \times 100/MRR \qquad (2)$$

where pc is the relative change in percent, MSR is the mean runoff for a scenario and MRR is the mean runoff for the reference).

Table 7: Change in predicted mean catchment runoff for the climate change scenarios relative to the reference scenario

Main sub-basin	Catchment	Percentage change from the Reference scenario			
		Ghana dry scenario	Ghana wet scenario	Global wet scenario	Global dry scenario
Black Volta	Lerinord	-8.5	1.0	11.8	-1.8
	Nwokuy	-16.5	-1.9	2.2	-5.8
	Dapola	-11.1	-1.7	4.9	-4.3
	Noumbiel	-9.7	-4.9	1.0	-7.2
	Bamboi	-8.0	3.3	1.0	-8.2
Sub-basin level		-10.6	-0.5	3.6	-5.7
White Volta	Wayen	-7.5	-0.3	13.2	-0.9
	Yakala	-9.5	0.5	6.7	-2.0
	Nangodi	-10.1	0.5	5.3	-2.6
	Pwalugu	-9.7	-0.1	2.0	-3.3
	Nawuni	-8.9	0.2	0.7	-5.4
Sub-basin level		-8.9	0.2	4.1	-3.7
Oti	Arly	-8.6	3.4	-1.0	-0.7
	Kompienga	-9.9	0.8	4.0	-2.2
	Mango	-8.2	3.3	0.9	-1.4
	Koumangou	-9.7	3.5	-0.4	-1.9
	Sabari	-9.0	2.5	-0.5	-4.1
	Ekumdipe	-8.3	2.8	-0.4	-7.3
Sub-basin level		-8.8	2.9	0.3	-2.8
Main Volta	Prang	-7.5	9.5	0.5	-9.5
	Senchi	-7.5	6.2	-0.5	-9.1
Sub-basin level		-7.5	6.5	-0.4	-9.1
Lower Volta	Delta	-9.1	7.8	0.9	-10.1
Densu	Densu	-18.8	35.7	-2.8	-17.3
Ayensu	Ayensu	-16.2	35.4	-1.9	-14.3
Nakwa	Nakwa	-31.1	71.7	12.9	-17.8
Amissa	Amissa	-21.3	60.6	-0.8	-18.6
Kakum	Kakum	-20.3	81.1	4.1	-17.8
Pra	Pra	-25.9	60.9	-12.2	-34.4
Ankobra	Ankobra	-22.8	71.6	-4.6	-21.5
Tano	Tano	-26.0	32.4	-12.8	-30.6
Bia	Bia	-12.7	13.2	-4.3	-15.1

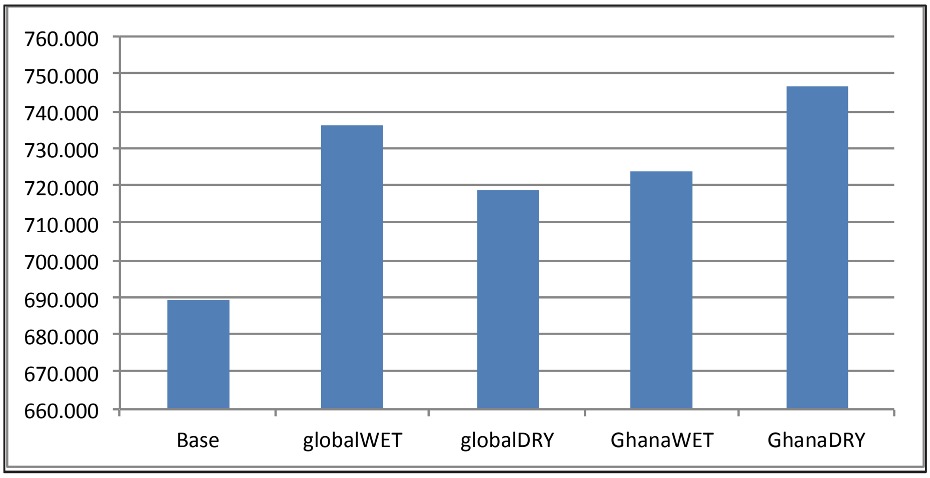
Source: Authors' compilation.

The results in Table 7 show that while for the Black and White Volta main sub-basins the Global Wet scenario is generally wetter than the Ghana Wet, it is the opposite for the other sub-basins. In fact, for the SWC basin systems, for example, the Global Wet is not wet at all. The results also show that the Ghana Dry scenario projects dryer conditions than the Global Dry scenario for most of the catchments. It is the wetter sub-basins of the Main Volta and the southwestern sub-basins of the Pra, Tano, and Bia that are the exceptions. Since the hydrological model couldn't simulate the runoffs in the SWC basin systems very well, it is likely that the change results for these two basin systems are not accurate. On the whole, it appears that the Global scenarios project less severe conditions than the Ghana scenarios, as far as water resources availability in the Volta and Ghana is concerned. Nevertheless, the inconsistency in the direction of change of predicted runoffs across the basins reaffirms the uncertainty of the level of climate change impacts on water resources at the local scale.

4.2 Impact of climate change on irrigation demand

The AquaCrop model indicates that irrigation water demand will rise under all four scenarios, when compared to the baseline. The model projects increased irrigation water demand based on both newly built irrigation infrastructure, and climate change. Figure 6 shows the increased average annual irrigation demand over and above the baseline for each of the climate scenarios in the analysis. Units are MCM/year averaged over the 40 years of the study.

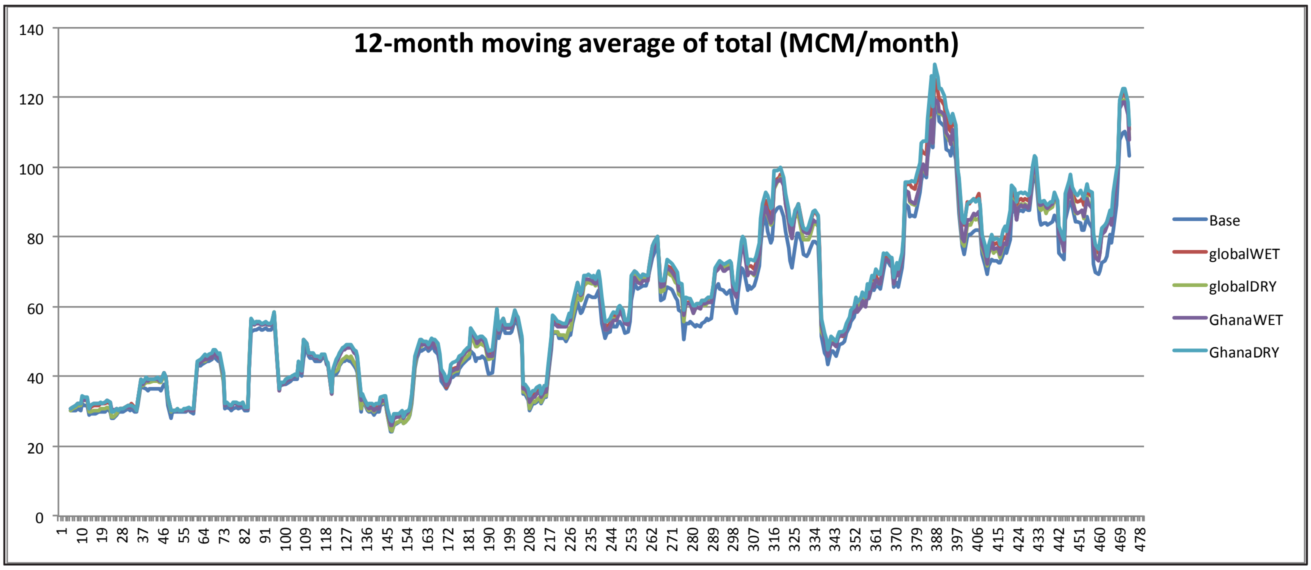
Figure 6: Average annual irrigation demand for water for all years in analysis (base is current withdrawal)



Source: Authors' compilation.

Figure 7 shows a smoothed, average monthly irrigation demand rising over the time of the analysis (2010-50). The general rise is a result of additional irrigation for agriculture over the period. The short cycles represent the annual rise and fall of irrigation water demand, with increases for seasonal irrigation needs, and decreases during rainy seasons, or limited crop production. During the later years of the analysis, the increased irrigation demand for all four scenarios over the baseline is more pronounced.

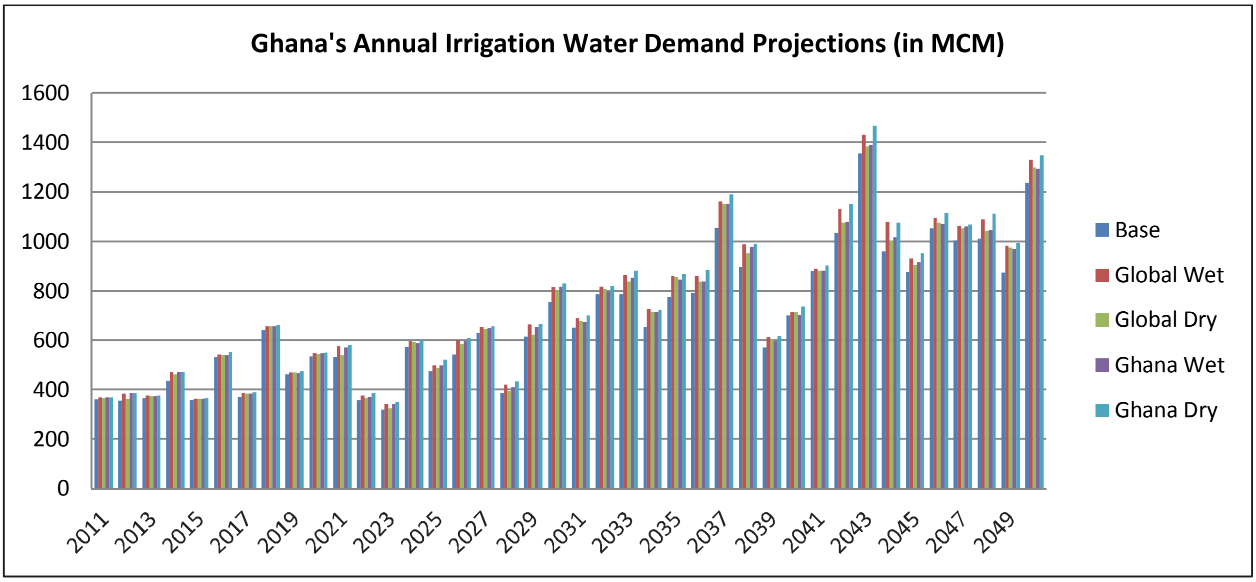
Figure 7: Month-by-month moving average of irrigation water demand for Ghana agriculture



Source: Authors' compilation.

Figure 8 shows Ghana's annual projected irrigation water demand during the forecasted period. The gradual upslope illustrates the increased irrigation demand over time and added infrastructure modeled. The variance between the baseline and each scenario illustrates the increased irrigation demand due to a changing climate in any given year.

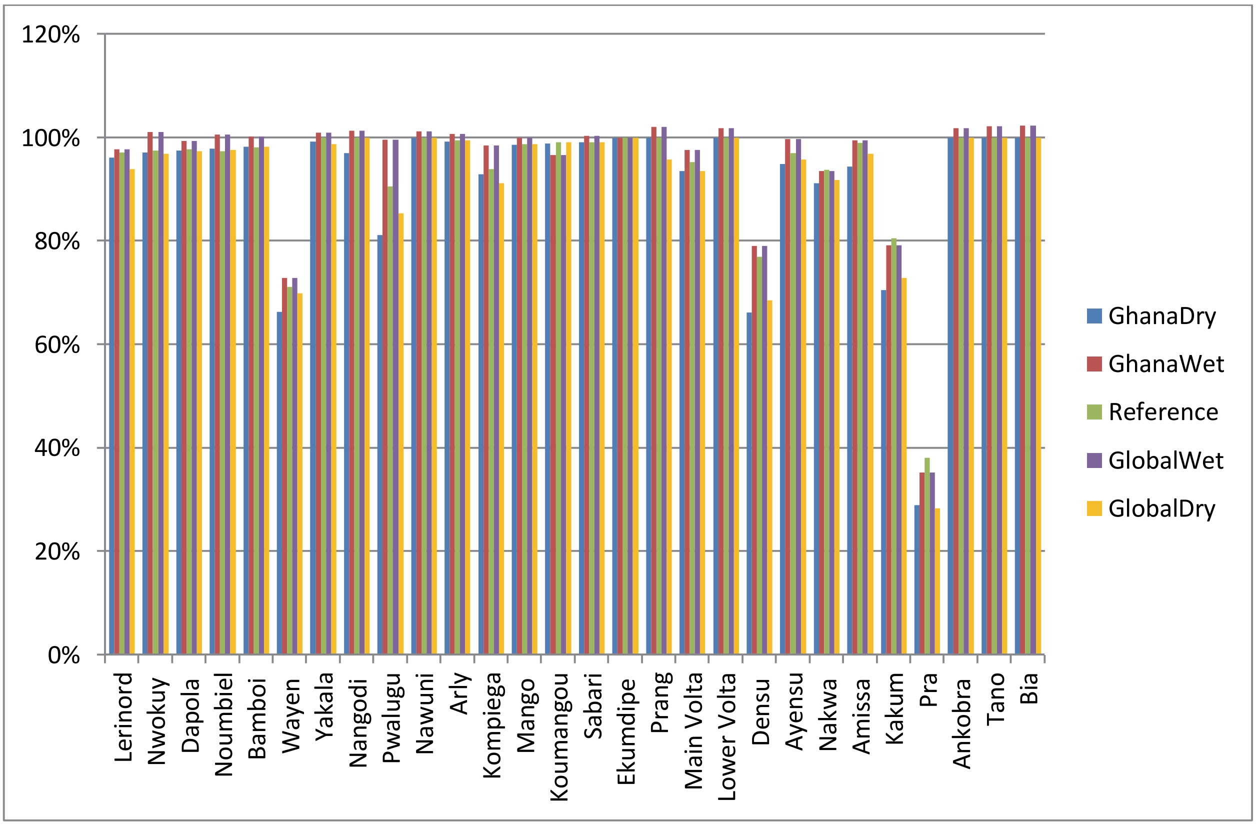
Figure 8: Irrigation water demand projections year for base and four scenarios



Source: Authors' compilation.

Mean annual agricultural water demand coverage averaged over the climate change scenario periods are presented in Figure 9 for all catchments and scenarios. It is observed from Figure 9 that agricultural water demands for the simulation period are not fully met except for the wet scenarios. The shortfall is rather large for the water stressed catchments of Wayen, Densu, and Kakum. The coverage from Pra is also very low and though the sub-basin is not water stressed it has huge municipal – it has the highest population among all the catchments – and hydropower demands to satisfy.

Figure 9: Agricultural water demand coverage

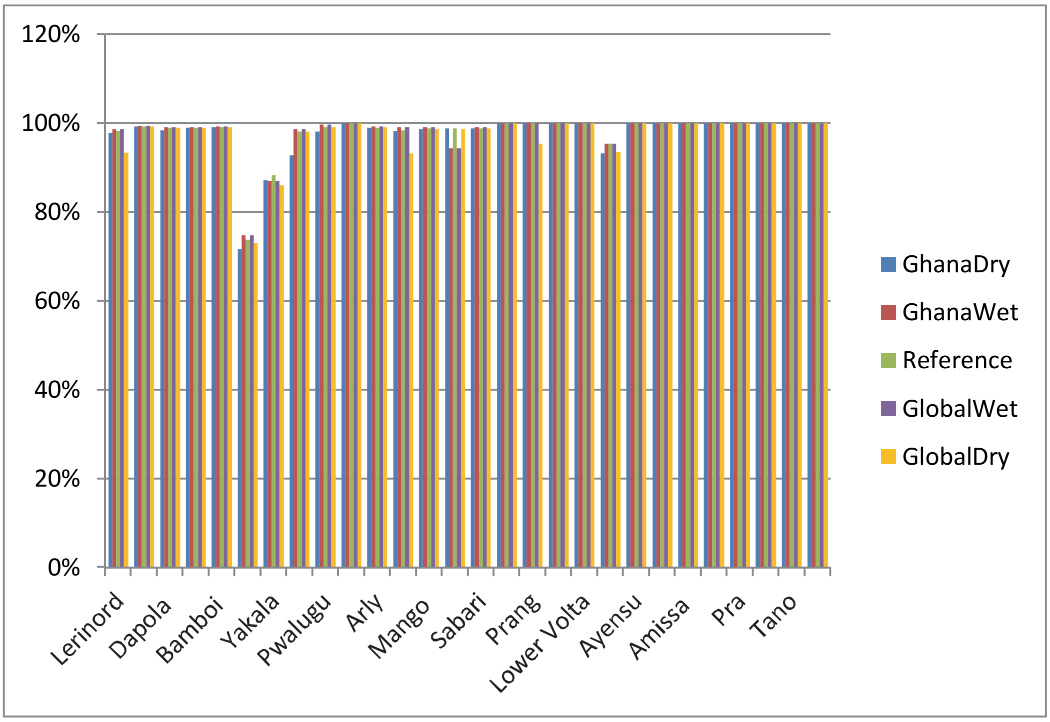


Source: Authors' compilation.

4.3 Impact of climate change on municipal demand coverage

The municipal water demand coverage for the basins averaged over the entire 2011-50 period is shown in Figure 10. On the whole, the coverages are high except for a few cases, particularly the small catchments in the more arid northern part of the Volta Basin such as Wayen and Yakala. Densu is the only sub-basin in the SWC basin system with poor demand coverage.

Figure 10: Municipal water demand coverage



Source: Authors' compilation.

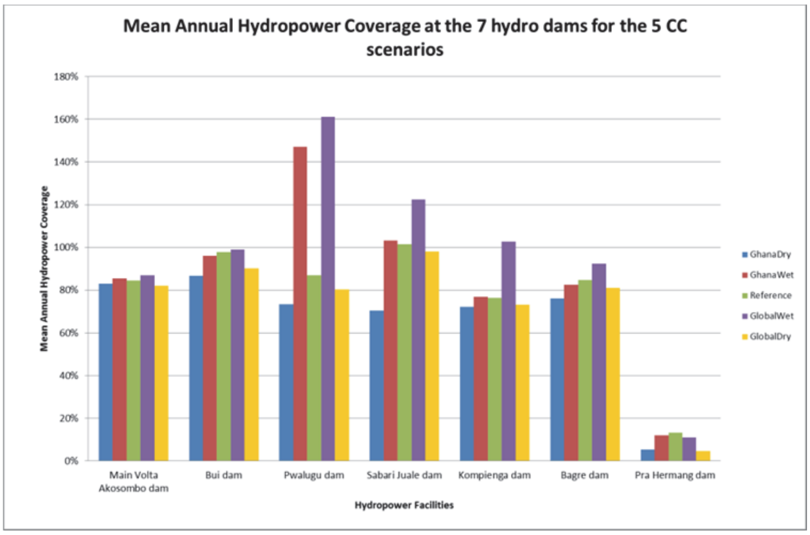
The municipal demand for this sub-basin includes half of the demand for the Greater Accra Metropolitan Area (GAMA) covering the city of Accra and the surrounding communities. Currently GAMA obtains half its water requirements from the Weija water supply facility on the Densu River – the other half is sourced from the Lower Volta below the Akosombo dam. The high population in the GAMA (highest in Ghana) thus puts great pressure on the water resources of the sub-basin.

4.4 Impact of climate change on hydropower production

The climate change impacts on hydropower generation potential are summarized in Figure 11 with percentage coverage computed from means taken over the entire 2011-50 period for the Bagre, Kompienga, and Akosombo facilities, 2014-50 for Bui and 2025-50 for Juale on the Oti, Pwalugu on the White Volta, and Hermang on the Pra Rivers. The coverages are potential since they can exceed 100 percent. The potential hydropower generation is based on flow availability only.

Figure 11 shows that there is variability in demand coverage at the facilities for the study period. The coverage for the Hermang facility in the Pra sub-basin is rather low. Again this points to inadequate basin runoff generated by CliRun. The percentage coverages are generally higher for the Global scenarios than for the Ghana scenarios, in agreement with the latter scenarios being generally drier than the former as pointed out earlier. The results also show that on the average, the demands for the two largest facilities, Akosombo and Bui, are not fully met under any of the scenarios.

Figure 11: Mean annual hydropower coverage for the seven plants under all four climate change scenarios generated from WEAP



Source: Authors' compilation.

5 Conclusions and recommendations

A WEAP model for the entire Volta Basin and all of Ghana has been set up. The model runs with input data on simulated sub-basin runoffs from the water balance model CliRun, expected municipal water demand, hydropower demand, and simulated agricultural water demand from AquaCrop. It has been successfully used to model the impact of climate change on the availability of water resources to meet various demands in the study area using four climate change scenarios.

The CliRun catchment runoff predictions for input to WEAP underestimate mean runoffs for the catchments but appropriate adjustment have been applied to them to enable WEAP to run satisfactorily. The simulated runoffs show that the global climate scenarios used tend to be wetter on the whole than the Ghana climate change scenarios. Runoffs in the Volta Basin are very sensitive to rainfall because of the basin being largely semi-arid to arid.

Rainfed agriculture is especially vulnerable. This analysis has shown the variability of different regions and crops in their susceptibility to different climate scenarios moving forward. Some regions and crops may be significantly impacted, while others are less so. But the overall trend is clear: higher temperatures and lower precipitation mean diminished crop productivity. Irrigation water demand is expected to rise in response to climate change, most significantly under the 'Ghana Dry' scenario.

Results from the modeling exercise also show that the basins studied would not have enough surface water resources to fully satisfy all three water demands (municipal, agriculture, hydropower) simultaneously even for the wet scenarios. This calls for an assessment of groundwater resources and integrated water resources management in the basins to ensure that both the resources that are under great pressure and the future demands on them are prudently managed. It should be noted that the large turbine flow at Akosombo means quite a lot of streamflow in the Lower Volta. This could be mobilized with the necessary infrastructure to further meet the water demands in the coastal regions of Ghana, in particular.

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