DIAGNOSTIC STUDY OF THE BLACK VOLTA BASIN IN GHANA

Final Report

Prepared by Allwaters Consult Limited

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Executive Summary

Introduction

The Global Water Initiative (GWI) is a worldwide program that is financed by the Howard G. Buffet Foundation. The long term goal of GWI is to generate lessons from Integrated Water Resources Management processes that inform policy change in the water sector, establishing platforms and frameworks that promote advocacy towards good governance of water resources.

This program is implemented in Ghana by a consortium of NGOs namely CARE International and Catholic Relief Services (CRS) together with the Regional Office for Central and West Africa of the International Union for Conservation of Nature (IUCN-PACO), based in Ouagadougou, Burkina Faso.

Recognizing that a river basin is the unit for planning in the Ghana Water Policy (2007), steps have been taken by IUCN-PACO to provide information that will lead to understanding the hydrology and water resource characteristics of the Black Volta basin. In view of this, Allwaters Consult Limited was contracted by IUCN to undertake this study in Ghana to guide future implementation of Integrated Watershed Management in the Black Volta basin.

The overall objective of this study was to prepare a document that will guide the future interventions of GWI in Ghana, characterise water resources (both current and future) of the Black Volta basin highlighting sustainable operational mechanisms including constraints that govern water resources. Specifically, the assignment sought to

i. Assess the hydrological situation of the Black Volta basin, delineate its' extent and limits, determine the interaction with other hydrologic systems, and the transboundary zone with Burkina Faso
ii. To understand the stakes of water resources, the potential of surface water and groundwater systems, uses, and stakeholders (whose activities impact directly or indirectly), management constraints as regards exploitation and suitability
iii. To assess the state of dug-outs, dams, wells, and characterize the agricultural or irrigation water use (current and future) on one hand, and the cultivated areas around these water bodies: surface, types of crop, seasonal (or not) use of water, on the other hand
iv. To examine the ecosystem approach into river basin planning and management of the Black Volta.

The work was carried out in three blocks. Block 1 involved desktop studies of the Black Volta and the Volta basin in general; Block 2 covered Field work where the consortium visited GWI communities, other communities of interest and Key stakeholders in the basin. The last block - Block 3 was mainly about report writing and validating the study.

Study Area

The Black Volta basin lays between Latitude $7^{\circ}00'00''$N and $14^{\circ}30'00''$N and Longitude $5^{\circ}30'00''$W and $1^{\circ}30'00''$W, and covers an estimated area of about 130,400 km^2. In Ghana, the basin covers an area of about 18,384km^2 constituting 14% of the basin. The Black Volta river basin is a trans-national river system that stretches from North to South through Mali, Burkina Faso, Ghana and Cote d'Ivoire, and from Burkina Faso, Cote d'Ivoire and Ghana from West to East.

The study was carried out in the portion of the basin within Ghana with a water audit section in the Upper West Region of Ghana within the basin. The study area covers 8 districts out of 19 districts which falls within the Black Volta basin in Ghana.

As of the year 2000 the Black Volta was home to about 4.5 million people in Burkina Faso, Ghana, Cote d'Ivoire and Mali. This population is estimated to grow to about 8 million by the year 2025. Population density in the basin ranges from 8 to 133people/km^2. Bouna department in Cote d'Ivoire and Sissala district in Ghana both have the lowest of 8 and Lawra district in Ghana has the highest of 133. The average population density is 43people/km^2.

In the Black Volta basin, most lands are used for agriculture with bush fallow food crop cultivation. The food crops cultivated are mostly under rain-fed cultivation of cereals including rice, millet, sorghum, and maize; yam, cassava, groundnuts and beans. In the dry season some farmers grow vegetables including tomatoes, pepper, okro, lettuce, cabbage and pumpkin especially in the Lawra district. Most farmers practice compound farming since lands closer to their houses are somewhat fertile. However, in the Lawra district the lands are highly degraded both in terms of physical status and soil fertility levels and can hardly support crop cultivation which contribute to low crop yield. This is exacerbated by the rather high population density. Animal grazing in the basin is mostly done on free range except in the dry season, where livestock owners/herdsmen migrate with their animals in search of water and feed in nearby communities.

The landcover maps prepared for the Black Volta basin show that in Burkina Faso most of the land has been developed for Agriculture (Rainfed and Irrigated) whereas in Ghana most of the land is under forest/grassland cover. There is therefore the potential to increase Agriculture land, but this has to be done in a sustainable manner.

The dominant soils in the Black Volta basin according to the FAO soil classification are Luvisols and Gleysols with altitudes ranging between 60m and 762m above m.s.l. In the Ghana portion of the basin, Ferric Luvisols is the most dominant soil type.

Temperature in Ghana normally never falls below $24^{\circ}C$ since the country is on the equator[1]. Annual mean temperature in the Volta basin is between 27-$30^{\circ}C$ and in the Black Volta, $26^{\circ}C$. Daily temperature rises as high as $44^{\circ}C$ during the day and could fall to $15^{\circ}C$ at night. The

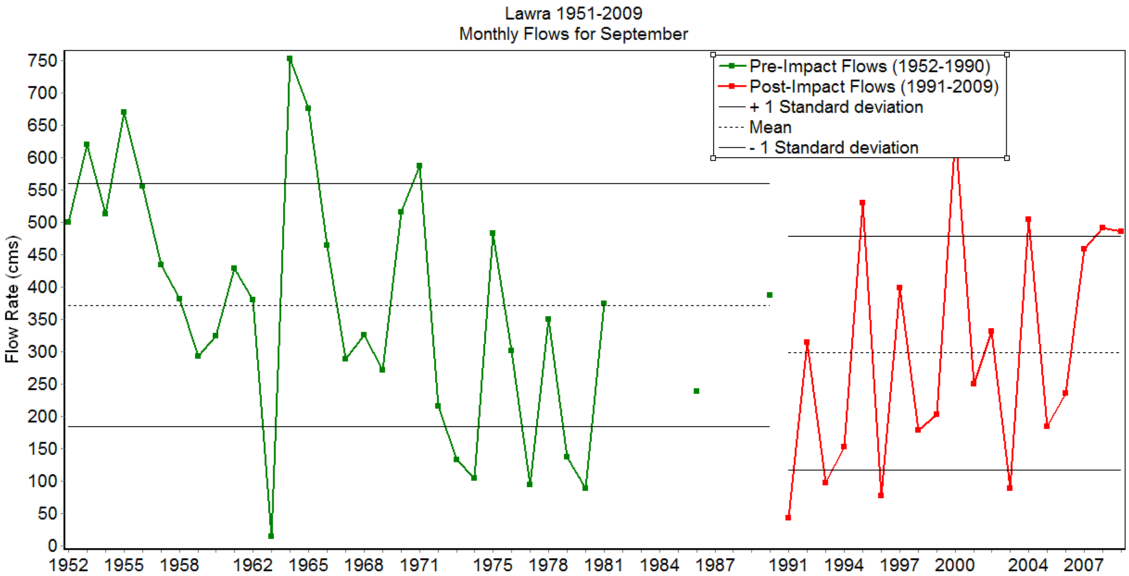
[1] BARRY *ET AL*, 2005. COMPREHENSIVE ASSESSMENT OF WATER MANAGEMENT IN AGRICULTURE. COMPARATIVE STUDY OF RIVER BASIN DEVELOPMENT AND MANAGEMENT.

hottest Months are March-April and the coolest, August[1]. Relative humidity is between 20-30% in the harmatan season and 70-80% in the rainy season.

Water Availability

The Black Volta basin is drained by the Bougouriba, Gbongbo, Grand Bale, Voun Hou, Sourou, Wenare, Bambassou, Bondami, Mouhoun (main Black Volta), Tain and Poni rivers as main tributaries.

The mean runoff in the Black Volta is estimated at 7km^3 per annum[2]. The driest and wettest months are March and September, respectively. Monthly flows in Lawra (upstream), Bui (Mid-stream) and Bamboi (downstream) were used to assess the runoff from the basin within Ghana.



Monthly flows for Lawra (1952-2009)

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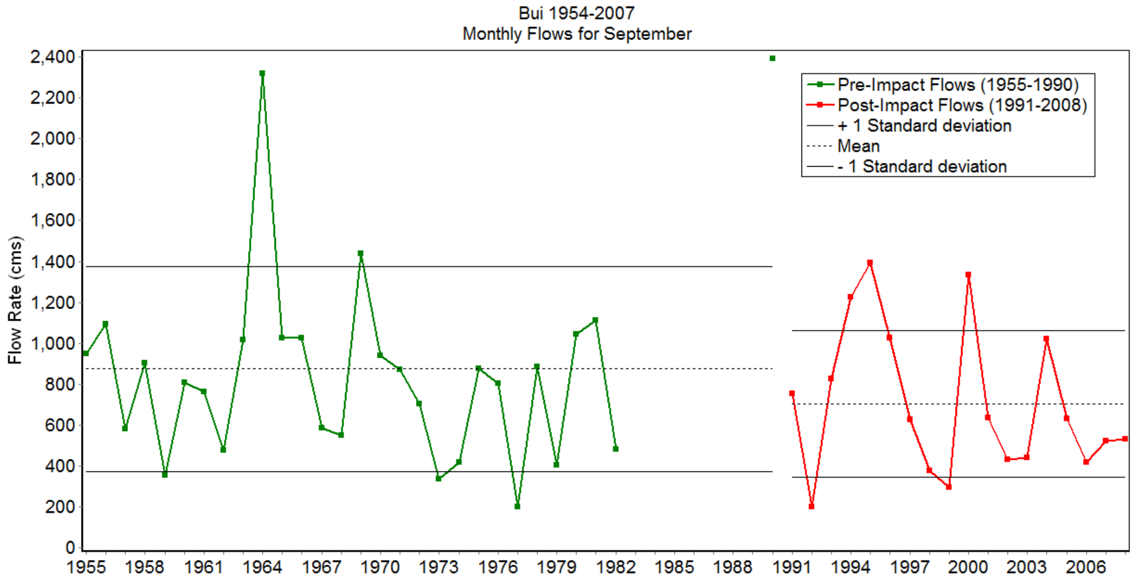
[2] ANDREINI ET. AL. (2000). VOLTA BASIN WATER BALANCE



Monthly flows for Bui (1955 – 2008)

The late 1980s and early 1990s marked the evolution of reservoirs in the basin; and reservoirs are still being constructed. This period (1990-2009) is referred to in this study as a post-impact period since the dams cause hydrological alterations in the basin, Periods (1952-1989) before the construction of the dams is called a pre-impact period. From the figures above it is evident that a large quantity of water flows to the Volta lake untapped. Although this flows are useful for hydropower production downstream there is much more to be tapped upstream while meeting hydropower (downstream) needs as well .

On the average, the mean annual groundwater recharge of the Volta River system is about 5-12% of annual precipitation in weathered rocks. Only rainfall values exceeding 380mm/annum in these weathered rocks recharge the groundwater system. Monitoring of groundwater quality is somewhat better than surface water quality due to the fact that the Black Volta is predominantly rural (about 70%) and their domestic demands are satisfied with groundwater. Apart from hardness, groundwater quality seems to be ok as shown in Table 6. The potential problems with groundwater are largely fluoride excesses and iodine deficiencies (i.e. less than 0.005 mg/l)[3].

Delineation of Subbasins

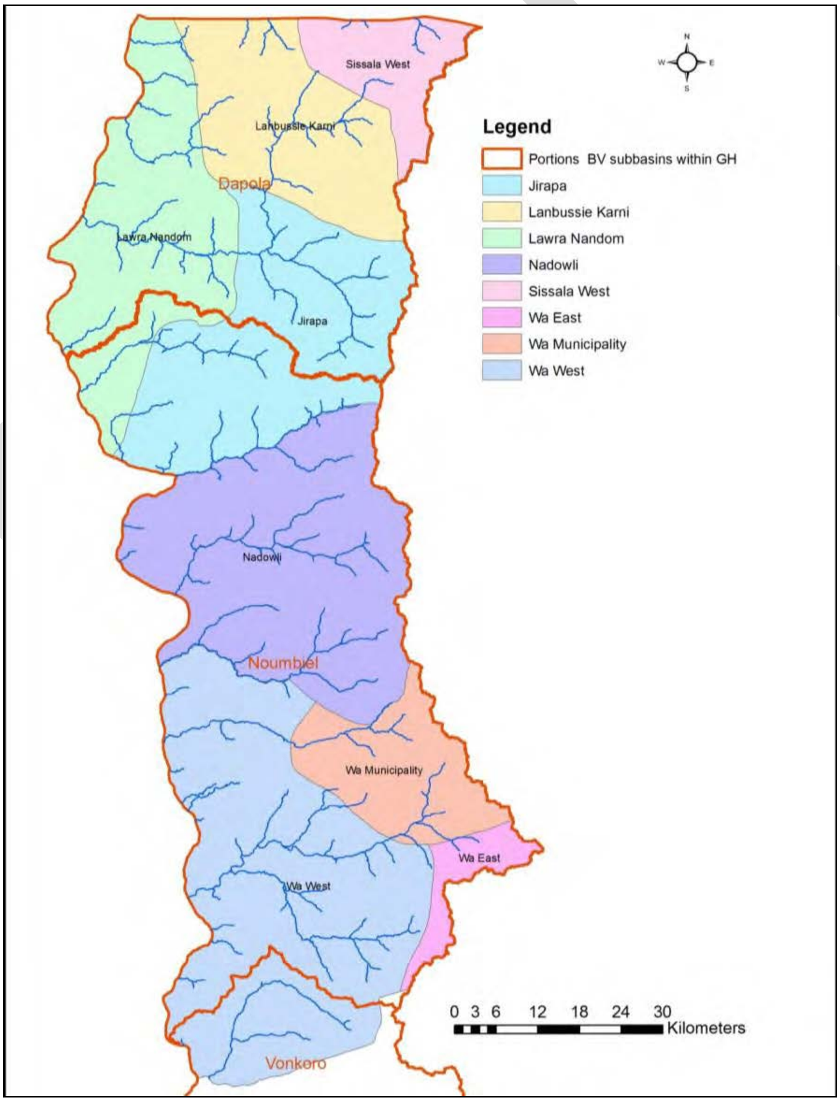
In Ghana, the Water Resources Commission (WRC) considers the whole portion of the Black Volta basin in Ghana as its unit of planning for IWRM. However this study delineated the basin into 5 main sub-basins in Ghana; Dapola, Noumbiel, Vonkoro, Bui and Bamboi. The study also considered the portion of the Black Volta Basin within the Upper West Region as its' water audit section (shown in the figure below). The WEAP model developed looked in detail at water allocation in the water audit section.

3 GROUNDWATER QUALITY IN GHANA. WATERAID WORKING DOCUMENT. PUBLISHED BY BRITISH GEOLOGICAL SURVEY, 2002.

The stations of interest to Ghana within the Black Volta basin includes the one listed in the table below.

The stations of interest to Ghana within the Black Volta basin

STATION	Latitude	Longitude	COUNTRY	RIVER
Dapola	10.570	-2.920	BF	Black Volta
Lawra	10.630	-2.920	GH	Black Volta
Noumbiel	9.680	-2.770	BF	Black Volta
Vonkoro	9.190	-2.710	CI	Black Volta
Bui	8.281	-2.238	GH	Black Volta
Bamboi	8.150	-2.030	GH	Black Volta



The Upper West Region within the Black Volta Basin

Water Demand in the Basin

Water use in the basin is mostly for agriculture, domestic purposes, fishing, livestock, the environment and currently mining (legal and galamsay). Portable water supply to the populace in the basin within Ghana is done largely by the GWCL for urban coverage; and the Community Water and Sanitation Agency (CWSA) for rural water supply.

The GWCL operates mainly by using surface water resources and sometimes wells and boreholes. It has 208 pipe borne water systems, 8000 boreholes with hand pumps, 10,000 hand-dug wells to supply water to urban towns including Wa Municpality[4].

CSWA uses mostly the small town water supply system with mechanized boreholes often as the source of supply.

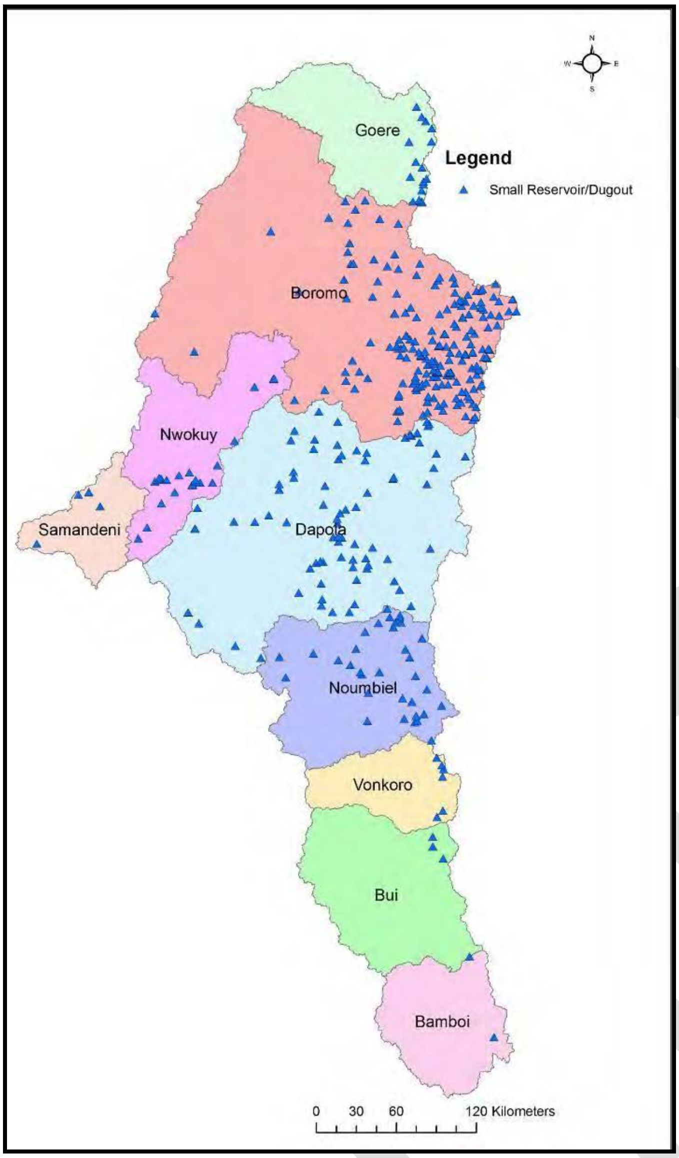
Rural domestic water demand is estimated as 50l/c/day while that of urban population in the basin is estimated at 120 l/c/day.

Most farmers in the Black Volta basin in Ghana are peasant farmers who practise compound farming. Irrigation is largely done using small reservoirs hence its water demand is met by small reservoirs. The only notable large irrigation scheme in the basin within Ghana is the Bui irrigation which has an estimated water use rate of 20,000m^3/ha/year and a projected irrigable land of about 800ha by 2030 under cultivation.

Livestock in the basin water from the main Black Volta river and its tributaries, and small reservoirs and dugouts. This usually serves as water source for large ruminants including cattle. However, small ruminants like goat and sheep often source their water needs from dugouts, wells and boreholes for which reason a trough is built at the water facility. Data collected by MOFA for 2010 shows that goat is the predominant livestock kept in the Upper West region. The region has over 600,000 herds of livestock with an annual water use rate of about 1.7Million m^3.

A number of small reservoirs are dotted in the Volta basin especially in the White Volta basin. This is very much utilized in the White Volta unlike in the Black Volta. The total annual water demand is estimated at 102Mm^3 for the entire Volta basin. In the Upper West Region of Ghana in the Black Volta basin alone, the annual water demand for small reservoirs was found to be 4.2Mm^3 representing about 4% with respect to small reservoir demand for the entire Volta basin.

[4] ADOM (1997). GHANA WATER RESOURCES MANAGEMENT STUDY. INFORMATION BUILDING BLOCK. MAIN REPORT – URBAN WATER SUPPLY



Small reservoirs in the Black Volta basin (left) and in the basin within Ghana (right)

Environmental flow is considered to be the minimum flow required to sustain habitat in rivers. It is considered in this study as the 25 percentile flow since detail study carried out on environmental flow requirement for the basin is not available. In previous studies it was assumed to be 0.05 m^3/s [5].

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[5] VOLTA WATER AUDIT UPDATE STUDY, 2012

Challenges regarding use of water in the Black Volta basin of Ghana

Most communities in the Black Volta are supplied with boreholes for their domestic water needs. Unfortunately minor routine maintenance and operation such as chlorination is not carried out. Whereas management mechanisms are operational through monthly levy and contributions from members who patronize the facility for the purpose of maintenance, other communities have adopted the pay as you fetch approach. The former was found to be faced with the challenge of effective collection and thus less sustainable.

Some communities have been provided with Small Reservoirs or Dugouts. However, no intensive large scale irrigation is carried out downstream of these facilities with the exception of the one in Bui. Most of these dugouts also dry up in the dry season when it is needed most for dry season vegetable gardening and livestock watering. This is primarily due to the fact that they are silted or have seepage problems. Regular desilting is not carried out by community members because they claim it is difficult to do when even some of the communities have been provided with the tools to be used by organizations like GWI.

Crops grown are mostly cereals like Maize, Sorghum and rice in the rainy season and mostly vegetables including pepper; tomatoes and onions in the dry season. The yields of these crops are low because of poor soil fertility. Women are most often given the poor lands in terms of soil fertility to farm on. This discrimination does not promote gender equity and poverty alleviation among women and household food security, in general.

The rainfall pattern is becoming more and more erratic and poses a major challenge in the basin as most farmers do rain-fed farming. This contributes to the low yields especially for the early maize and millet. There is the need to therefore shift towards efficient and productive irrigation where farmers could make up for their losses.

Crop production in the Upper West region seems to be increasing. However, there is no corresponding increase in yields. So there is intensification of farming without necessarily improving productivity. This does not encourage the young folks in the communities to engage in active farming hence leads to migration of the youth to big cities in the countries for non-existent jobs.

Application of water in farms is mostly done with buckets and ropes or watering cans. This is somewhat inefficient and tiresome when large areas of lands are to be irrigated. Those who use water pumps also complain of high cost of fuel to run their pumps. Providing solar pumps with tight security could be an option out of this problem. GWI, CWSA and other organizations have introduced solar pumps to run community water supply systems which seem to be efficient. This could therefore be looked at in more detail through benefit-cost analysis.

There is the need to train the youth in most communities in non-farm based income generating activities or trades to supplement the income they generate from farming. This is indeed needed to ensure that they do not migrate to cities where it mostly ends up in hardships.

Productivity of irrigation or farming is low and so is water application. With poor soils and intensified agriculture, low yields seems to be the only result. Farmers need to be educated on sustainable irrigation technologies and farming practices which would improve their crop yields. This cannot stop there! There is the need to train them also on micro-financing so they can be more productive and shift gradually from subsistence to commercial farming and livestock rearing.

Access to Markets is not a major problem since markets for food stuff and livestock are within 5km distance from most communities. In other communities farmers have to either walk or ride bicycles/motors over distances of more than 25km to sell their produce. There is the need to engage farmers in innovative ways of marketing their goods to ensure market queens do monopolise the system as is currently being done.

Good book or record keeping is essential for farmers so they can track their progress. Currently this is not done so it is difficult for farmers to quantify their productions and profit margins. They need to be taught how to carry out basic cost-benefit analysis.

The main transboundary issue in the basin has to do with the nomads also known as the "fulanis" who cause a lot of problems for the indigenes. Some of the issues raised include:

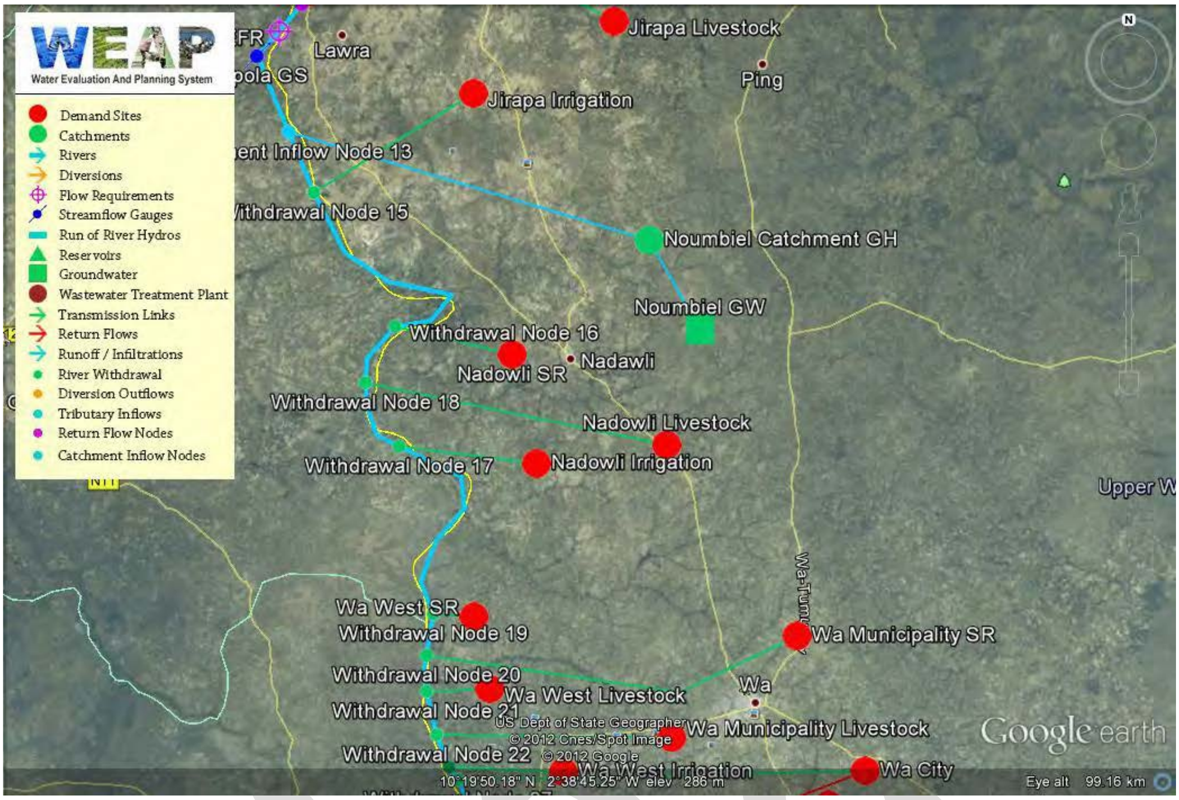
- Destruction of crops by their livestock
- Use of limited quantity of water in dugouts meant for the livestock of the indigenes
- Illegal possession and occupancies of lands meant for indigenes
- Raping of women
- Arm robbery

Another transboundary issue to be addressed in the basin is the issue of flooding where upstream releases from dams is purported to cause flooding downstream. This has to be studied critically with some hydrological (flood) models.

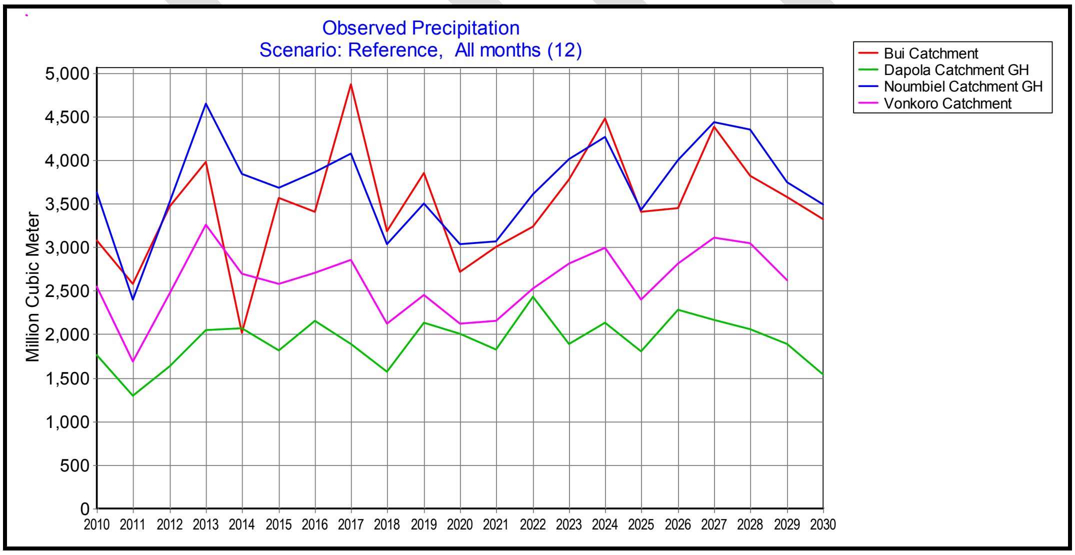
The platform to be created will have to find a novel way to address some of these pressing issues in the basin within Ghana taking into account existing traditional institutions and norms.

Water Allocation in the Upper West Region of the Black Volta Basin

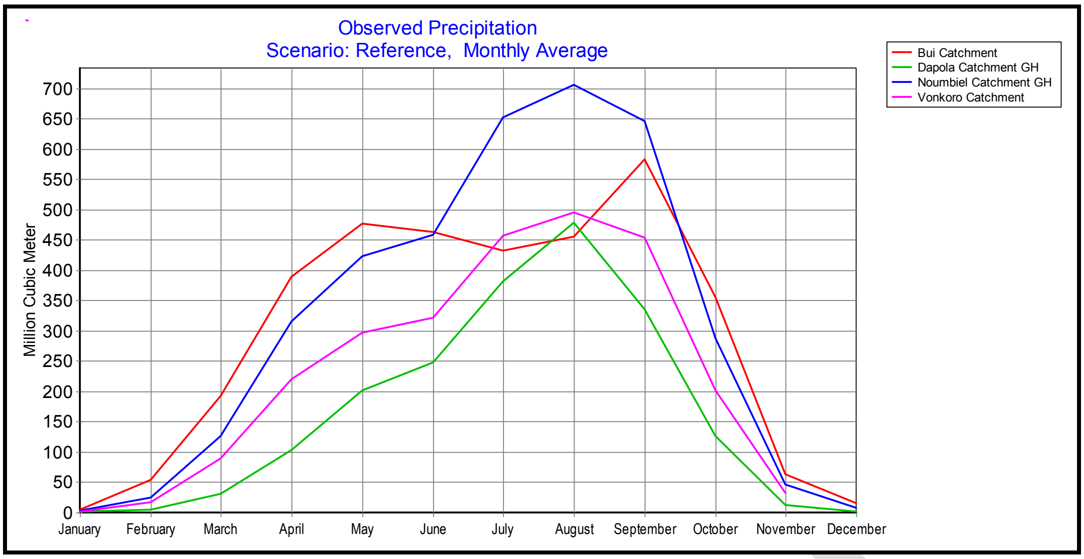
A WEAP model was developed using climate (Rainfall, relative humidity, net evaporation, temperature, cloudiness fraction), hydrological (monthly stream flow) and demographic data sets including population and landuse for the Upper West Region Water Audit Section (UWRWAS). Results show that there is enough water to meet all needs in the basin under all 3 climate scenarios considered (Reference, drier and wetter climate scenarios) with a 1 degree change in temperature. A schematic of the model displayed with a google map background is shown in the figure below. The figures below show some of the model inputs and outputs.



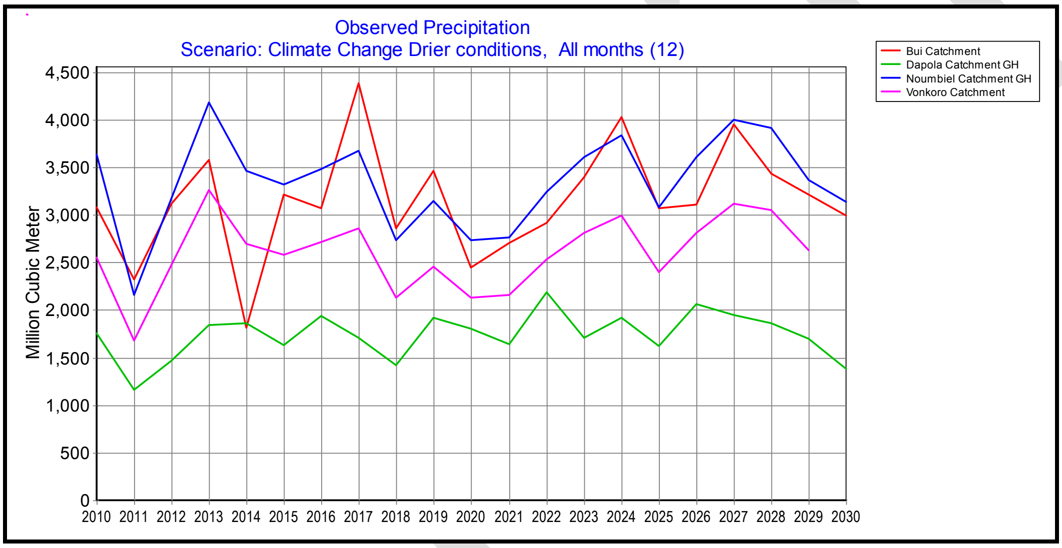
Schematic of the Upper West Region WEAP model



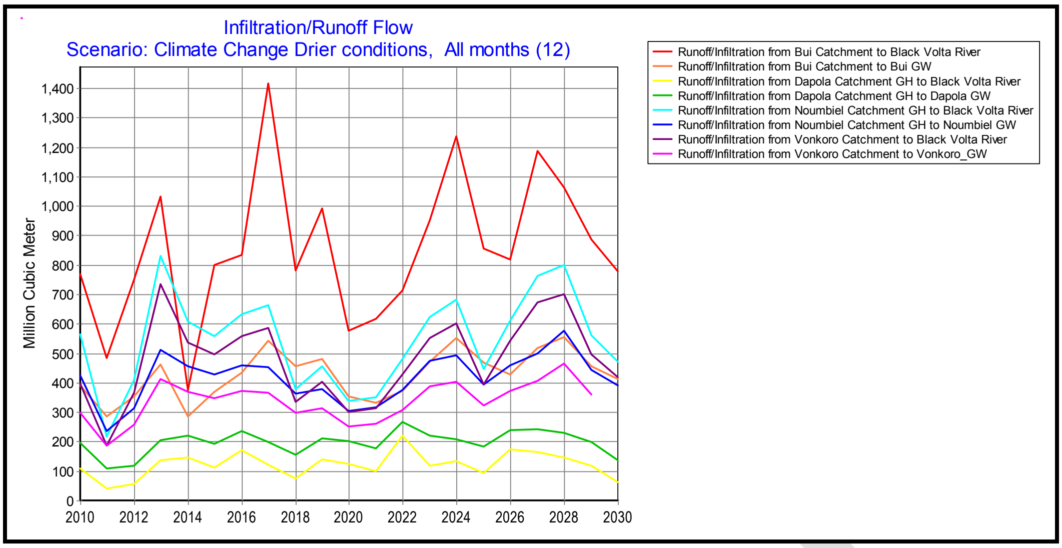
Annual Precipitation in the Black Volta subbasins within Ghana – Reference condition



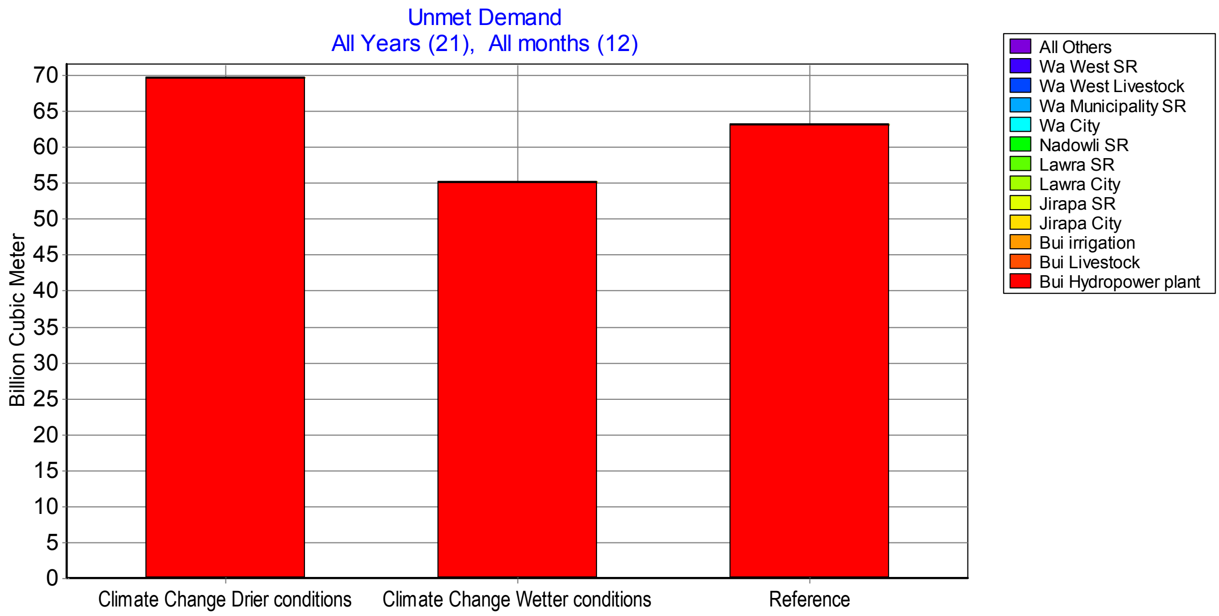
Monthly Average Precipitation in the Black Volta basins within Ghana – Reference condition



Annual Precipitation in the Black Volta basins within Ghana – Drier Condition



Runoff/Infiltration generated in the Black Volta sub-basins within Ghana – Drier condition



Unmet water demands for all scenarios and all years

Water Governance in the Basin

Water is a vital resource which plays a major role in the developmental agenda of all the riparian countries of the Volta basin. There has been over exploitation and pollution of water resources base in the basin due to uncoordinated management and lack of water governance. Among the competing uses of water in each riparian state are irrigation, fisheries, domestic water supply and livestock watering. There also exist competition over water by upstream and downstream countries notably among them is that between Ghana and Burkina Faso. In order to eradicate suspicion and build trust among the states sharing the common resource, it is important to work towards establishment of a coordinated effort of water management and institutionalization of pragmatic governance systems.

Governance to say is the most influential factor, as far as organizing framework for decision making is concerned. As far as IWRM is concerned, there have been a lot of efforts in rolling out platforms where issues pertaining to the management of water resources are dealt with. One of such platforms was the Volta Water Governance Project (PAGEV) which operated from 2004-2007 (phase I) and continued until about 2011 with the second phase. This project was sponsored by IUCN in collaboration with Global Water Partnership (GWP) with the aim of improving water governance in the White Volta basin with particular focus on Ghana and Burkina Faso. The processes of the project accelerated the establishment of platforms across the border of the two countries, fostering consultations and joint planning. The PAGEV complemented the GEF supported Volta Basin Land and Water Management Programme, (GEF-Volta) involving all the six riparian countries, that aims to support coordination efforts in the eventual management framework for the Volta River Basin[6,7].

Another platform that has ensured the promotion of IWM is the GLOWA Volta project which was funded by the German Federal Ministry of Education and Research. The GLOWA-Volta initiative began the process of developing a scientifically sound Decision Support System (DSS) for the assessment, sustainable use, and development of the Volta Basin's water resources (WRC, 2002). This project is implemented in collaboration with established state institutions, such as the WRC of Ghana, within the White Volta Basin, during the period 2004 – 2006. The project was particularly seen as a way of generating and disseminating scientific information between Ghana and Burkina Faso and by so doing facilitating decision making on the management of the shared water resources[8].

However, in the Black Volta Basin there is no active platform for IWRM. GWI through CARE and CRS established a platform for Water Management but unfortunately it became a WASH platform. It was very active at the beginning but seems to have died off. It would be good to revive this platform and see how to broaden its scope within the proposed IWRM strategy to be implemented.

Integration of GWI interventions into the National IWRM strategic framework

The WRC is the national institution mandated to regulate and manage water resources in the country and to coordinate government policies in relation to them. For all practical purposes WRC is yet to initiate on the ground, processes towards creation of management structure to coordinate water related issues in the Black Volta basin. To manage effectively water resources in the basin and to respond to current priorities, it is important to adopt a holistic approach to water resources management and development. One approach that has gained recognition worldwide is Integrated Water Resources Management (IWRM), which has been adopted by WRC and used to develop action plans for basins where management structures have been established including the Densu and White Volta basins. This way, the GWI could assist WRC

[6] IUCN, 2003
[7] WRC, 2004
[8] Van Edig et al., 2001

while playing her 'role' and to draw lessons from the IWRM processes in the field worth sharing with WRC.

Since the inception of GWI in the year 2008 in the Black Volta basin, interventions have been implemented in communities that do not derive roots from any national framework for the said basin. It is imperative therefore, to initiate integrated water resources management processes in strong collaboration with WRC so as to buttress basis for the interventions being delivered in the project area while ensuring feedbacks towards policy change. While recognizing that GWI is a project with specific life span, association with WRC will seek to provide mechanisms for sustaining the interventions. Thus formalizing the relationship with the national institution is paramount in order to set pathways for influence and advocacy for practical solutions in the water and related sectors.

It is worth to note that financing of water resources development and management goes beyond the means of central government. The need to mobilize new sources of finance is pre-requisite towards achievement of expectations of vulnerable communities. Further, integrated management of water resources will be facilitated and enhanced if appropriate partnerships are developed among stakeholders, and capacity built to enable them to function effectively.

To ensure sustainable development of these finite resources, water resources management should be considered within the context of the following two main areas:

- Conservation of water resources to sustain quality and availability, health of the people and to guarantee the integrity of the environment.
- Regulation and control of water use and waste disposal, to stay within the natural capacity of the water resource base, which must necessarily maintain its regeneration and self-purification characteristics. Advocacy could help in this regard.

The implementation of IWRM should be geared towards ensuring sustainability of water resource in the basin and this could effectively be achieved by adopting the following measures;

- Strengthening the regulatory and institutional framework for managing and protecting water resources for water security and enhancing resilience to climate change
- Enhancing public awareness and interest in water resource management issues
- Improving access to water resources knowledge base to facilitate water resources planning and decision making

Vision for the sustainable development of the Black Volta Basin

In order to ensure food security and improved livelihood of the inhabitants, measures should be introduced to ensure the judicious use of the available water resources. Surface water resources can also be developed employing strict sector policies so as not to deplete the resource base of the basin. In so doing, farmers will access water for their farming activities which will culminate into livelihood improvement.

Irrigation schemes developed around small reservoirs have not been utilized at all in the basin. Less than 2% of planned irrigable areas are under actual irrigation[9]. This situation has to change with the major setbacks resolved.

GWI partners (CARE, CRS and IUCN) have assisted some communities to draw strategic IWRM Plans. These plans have been reviewed and realised to be too ambitious. It is therefore necessary to review these plans with the communities and draw a plan with a road map that is easily implementable.

The plans drawn could be the basis for a master plan for the basin. It would be expedient to start from the 3 upstream basins namely Dapola, Noumbiel and Vonkoro. GWI is already well known in these basins and so could give a smooth start of planned activities.

Evidence based-learning is the way out. This means that GWI would have to use some communities as pilots to initiate IWRM interventions in the basin through participatory learning and not just advocacy. Advocacy is good but on its own cannot achieve the intended objectives. For instance what advocacy can one do in a community that has unreliable and very low rainfall without a reservoir, dugout or a borehole to improve upon their livelihoods and alleviate their poverty? Talks alone would not materialise, the talks must be followed with actions on the ground. That is the only way the commitment of the community (grassroot stakeholders) can be gained. This could be out-scaled when they are successful.

IWRM plans without action plan is less useful. GWI and its partners would have to set up a basin platform to review plans drawn or to be drawn and provide concrete activities (action plans) towards implementing those IWRM plans.

Most often IWRM awareness is created without any baseline study. It is important for GWI to conduct a baseline study to enable it measure the impact of its activities.

Communication of IWRM Plans, activities, strategies and results could be done in a number of ways. Most notable among these are the use of radio and TV programs in local dialects, Newsletters, brochures, National and Private Newspapers, Symposiums, Quizzes, use of sign boards (attractive advertisements/education) among others.

At the local communities, Video-vans can be sent occasionally to show documentaries that will educate and motivate the inhabitants to continue with their IWRM activities.

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[9] Data from GIDA, Upper West Region

District water quality indices could be published quarterly to motivate the district assemblies to carry on with their IWRM activities. Rewards or awards could also be given to the best districts and individuals and advertised to motivate others to do likewise. T'shirts and Cups/hats could be printed with Key IWRM messages on them and given to people as souvenirs.

Giving regular talks on IWRM issues in Primary, Secondary and Tertiary education institutions could also be another avenue to educate people on IWRM issues. These schools visited could be given the souvenirs mentioned above to take home which might generate discussions of these subjects at the homes of these students.

Stakeholders at the validation workshop came up with a vision for the UWRWAS as "Sustainable Use of Resources for Food Security and Economic Growth by All for All by 2025" with a mission to "ensure food security and economic growth through the development and effective utilisation of resources in the Black Volta Basin in an equitable and sustainable manner for the present and future generations".

Conclusions

The following conclusions have been drawn from the study:

- The Black Volta Basin in Ghana is delineated into 3 Water Audit Sections to facilitate its management.

- The water resources of the Black Volta have been assessed. Almost all populations depend on groundwater for their domestic water requirements. The water available in the basin could meet the water demands of the various uses by 2030 except Bui hydropower which would benefit largely on flows from outside Ghana.

- A number of small reservoirs and dugouts in the Upper West Region are not being used productively owing to their silted condition thereby reducing storage. Due to the poor construction of some dugouts /reservoirs, the water stored dries up when the water is needed most. Moreover, management of the water facilities is a challenge.

- There is high potential to increase the cropping areas within the basin in Ghana owing to the suitability of land. Sustainable farming practices are required to forestall biodiversity in the basin, and therefore the protection of reserved areas.

- There is no active platform for IWRM in the basin currently. Activities of water related technical institutions are very much uncoordinated. There is a need for a basin framework on IWRM and coordination to ensure coherence.

- The value chain approach with associated platforms is hardly used in the basin in Ghana with the exception of the seedlings platform being managed by MOFA and SARI under the auspices of UNDP in Wa. This could provide opportunities for all stakeholders to meet and discuss ways of solving existing problems efficiently and effectively.

- The use of TV and Radio programs with phone-in sections in local dialects and English, Newspapers, brochures, sign boards, souvenirs, public lectures, talks, symposia, and publishing of Water Quality Index (WQI) of districts quarterly in the media with awards are some of the most promising communication strategies identified.

Recommendations

After a careful analyses the following recommendations have been made:

- There is a large potential to increase livestock production in the Ghana portion of the basin. However, women could be dotted with small ruminant support to improve their social capital towards strengthening livelihoods of households.

- Integrated watershed management with trans-boundary orientation is key in the basin and should be pursued with neighboring countries.

- Advocacy on agriculture especially irrigation is good but has to be done together with evidence based learning with some infrastructure and demonstrations to enhance the likelihood of adoption.

- For farmers to be productive, improve their yields and also be able to feed their livestock by growing a mixture of cereals and legumes including groundnut and vegetables in the dry season. The residues from these crops can be used to feed animals as supplementary feeds.

- GWI has started a platform for pastoralists and should continue to facilitate innovative ways to address issues with cattle herdsmen in the basin within Ghana taking into account international water laws and existing international relations and treaties between riparian countries.

- Platforms for IWRM must be established at the basin level through consultative process. The composition shall be determined by the stakeholders in close collaboration with the Water Resources Commission. The entire process of setting up the IWRM platform should be monitored, evaluated and documented.

- In the future, it is imperative to establish formal collaborative arrangements with state institutions such that the project would operate with the scope of the national orientation, ensuring feedbacks of lessons learned towards influence and policy change while ensuring sustainability.

- The next study should look at fisheries in the Black Volta River in detail.

List of Abbreviations

AESL	Architectural and Engineering Services Limited
AGRA	Alliance for a Green Revolution in Africa
CRS	Catholic Relief Services
CSIR	Centre for Scientific and Industrial Research
CWSA	Community Water and Sanitation Agency
DSS	Decision Support System
EPA	Environmental Protection Agency
FAO	Food and Agriculture Organisation
GAEC	The Ghana Atomic Energy Commission
GEF	Global Environmental Facility
GIDA	Ghana Irrigation Development Authority
GLOWA	Global Change in the Hydrological Cycle
GMet	Ghana Meterological Agency
GSB	The Ghana Standards Board
GSS	Ghana Statistical Services
GWCL	Ghana Water Company Limited
GWI	Global Water Initiative
GWP	Global Water Partnership
IUCN	International Union for Conservation of Nature
IWM	Intergrated Watershed Management
IWRM	Intergrated Water Resources Management
MOFA	Ministry of Food and Agriculture
NADMO	National Diseaster Management Organisation
NGO	Non-Governmental Organization
PAGEV	Project for Improving Water Governance in the Volta Basin
SARI	Savannah Agriculture Research Institute
SRI	Soil Research Institute
TLU	Tropical Livestock Unit
TV	Television
VBA	Volta Basin Authority
WASH	Water Sanitation and Health
WATSAN	Water and Sanitation
WEAP	Water Evaluation and Planning
WRC	Water Resources Commission
WRI	Water Research Institute
WUA	Water Users Association

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1. INTRODUCTION

1.1 Background to the study

The Global Water Initiative (GWI) is a worldwide program that is financed by the Howard G. Buffet Foundation. The long term goal of GWI is to generate lessons from Integrated Water Resources Management processes that inform policy change in the water sector, establishing platforms and frameworks that promote advocacy towards good governance of water resources.

This program is implemented in Ghana by a consortium of NGOs namely CARE International and Catholic Relief Services (CRS) together with the Regional Office for Central and West Africa of the International Union for Conservation of Nature (IUCN-PACO), based in Ouagadougou, Burkina Faso.

Recognizing that a river basin is the unit for planning in the Ghana Water Policy (2007), steps have been taken by IUCN-PACO to provide information that will lead to understanding the hydrology and water resource characteristics of the Black Volta basin. In view of this, Allwaters Consult Limited was contracted by IUCN to undertake this study in Ghana to guide future implementation of Integrated Watershed Management in the Black Volta basin.

1.2 Objectives and Scope of the study

1.2.1 *Objective of the study*

The overall objective of the study was to prepare a document that will guide the future interventions of GWI in Ghana, characterise water resources (both current and future) of the Black Volta basin highlighting sustainable operational mechanisms including constraints that govern water resources.

Specifically, the assignment sought to

- Assess the hydrological situation of the Black Volta basin, delineate its' extent and limits, determine the interaction with other hydrologic systems, and the trans-boundary zone with Burkina Faso
- To understand the stakes of water resources, the potential of surface water and groundwater systems, uses, and stakeholders (whose activities impact directly or indirectly), management constraints as regards exploitation and suitability
- To assess the state of dug-outs, dams, wells, and characterize the agricultural or irrigation water use (current and future) on one hand, and the cultivated areas around these water bodies: surface, types of crop, seasonal (or not) use of water, on the other hand
- To examine the ecosystem approach into river basin planning and management of the Black Volta.

1.2.2 *Scope of work*

The work carried out included the following;

i. Delimited the Black Volta basin and delineated the sub-catchments taking into account the demographic and political administrative settings.

ii. Took inventory of, and state of water systems including reservoirs/dams, dug-outs and wells from National Institutions namely Ministry of Food and Agriculture (MOFA) and Ghana Irrigation Development Authority (GIDA).

iii. Assessed the agricultural/irrigation land use around the water systems noted in point (ii) above in each sub-catchments including the crops grown and cropping pattern.

iv. Assessed water use including irrigation agriculture and projected developments in the basin, assessing their impacts/threats on the water resource and land.

v. Examined the current state of water governance in the basin, prospects including trans-boundary mechanisms, and the processes that foster integration of GWI interventions into national IWRM strategic frameworks.

vi. Made proposals that will enhance better management of the water and other natural resources of the Black Volta basin.

vii. Formulated a clear vision for the sustainable development of the Black Volta Basin Resources.

viii. Proposed communication strategy or products with respect to IWRM that highlight water education among primary stakeholders while informing secondary actors across scales of the hydrologic characteristics of the Black Volta.

1.3 **Work Plan**

The work was carried out in three blocks. Block 1 involved desktop studies of the Black Volta and the Volta basin in general; Block 2 covered field work where the consultant visited GWI communities and other communities of interest and Key stakeholders in the basin. The last block - Block 3 was mainly about report writing and validating the study.

2. STUDY AREA

2.1 Political or Administrative Settings of the Black Volta Basin

The Black Volta basin (shown in Figure 1) is between Latitude 7°00'00"N and 14°30'00"N and Longitude 5°30'00"W and 1°30'00"W, and covers an estimated area of about 130,400 km^2 as against other figures stated in some literature as 149,000km^2. The Black Volta constitutes about 32.6% of the Volta basin. This normally occurs when some portion of Bamboi which belongs to the Lower Volta is added to the basin. The portion within Ghana (with Bamboi excluded) covers an area of about 18,384km^2 constituting 14% of the basin. The Black Volta river basin is a trans-national river system that stretches from North to South through Mali, Burkina Faso, Ghana and Cote d'Ivoire, and from Burkina Faso, Cote d'Ivoire and Ghana from West to East.

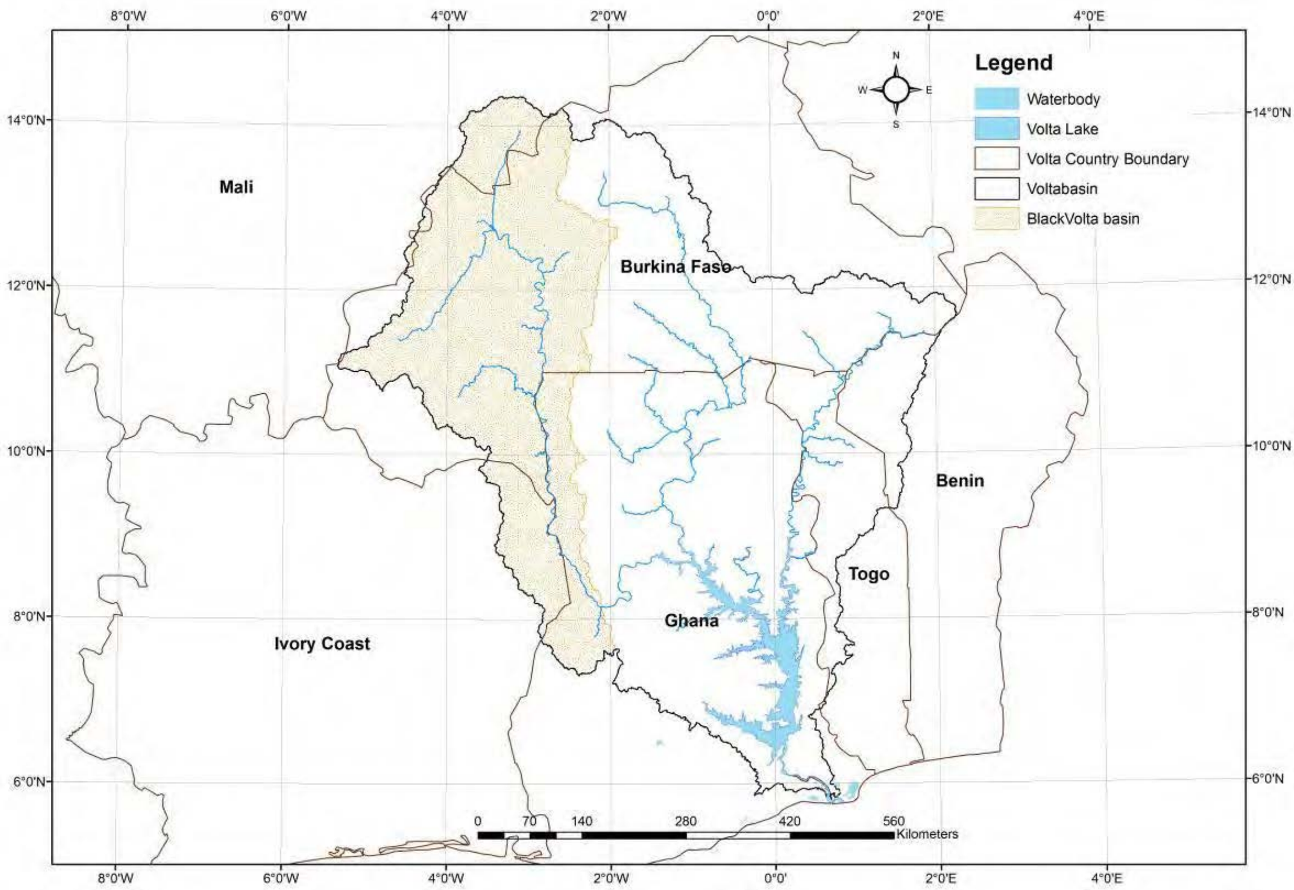

Figure 1: The Black Volta within the Volta Basin

The headwater of the main river course is from Burkina Faso. It then flows to Mali and then flows downstream along the border between Ghana and Cote d'Ivoire before discharging into the Volta Lake in Ghana through Bui and Bamboi. It covers a distance of about 1350km from Burkina Faso to the Volta Lake. The trans-national character of the river basin gives it strategic importance towards strengthening bi/multi lateral cooperation, and to build trust among riparian states in the management of shared natural resources, and in particular, water resources.

Politically or administratively, the basin covers 19 districts (based on the 170 District demarcations) in Ghana, 14 provinces in Burkina Faso, 2 departments in Cote d'Ivoire and 3 Regions in Mali. Figure 2 shows the map of districts and provinces in Ghana and Burkina Faso partially or wholly within the Black Volta basin.

Figure 2: Political/Administrative regions within the Black Volta Basin

2.2 **Population**

As of the year 2000 the Black Volta was home to about 4.5 million people in Burkina Faso, Ghana, Cote d'Ivoire and Mali[10]. This population is estimated to grow to about 8 million by the year 2025. The population distribution by district, province, department and region is given in *Appendix2*. Table 1 gives the population distribution at district level based on the 2010 Population and housing census carried out by the Ghana Statistical Services (GSS).
Population density in the basin ranges from 8 to 133people/km^2. Bouna department in Cote d'Ivoire and Sissala district in Ghana both have the lowest of 8 and Lawra district in Ghana has the highest of 133. The average population density is 43people/km^2. The population density map of the Black Volta is shown in Figure 3. In the valleys in the Black Volta people are prone to Onchocerciasis which is the major health threat in the basin.

Focusing on the Upper West Region of Ghana where GWI operates currently, the total population of the region is 702,110 people[11] recording about 18% increase relative to 576,583 in the year 2000. Until the year 2004, the Upper West region consisted of five districts. Thus four new districts were carved out from the existing five districts.

[10] Based on UNEP Population count in 2000 and based on old district/department/province/regional demarcation

[11] GSS (2012), Population And Housing Census Carried Out In 2010

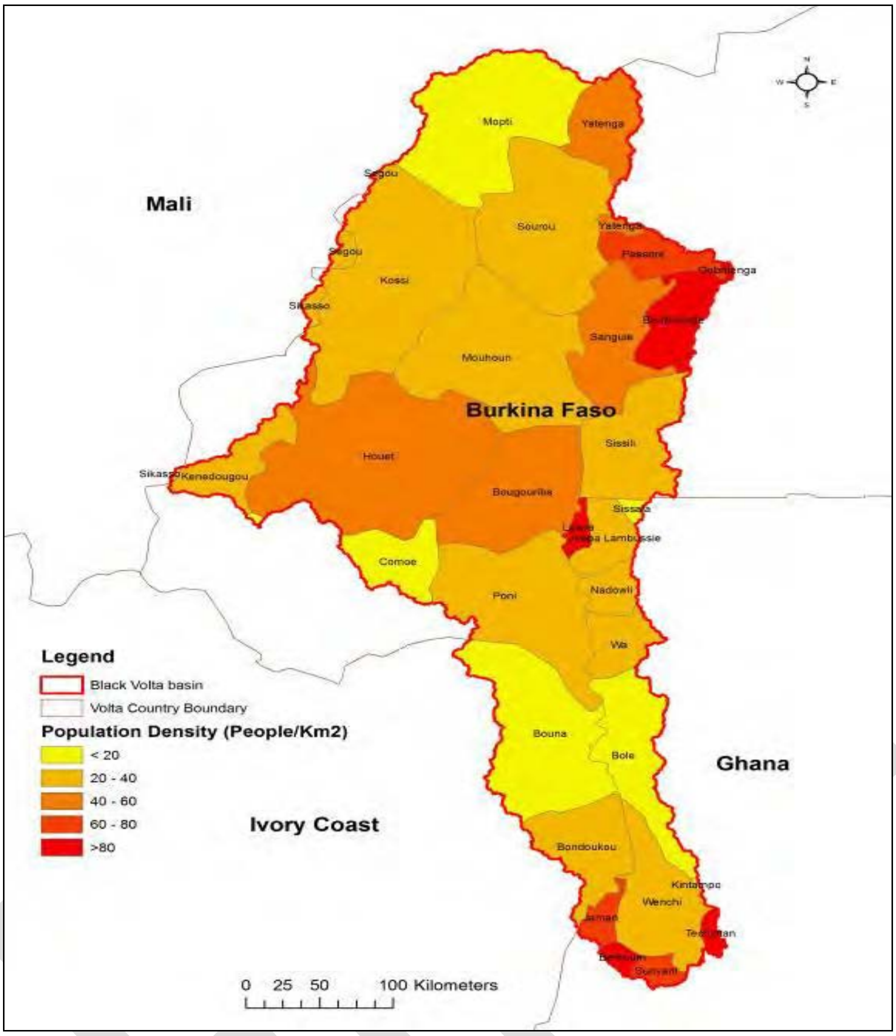

Figure 3: Population Density in the Black Volta Basin

Table 1 District population distribution in the Upper West Region[2]

District	Total	Male	Female	% of Female	% Urban
Wa West	81,348	40,227	41,121	50.5	-
Wa Municipal	107,214	52,996	54,218	50.6	30
Wa East	72,074	36,396	35,678	49.5	-
Sissala East	56,528	27,503	29,025	51.3	-
Nadowli	94,388	44,724	49,664	52.6	-
Jirapa	88,402	41,592	46,810	53.0	5
Sisala West	49,573	24,151	25,422	51.3	-
Lambussie Karni	51,654	24,952	26,702	51.7	-
Lawra	100,929	48,641	52,288	51.8	14
Total	702110	341182	360928	51.4	-

2.3 **Landuse/ Landcover**

In the Black Volta basin, most lands are used for agriculture with bush fallow food crop cultivation. The food crops cultivated are mostly under rain-fed grown of cereals including rice, millet, sorghum, and maize; yam, cassava, groundnuts and beans. In the dry season some farmers grow vegetables including tomatoes, pepper, okro, lettuce, cabbage and pumpkin especially in the Lawra district. Most farmers practice compound farming since lands closer to their houses are somewhat fertile. However, in the Lawra district the lands are highly degraded both in terms of physical status and soil fertility levels and can hardly support crop cultivation which contribute to low crop yield. This is exacerbated by the rather high population density.

Animal grazing in the basin is mostly done on free range except in the dry season, where livestock owners/herdsmen migrate with their animals in search of water and feed in nearby communities[12]. Hence in the basin there are no clearly demarcated lands for grazing. In general, the vegetation is greener in the lower reaches of the basin in Ghana that favors migration of cattle inland (figure 5). This practice is not limited to Ghana. For communities lying along the border of the Volta basin riparian countries, cattle herdsmen migrate from Burkina Faso to Ghana in search of greener pasture. In so doing, they, more often than not, use unapproved routes into the country as their movement is influenced by the presence of green vegetation in field in the hinterland. Their migration has far reaching consequences as regards the livelihoods of the recipient communities which mostly has the tendency to generate conflicts. Largely, communities on either side of the border are related family-wise, and though may be seen within the national lens as different people, locally could dispose mechanisms that foster peaceful co-existence in the trans-border region. This orientation needs to be formalized in order to strengthen the fraternity and cooperation of the two countries.

Figure 4 shows the landcover changes in the Volta basin. It could be deduced from the figure that most grass lands are being turned into Agriculture Land. Forest reserve had been depleted but the Ghana portion appears to be intact which is commendable. The current situation would be challenged in the coming years with the onset of industrial development including mining and population expansion such as the case of Lawra district. Clearly, environmental awareness creation is necessary to inform a kind of controlled development before the environment is irresponsibly tempered with. The general and detailed landcover/landuse maps for the basin are presented in Figures 5 and 6.

[12] BARRY *ET AL*, 2005. COMPREHENSIVE ASSESSMENT OF WATER MANAGEMENT IN AGRICULTURE. COMPARATIVE STUDY OF RIVER BASIN DEVELOPMENT AND MANAGEMENT

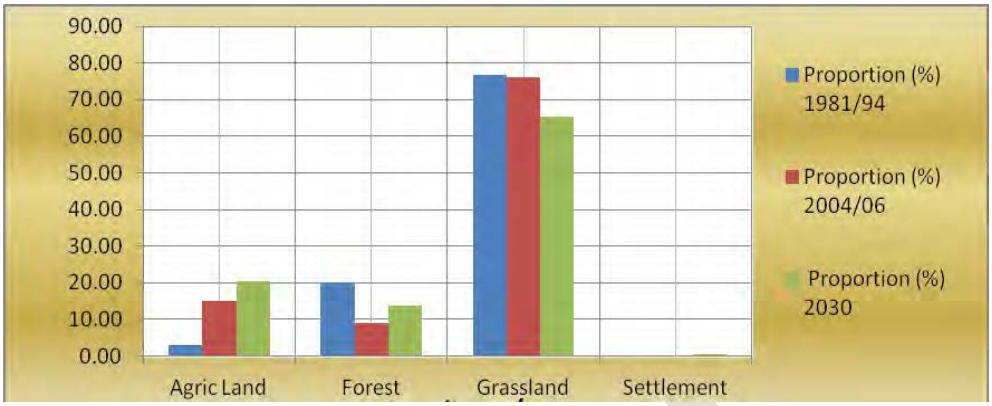

Figure 4: Proportion of land use/cover and projection for the Volta Basin[13]

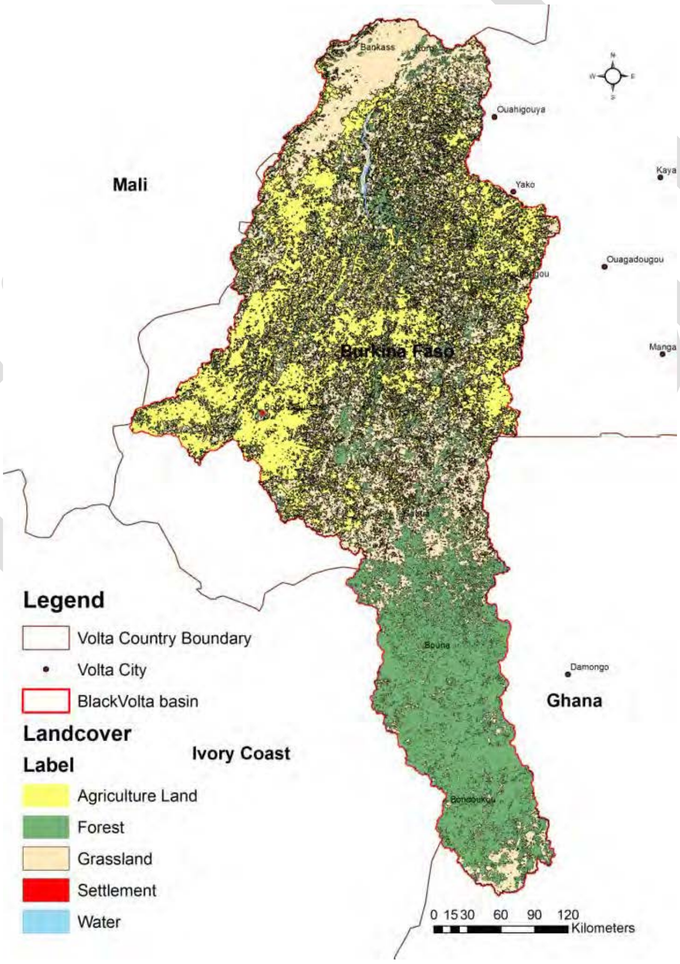

Figure 5: Generalised Landuse map of the Black Volta Basin[14]

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[13] WATER AUDIT UPDATE STUDY, 2012

[14] LANDCOVER MAP PREPARED FROM MERIS 2004/2006 COMPOSITE IMAGE

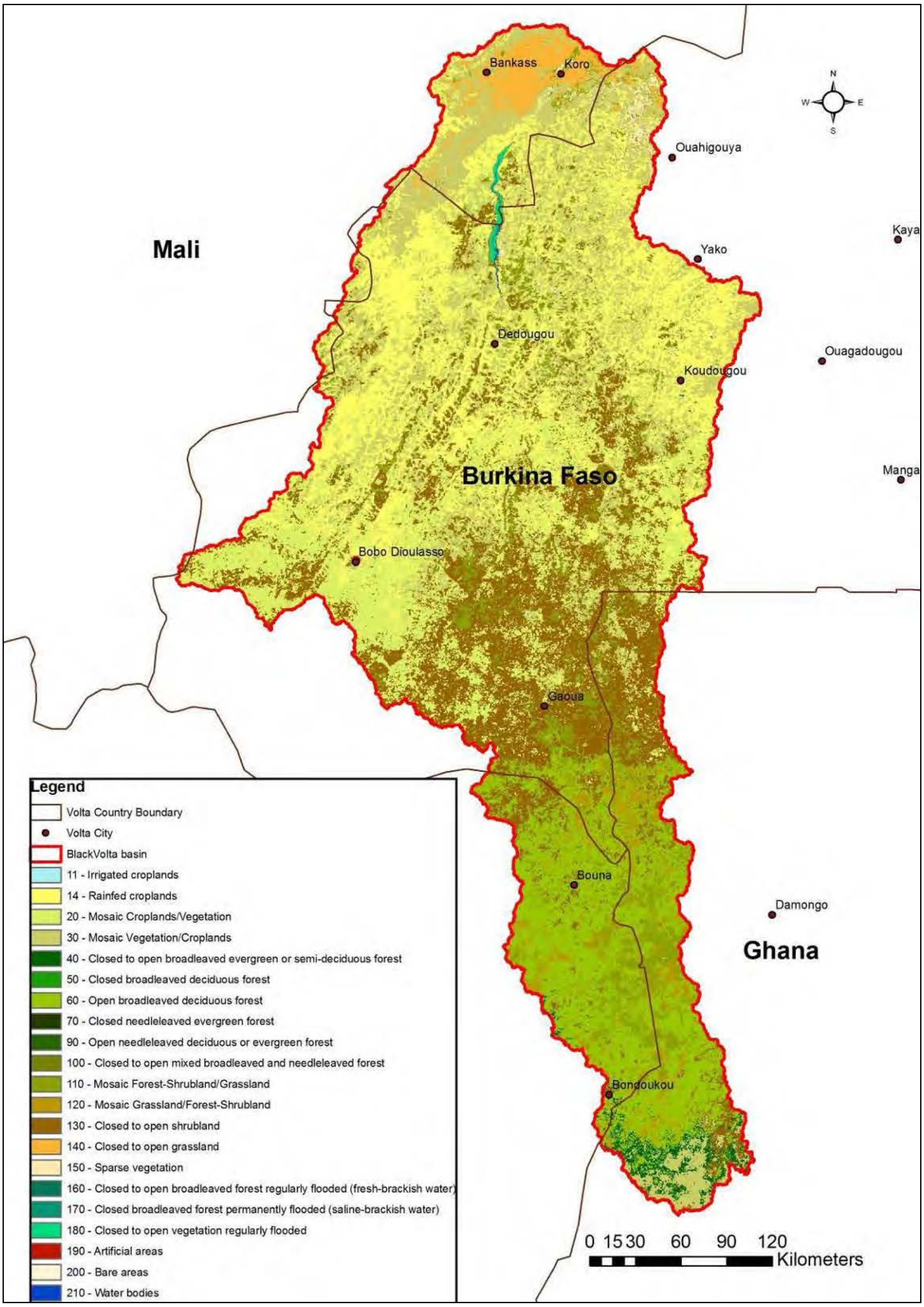
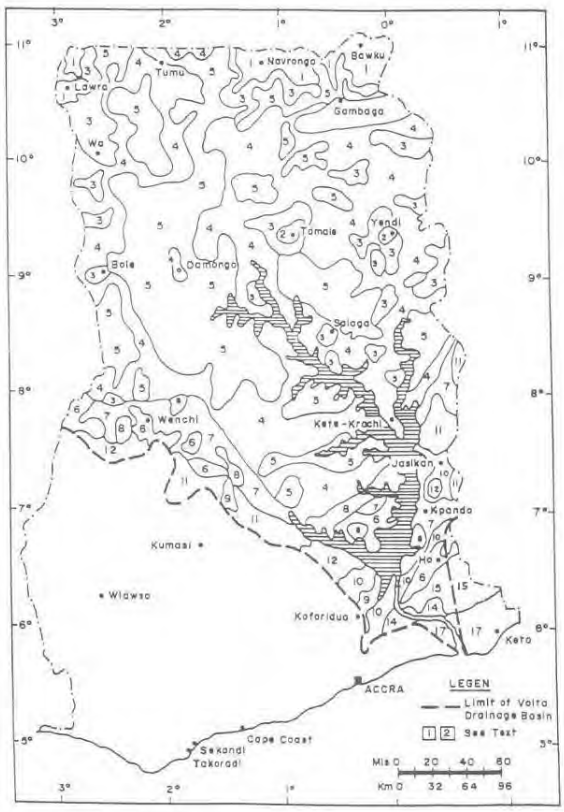


Figure 6: Detailed Landcover map prepared from MERIS 2004/2006 Composite

The landcover maps prepared for the Black Volta basin show that in Burkina Faso most of the land has been developed for Agriculture (Rainfed and Irrigated) whereas in Ghana most of the land is under forest/grassland cover. There is therefore the potential to increase Agriculture land, but this has to be done in a sustainable manner. A comprehensive landuse map of the basin does not exist. In Ghana the Volta Basin Research project at University of Ghana, Legon developed a landuse map which is shown in Figure 7. This is however, old and needs to be updated.



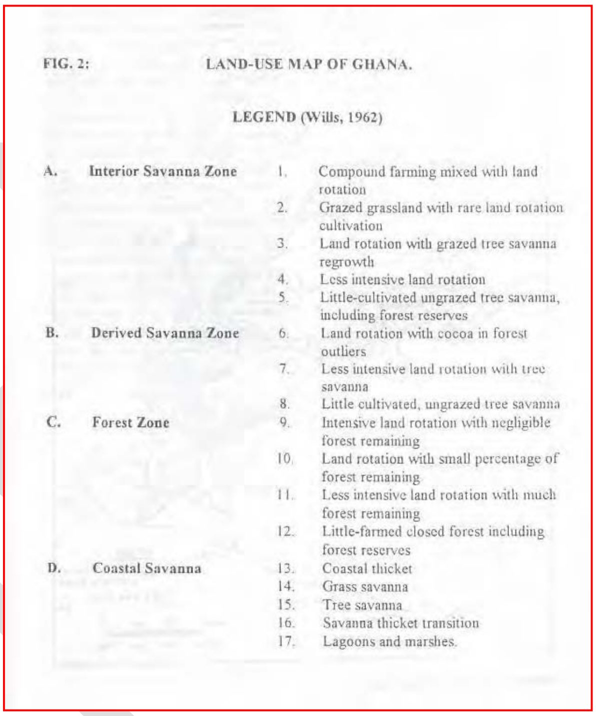


FIG. 2: LAND-USE MAP OF GHANA.

LEGEND (Wills, 1962)

A.	Interior Savanna Zone	1.	Compound farming mixed with land rotation
		2.	Grazed grassland with rare land rotation cultivation
		3.	Land rotation with grazed tree savanna regrowth
		4.	Less intensive land rotation
		5.	Little-cultivated ungrazed tree savanna, including forest reserves
B.	Derived Savanna Zone	6.	Land rotation with cocoa in forest outliers
		7.	Less intensive land rotation with tree savanna
		8.	Little cultivated, ungrazed tree savanna
C.	Forest Zone	9.	Intensive land rotation with negligible forest remaining
		10.	Land rotation with small percentage of forest remaining
		11.	Less intensive land rotation with much forest remaining
		12.	Little-farmed closed forest including forest reserves
D.	Coastal Savanna	13.	Coastal thicket
		14.	Grass savanna
		15.	Tree savanna
		16.	Savanna thicket transition
		17.	Lagoons and marshes.

Figure 7: Landuse map of Ghana[15]

2.4 **Geology and Soil**

The dominant soils in the Black Volta basin according to the FAO soil classification, as shown in Figure 8 are Luvisols and Gleysols with altitudes ranging between 60m and 762m above m.s.l. In the Ghana portion of the basin, Ferric Luvisols is the most dominant.

[15] Gorden and Amatekpor (1999): The sustainable Integrated Development of the Volta Basin in Ghana

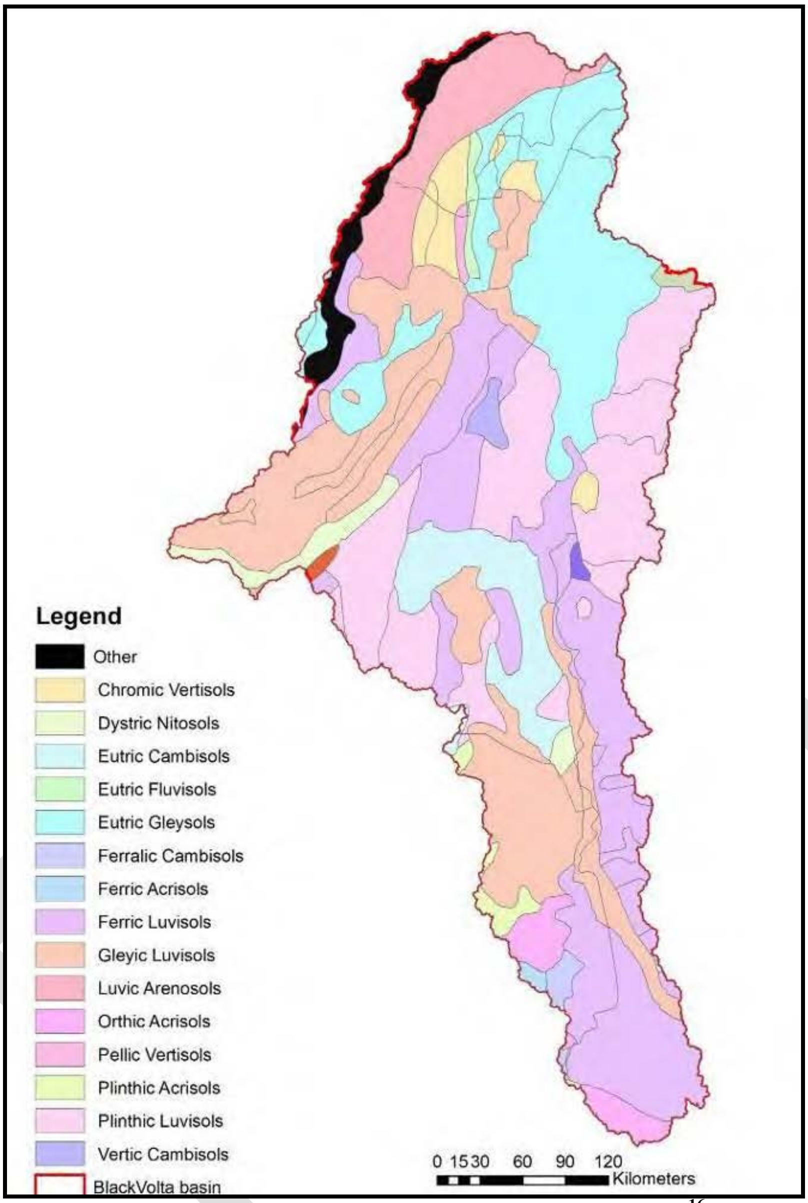


Figure 8: Dominant Soil in the Black Volta basin[16]

Soil Research Institute (SRI) carried out a more detail soil classification for some parts of Ghana. An example of the Soil classification system for the Upper West Region portion of the Black Volta basin is shown in Figure 9. Detailed soil description is given in *Appendix 3*. According to the National Soil Classification system the predominant soil in the Upper West is Lixisol which comprise soils that have higher clay content in the subsoil than in the topsoil as a result of pedogenetic processes (especially clay migration) leading to an argic subsoil horizon. Lixisols have a high base saturation and low-activity clays[17].

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[16] Map produced using data from Land and Water Development Division, FAO, Rome (1995)
[17] SRI soil attribute data (Undated)

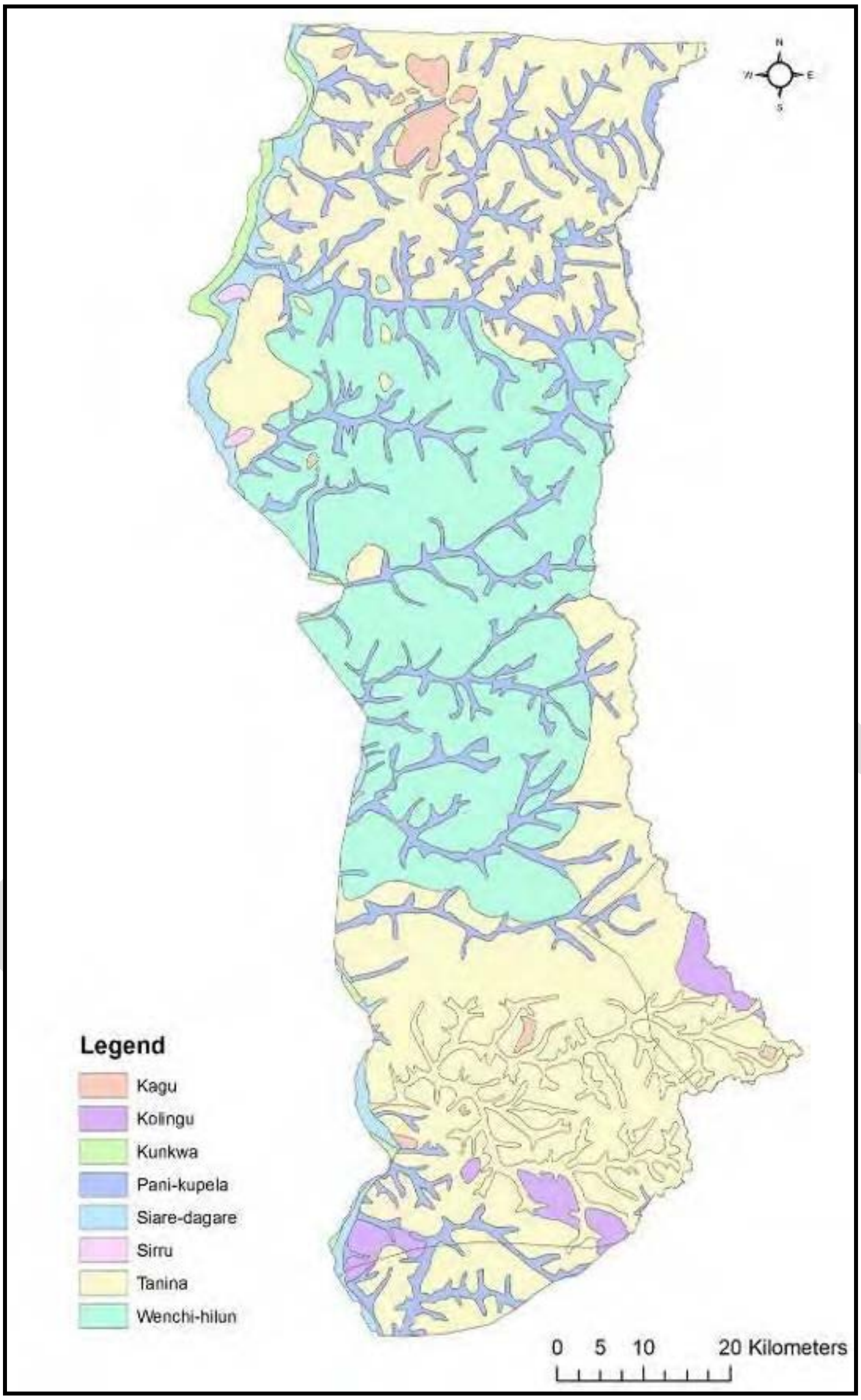
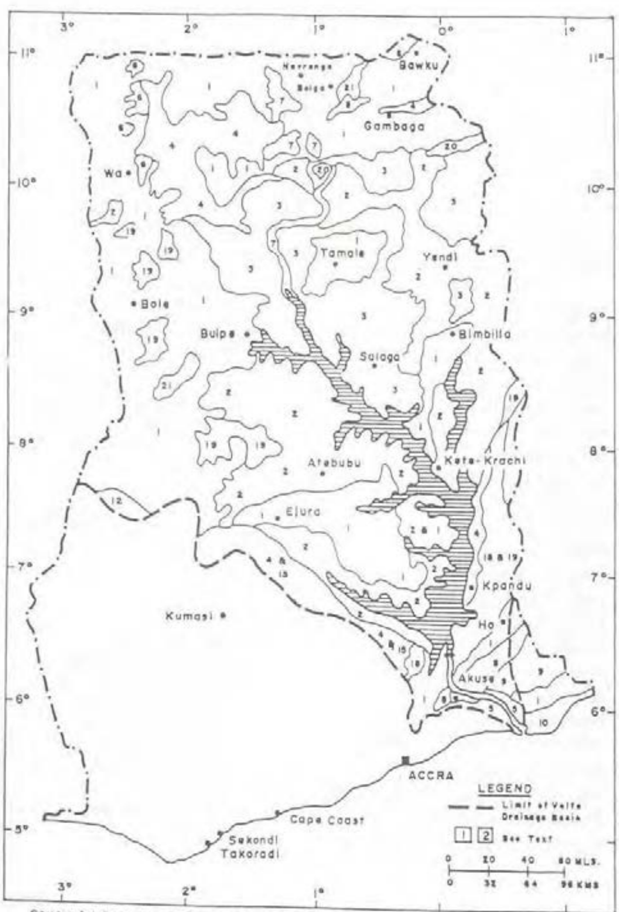


Figure 9: National Soil Classification for the Upper West Region of Ghana in the Volta basin

A soil map of Ghana produced by Obeng in 1971 and adapted by Gordon and Amatekpor is given in Figure 10. From the figure, the Black Volta Basin in Ghana is characterized mainly by Savannah Ochrosols and patches of Savannah Ochrosols-Lithosols.



Source: Adapted and Reduced from Obeng (1971), S. R. I, Kumasi.

IARTER'S mer 1956, 1962)	USDA (1960, 1967)
iavannah Ochrosols	Oxisols, Eutrustox
iavannah Ochrosol-Groundwater Laterites	Oxisols - Inceptisols
iroundwater Laterites	Inceptisols
iavannah Lithosols	Entisols (Ustents, Lithic)
iavannah Gleisols	Entisols (Ustents)
avannah Gleisols-Tropical Black Clays	Entisols-Vertisols
avannah Gleisols-Alluviosols	Entisols (Ustents, Fluvents
'ropical Black & Brown Clays	Vertisols
'ropical Grey Earths & Regosolic GWL	Alfisols - Entisols
odium Vleisols	Inceptisols (Halaquepts)
orest Oxysols	Oxisols
orest Ochrosols	Ultisols
orest Ochrosols-Oxysol Intergrades	Oxisols - Ultisols
orest Rubrisol-Ochrosol Intergrades	Ultisols
orest Lithosols	Entisols (Aquents, Lithic)
orest Gleisols	Entisols (Aquents)
egosols	Entisols (Psamments)
orest Ochrosol - Lithosols	Ultisols - Entisols
ivannah Ochrosol-Lithosols	Oxisols - Entisols
ivannah Lithosols-Gleisols	Entisols (Ustents, Fluvents)
ivannah Brunosols-Ochrosol Intergrades	Ultisols
orest Gleisols-Alluviosols	Entisols (Ustents - Fluvents)
egosolic Groundwater Podzols	Entisols

Figure 10: Soil Map of Ghana[18]

The geology of the Black Volta Basin is mostly granite, Birimian (known for its Gold Mining Potential), the Voltaian systems and to some extent the Tarkwaian system as shown in Figure 11 (*The legend of the map obtained is however not very clear*). The Birimian system is made up of metamorphosed lavas, pyroclastic rocks, phyllites, schists, tuffs, and greywackes while the Tarkwaian formation consist of quartzites, phyllites, grits, conglomerates, and schist. In the basin Groundwater occurs mostly as a result of fractures in rocks and not its inherent porosity[7].

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[18] Gorden and Amatekpor (1999): The sustainable Integrated Development of the Volta Basin in Ghana

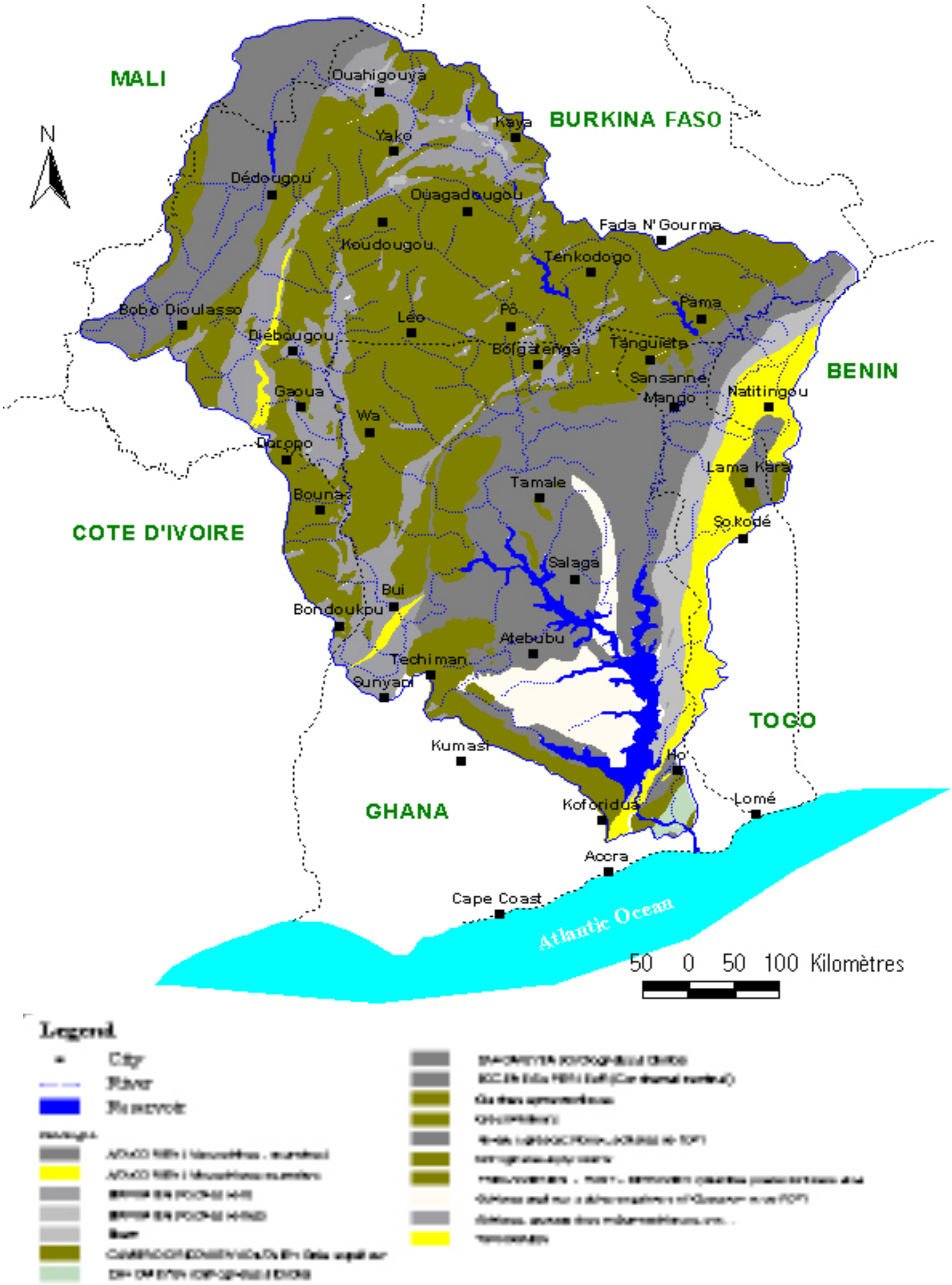


Figure 11 Geological Map of the Volta Basin[19]

19 Volta Basin Profile. Baseline Report No. 8. Volta River Basin: Enhancing Agriculture Water Productivity through Strategic Research (2005).

2.5 **Drainage Network**

The Black Volta basin is drained by the Bougouriba, Gbongbo, Grand Bale, Voun Hou, Sourou, Wenare, Bambassou, Bondami, Mouhoun (main Black Volta), Tain and Poni rivers as main tributaries. The river network of the basin is shown in Figure 18.

2.6 **Vegetation**

A map of the Agro-ecological zones in Burkina Faso and Ghana within the Black Volta is shown in Figure 12. Most part of the basin fall within the Savannah zone.

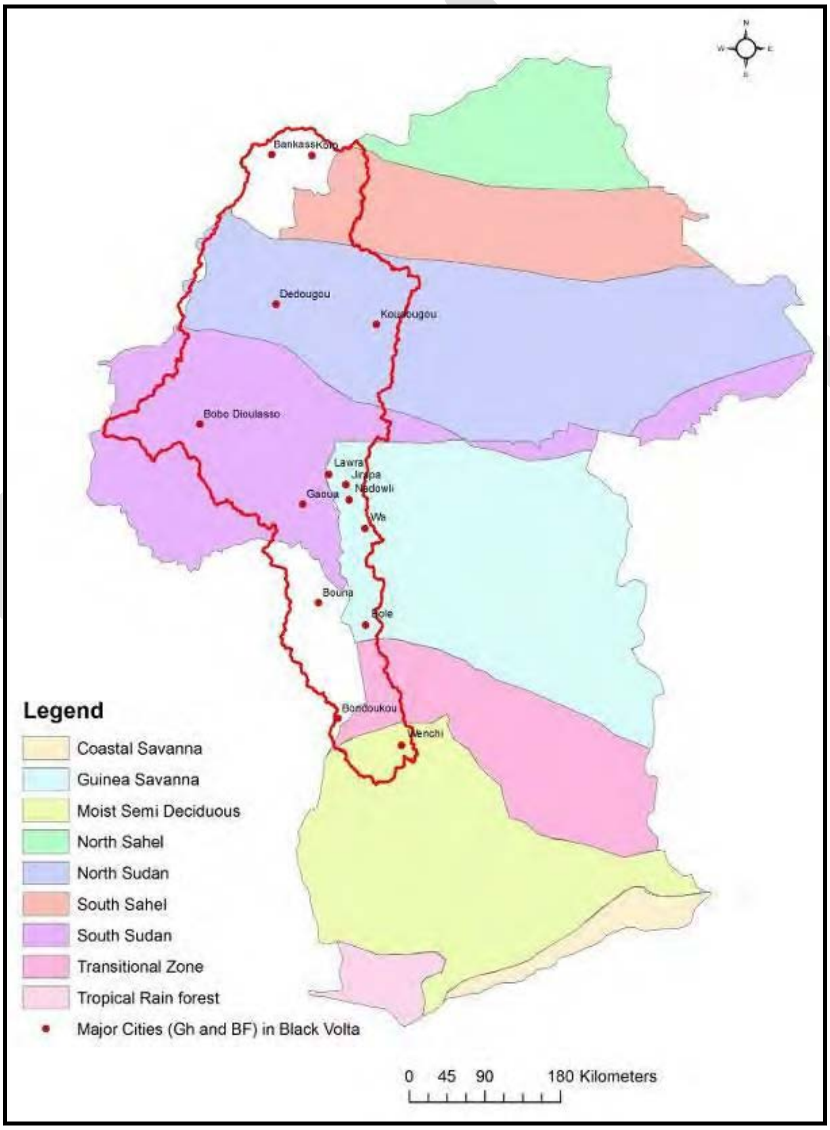


Figure 12: Agro-ecological Zones in the BV[20]

2.7 Climate

2.7.1 *Rainfall and Evaporation*

In the Black Volta basin, annual rainfall values vary from about 1043mm to 1270mm to the south. The minimum potential evaporation is about 1450mm/year to about 1800mmm/year [21] and average runoff is about 243m^3/year. The mean monthly runoff from the basin within Ghana varies from a maximum of 623m^3 to a minimum of about 2m^3. The rainfall, temperature and evapo-transpiration patterns in the basin within Ghana are presented in Figures 13, 14a and 14b.

[20] Map produced using data from the GLOWA Volta Basin Kit

[21] Volta Basin Profile, Baseline Report No. 8. Volta River Basin: Enhancing Agriculture Water Productivity through Strategic Research (2005).

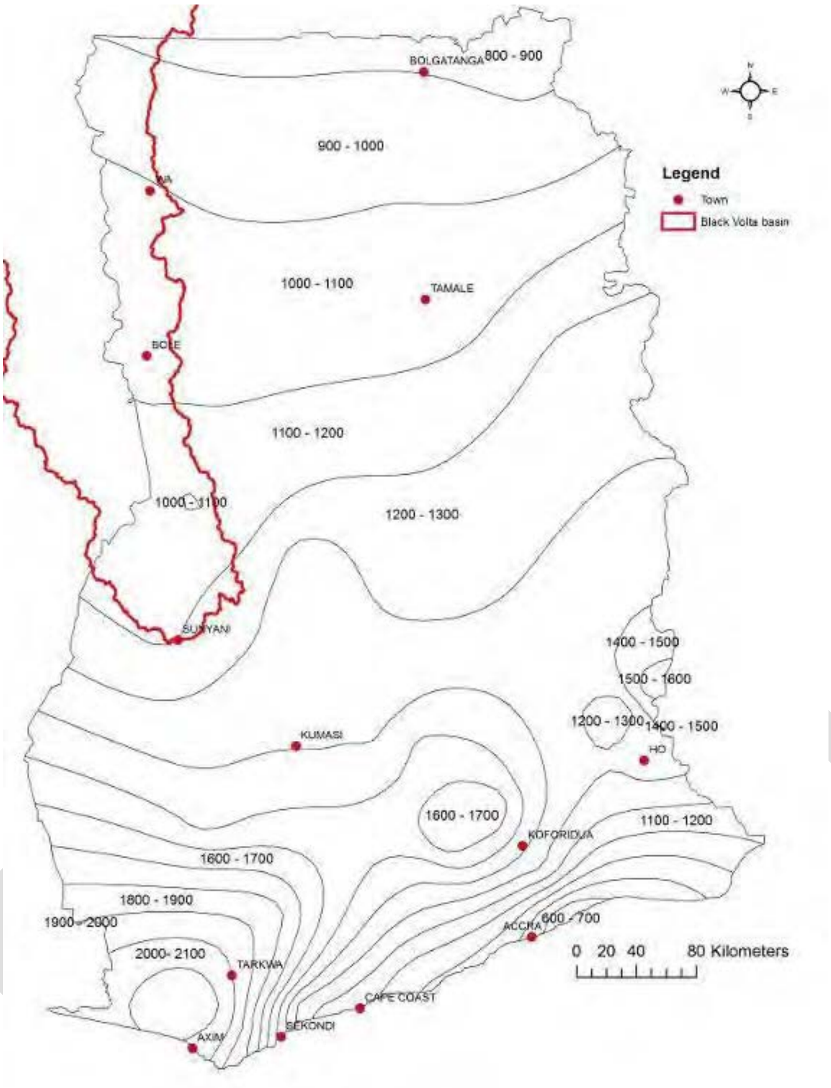
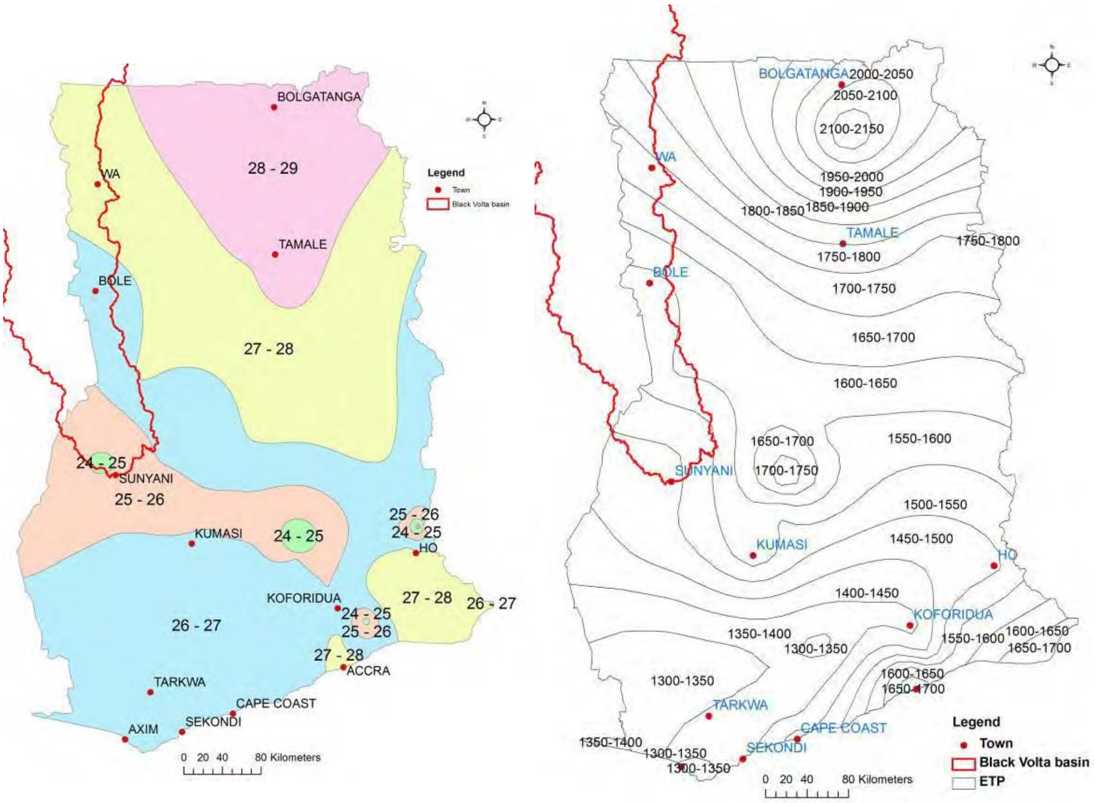


Figure 13: Rainfall pattern of the basin within Ghana based on 1990 Isohyets



(a) (b)

Figure 14: (a) Temperature and (b) Evapo-transpiration over Ghana

2.7.2 *Temperature and Humidity*

Temperature in Ghana normally never falls below 24^{o}C since the country is on the equator[22]. Annual mean temperature in the Volta basin is between 27-30^{o}C and in the Black Volta, 26^{o}C. Daily temperature rises as high as 44^{o}C during the day and could fall to 15^{o}C at night. The hottest Month is March-April and the coolest, August[10].

Relative humidity is between 20-30% in the harmatan season and 70-80% in the rainy season[10].

2.8 Agriculture Labour Force

Field survey conducted in the Black Volta basin within Ghana has shown that the young population (18-40years) mostly migrate to big cities like Kumasi and Accra often for non-existent jobs. The active age group engaged mostly in subsistence farming is between 45-60 years.

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[22] **BARRY *ET AL*, 2005. COMPREHENSIVE ASSESSMENT OF WATER MANAGEMENT IN AGRICULTURE. COMPARATIVE STUDY OF RIVER BASIN DEVELOPMENT AND MANAGEMENT.**

2.9 **Suitability of land for Agriculture**

Figure 15 shows that there are very little constraints with regards to use of land in the Black Volta for Agriculture. These parameters analysed include climate, soil, slope and terrain[23]. From the map, all the labels are below 20 which is the range for lands with very low constraints or invariably very high suitability for Agriculture on a global scale.

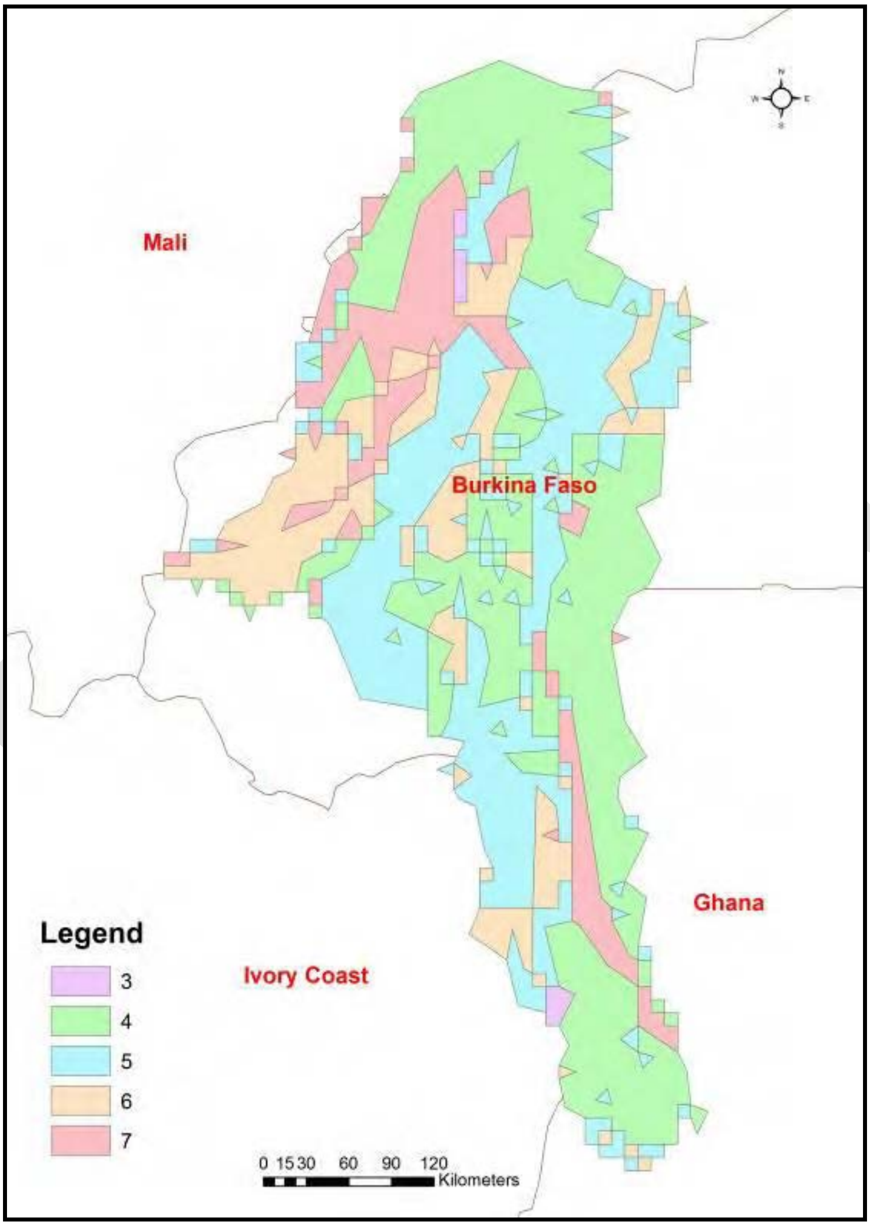

Figure 15: Climate, Soil, Slope and terrain constraints for Agriculture in the Black Volta Map

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[23] Post, W. M., and L. Zobler, L., 2000. Global Soil Types, 0.5-Degree Grid (Modified Zobler). Data set. Available on-line [http://www.daac.ornl.gov] from Oak Ridge National Laboratory Distributed Active Archive Center, Oak Ridge, Tennessee, U.S.A.

3. HYDROLOGY OF THE BLACK VOLTA BASIN

3.1 The basin approach

In Ghana, the Water Resources Commission (WRC) considers the whole portion of the Black Volta basin in Ghana as its unit of planning for IWRM. Figure 16 shows the basins in Ghana with WRC basin offices hatched. The rest of the basins are yet to be considered for a structured implementation of IWRM plans. GWI's programme in the Black Volta basin will therefore go a long way to support WRC fulfill its mandate which is to promote IWRM in Ghana through water use regulation, pollution monitoring and water resource assessment activities for effective planning at river basin level. Hence GWI could facilitate the setting up of a WRC basin office in the Black Volta and contribute to the effective implementation of Watershed Management in the basin.

Currently, WRC is operating in Densu, the White Volta, Ankobra, Pra and Tano basins. The basins were set up in the same chronological order with Densu being the first basin to be set up and Tano the last one (which makes it the most current). The setting up of the basins has largely been due to prioritization and urgency for the solution of problems identified in the respective basins.

The Densu basin was the first basin to be set up in Ghana. The major problem identified in the basin was pollution from farmers and industries. The second basin, the White Volta basin was set up to resolve trans-boundary issues between Ghana and Burkina Faso, and in the process foster cooperation and good neighborliness between the two countries. The third basin was the Ankobra basin set up in the South-Western portion of the Country due to the increase in mining activities that was polluting the water bodies in the basin. The fourth basins; Pra was set up to resolve issues with population explosion which results in pollution. In addition to fostering good cooperation between Ghana and Cote d'Ivoire, the Tano (fifth basin) was also set up to curb pollution from mining activities in the basin. Steps are being taken to operationalize fully the two latter basin secretariats. A map of the river basins in Ghana is shown in Figure 16.

In view of this, it is not farfetched to say that there is a need to look at trans-boundary issues between Ghana, Burkina Faso and Cote D'Ivoire in the Black Volta basin together with land degradation and pollution from agriculture activities. Another major issue in the basin is poverty and inadequate food security. While these issues are of national importance and require the attention of stakeholders across scales, the present study could mark the process towards the establishment of consultative forum for integrated watershed management of the Black Volta basin, and to implement prioritized action(s) in a coordinated and structured manner.

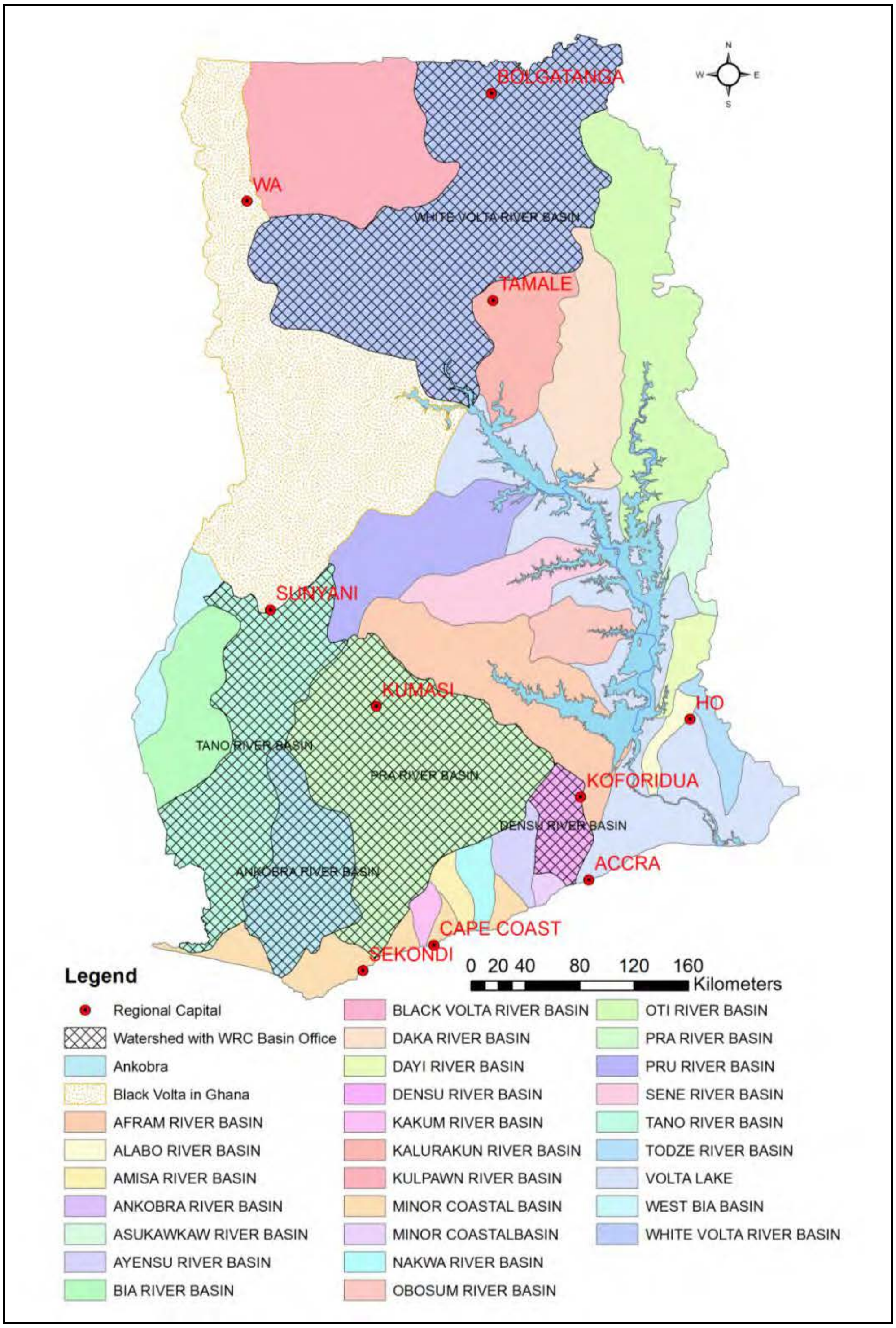

Figure 16: River basins in Ghana

3.2 Sub-Catchments within the Volta Basin

There are about 25 Sub-catchments/basins within the Volta basin (shown in Figure 17). This depends to a large extent on the level of details required for the analysis under consideration since these sub-basins could be divided further.

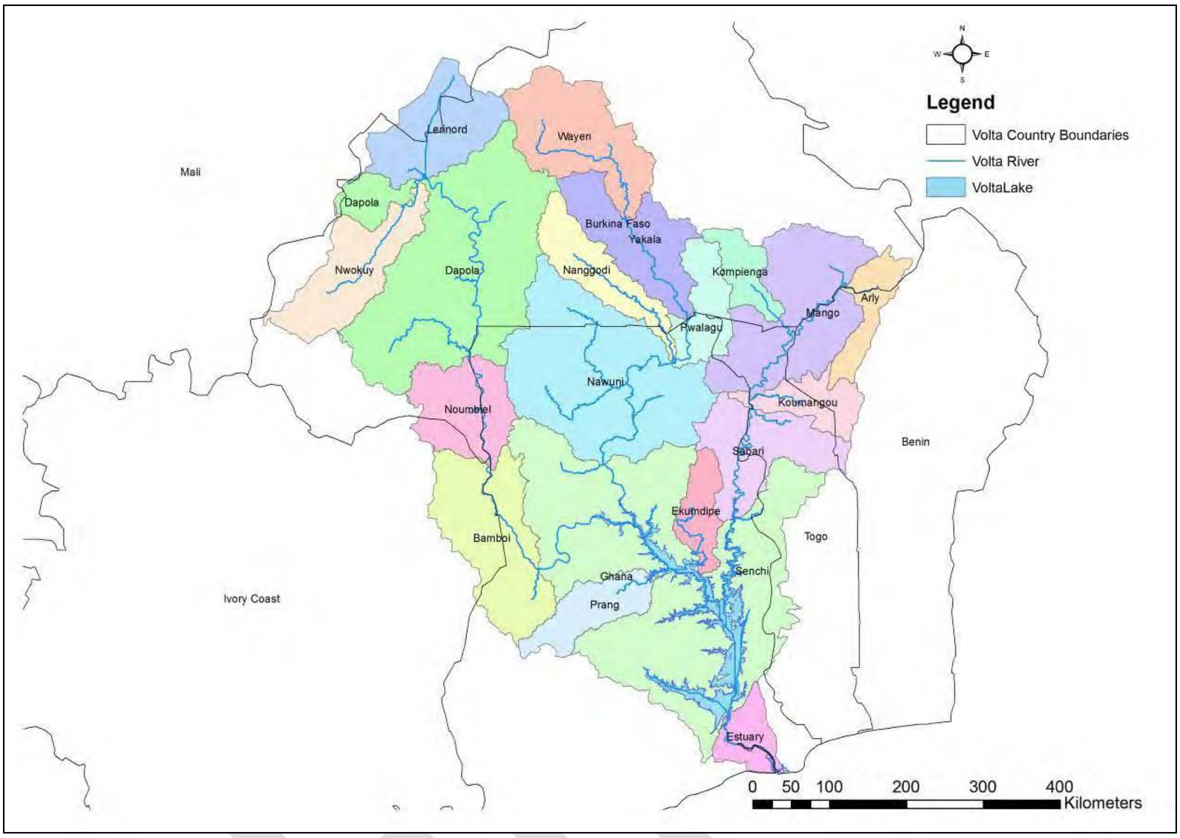

Figure 17: Watersheds within the Volta Basin[24]

3.3 The Black Volta Basin

The number of sub-basins normally delineated for a watershed/basin depends on the availability and consistency of hydrological data needed for modeling. In Figure 18, the Black Volta basin has been divided into 9 sub-basins.

Table 2: Sub-basins in the Black Volta basin

Name	Area (km^2)		Name	Area (km^2)
1. Bamboi	7525		6. Noumbiel	12499
2. Boromo	38171		7. Nwokuy	10474
3. Bui	11590		8. Samandeni	4425
4. Dapola	31680		9. Vonkoro	5347

[24] DATA USED TO PREPARE THE MAP IS FROM BFP VOLTA (2008)

5. Goere	8692			

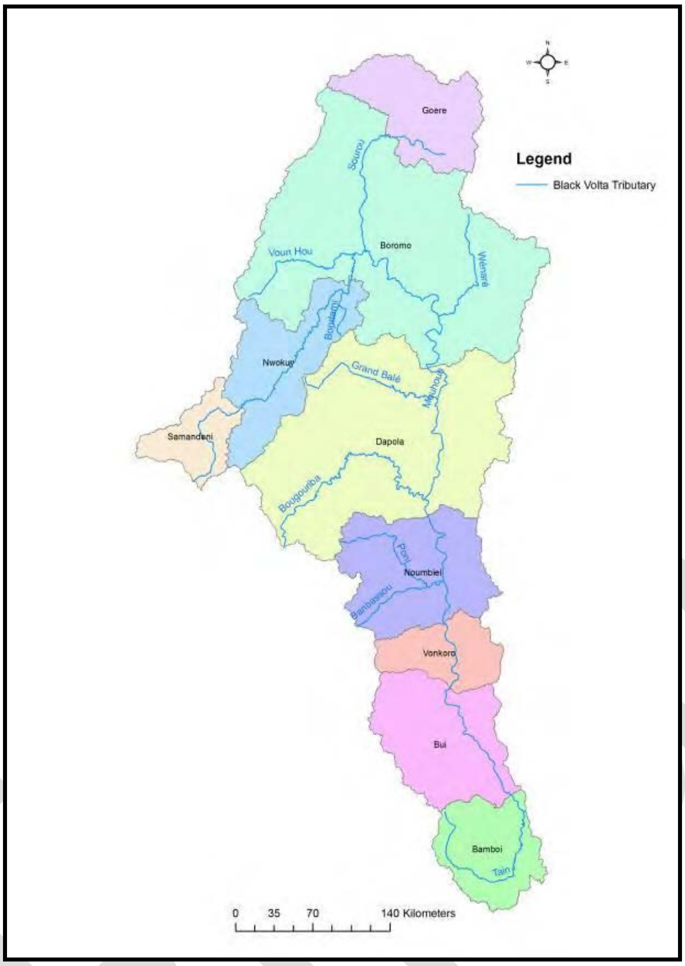

Figure 18: Sub-basins in the Black Volta Basin[25]

Figure 19 shows the portions of the Black Volta sub-basins that fall within Ghana. There are 5 sub-basins that fall within Ghana. These are the Bamboi, Bui, Dapola, Noumbiel and Vonkoro sub-basins. Table 3 shows the proportions of the sub-basins within Ghana.

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[25] MAP ADAPTED USING DATA FROM THE VOLTA BASIN FOCAL PROJECT (2008)

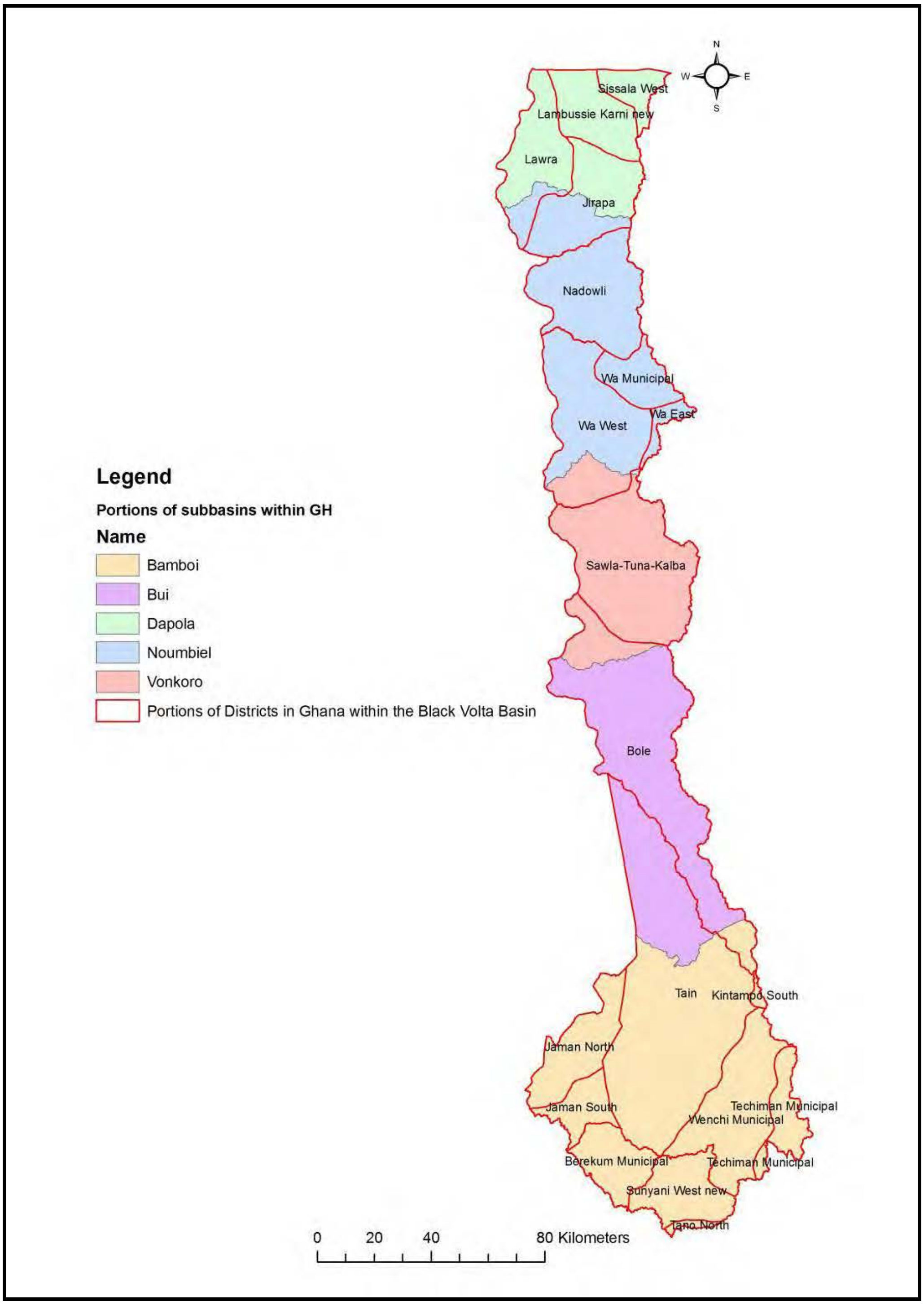


Figure 19: Portions of Sub-basins within Ghana

Table 3: Portions of Sub-basins within Ghana

Name	Area of Sub-basin (km^2)	Area of sub-basin within Ghana (km^2)	% of Area within Ghana
Bamboi	7525	6676	88.7
Bui	11590	3338	28.8
Dapola	31680	2138	6.7
Noumbiel	12499	3663	29.3
Vonkoro	5347	2569	48.0

3.4 Surface Water

3.4.1 *Surface Water Availability within Ghana*

The mean runoff in the Black Volta is estimated at $7km^3$ per annum[26]. The driest and wettest months are March and September, respectively. Monthly flows in Lawra (upstream), Bui (Mid-stream) and Bamboi (downstream) is shown in Figure 20[27].

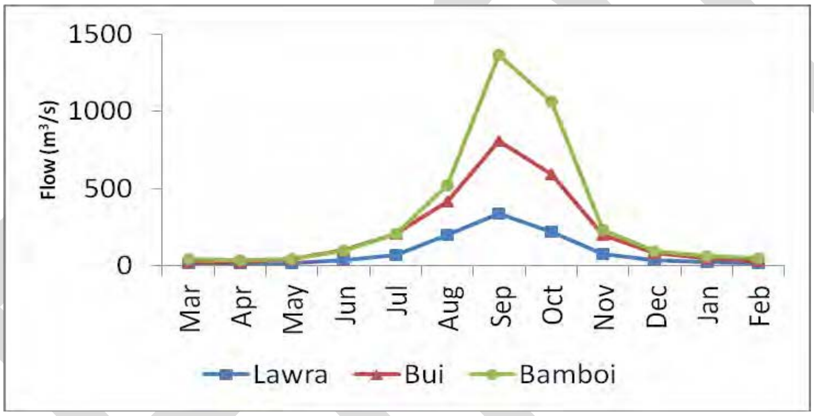


Figure 20: Monthly flows in the Black Volta Bain

All stations in the Black Volta basin of Ghana, with the exception of Chache, have been selected and used for the analysis. There are four stations in total. Three (3) of them namely Lawra, Bui and Bamboi were selected to represent the upstream, midstream and downstream of the basin in Ghana respectively. Figures 21-29 show the flows for March and September and the monthly minimum flows in the basin fixed as the 25 percentile flow for Lawra, Bui and Bamboi.

The 1990s started with the evolution of a number of small reservoirs and medium scale dams in the Black Volta basin. The period before the dams is referred to in this section as pre-impact and the period after; post-impact since the dams could alter flows within the basin.

[26] ANDREINI ET. AL. (2000). VOLTA BASIN WATER BALANCE
[27] DATA ANALYSED USING THE INDICATORS OF HYDROLOGIC ALTERATIONS (IAH)

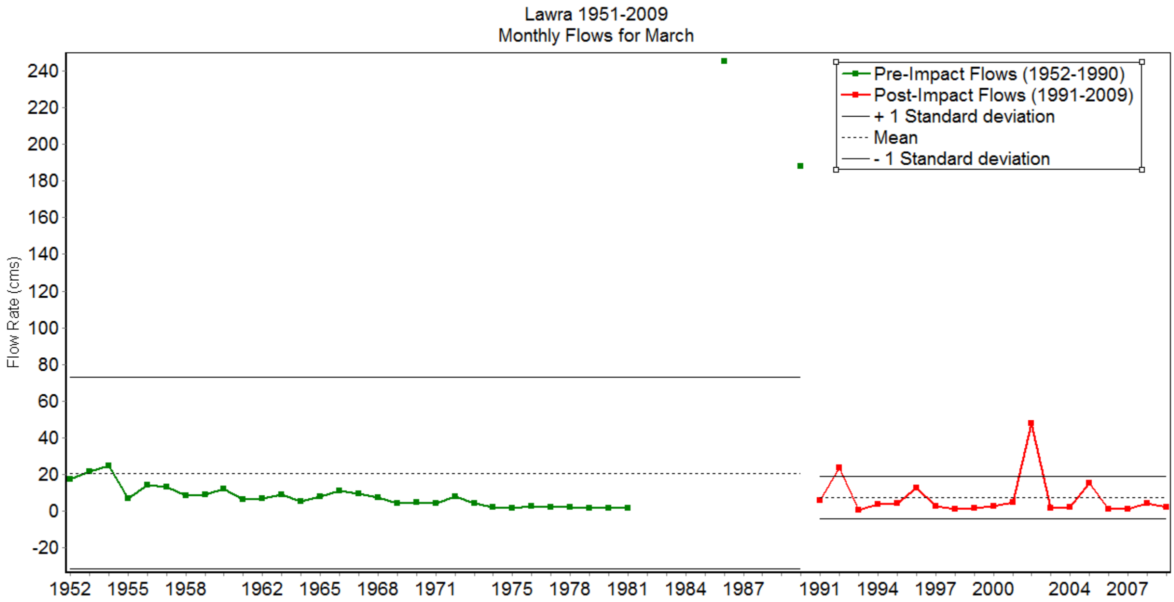


Figure 21: Monthly flows for March at Lawra

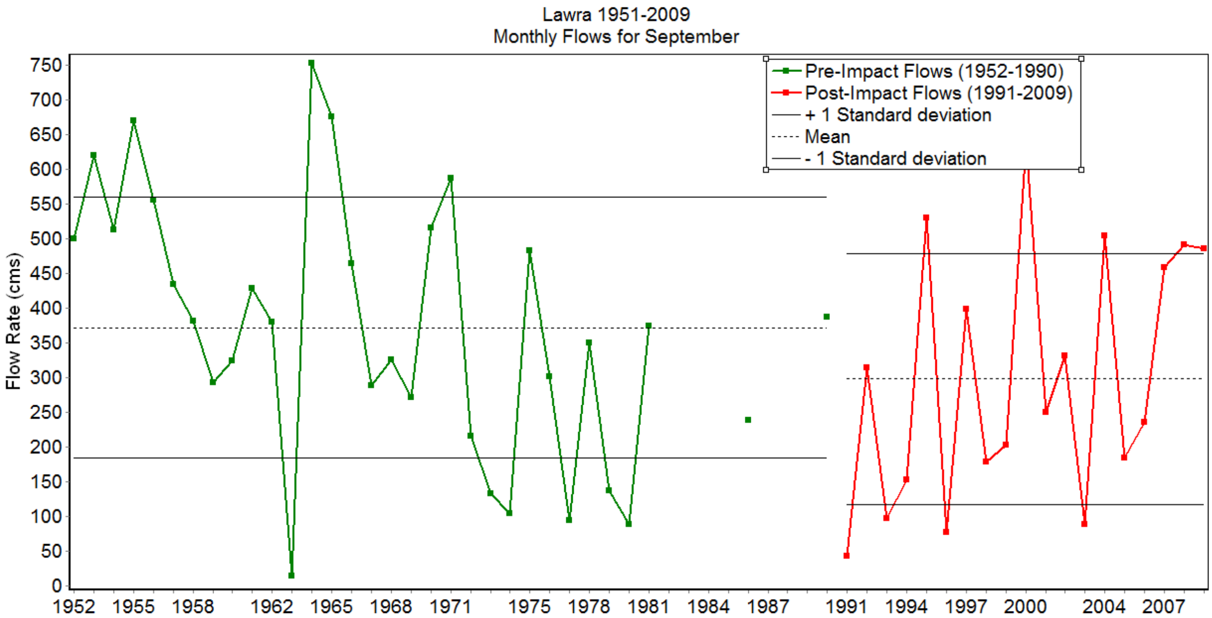


Figure 22: Monthly flows for September at Lawra

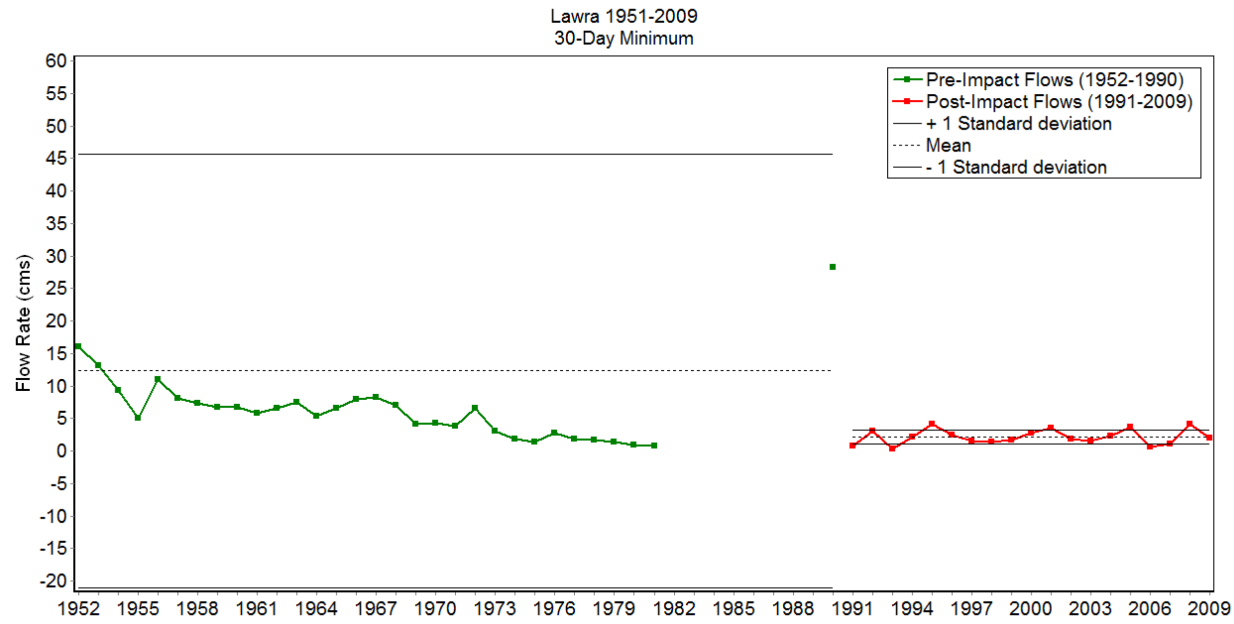


Figure 23: 30-day Minimum flow at Lawra

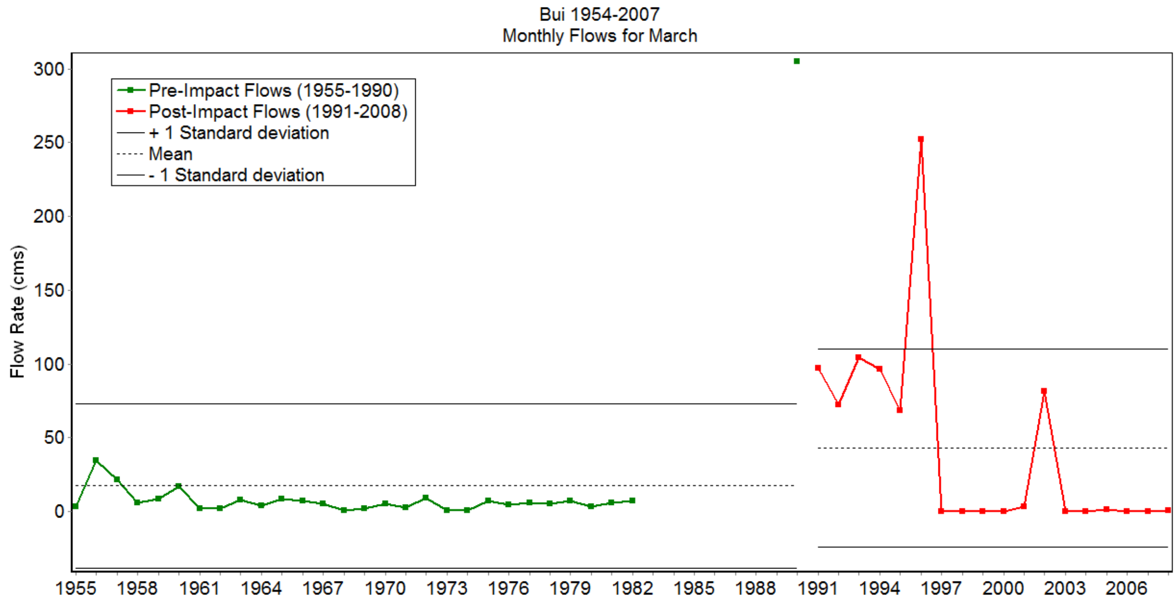


Figure 24: Monthly flows for March at Bui

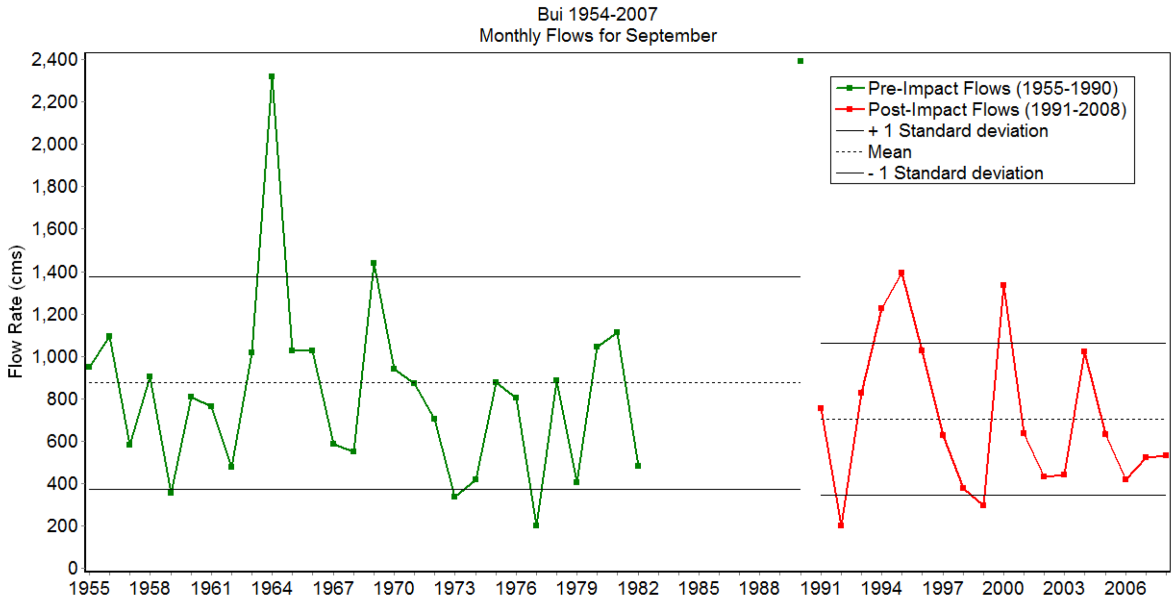


Figure 25: Monthly flows for September at Bui

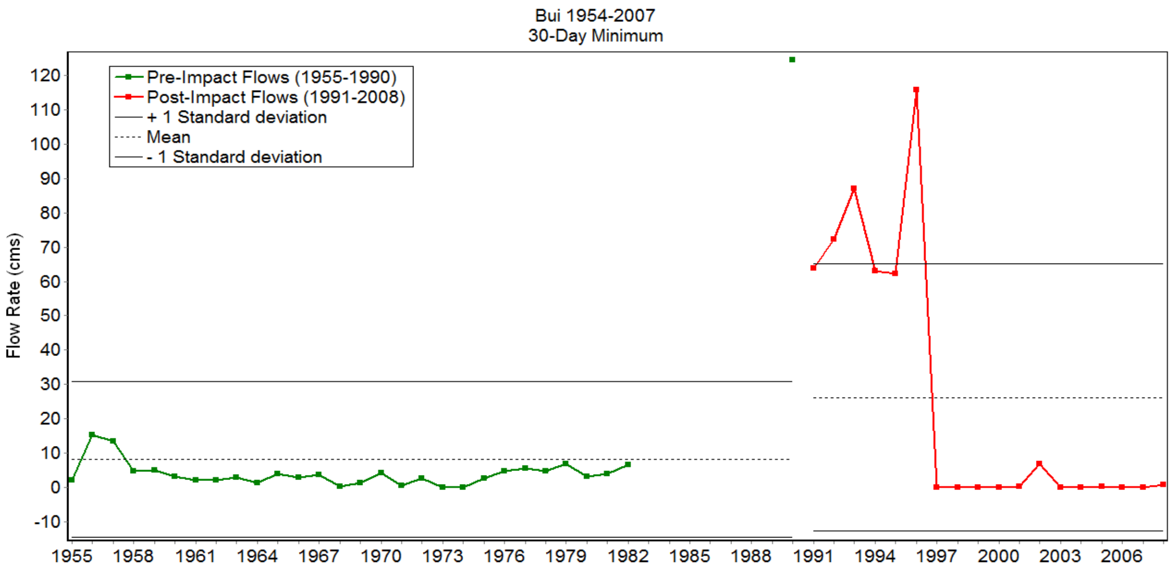


Figure 26: 30-day minimum flow at Bui

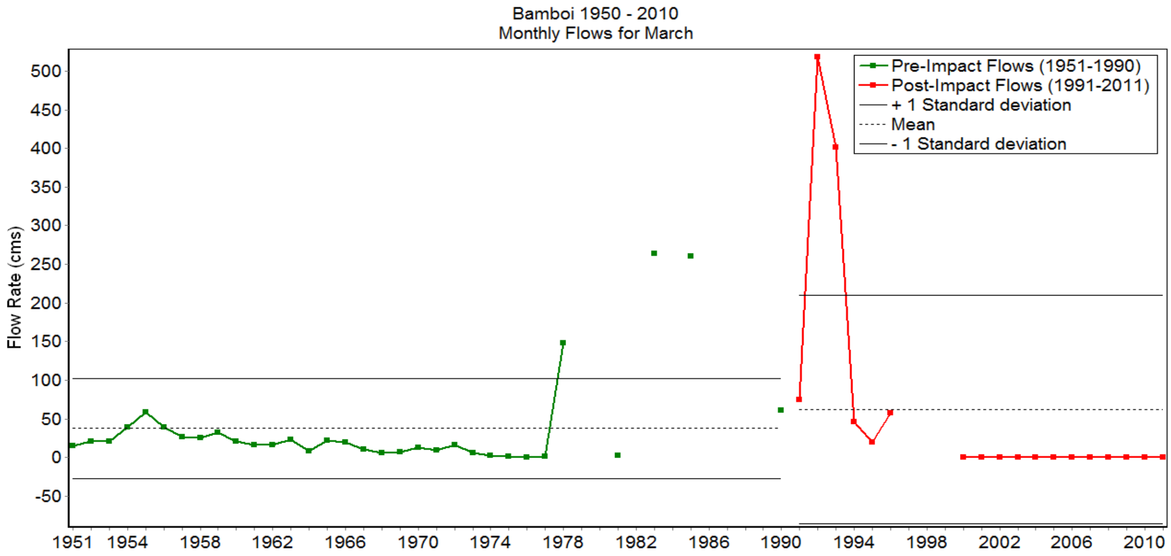


Figure 27: Monthly flow for March at Bamboi

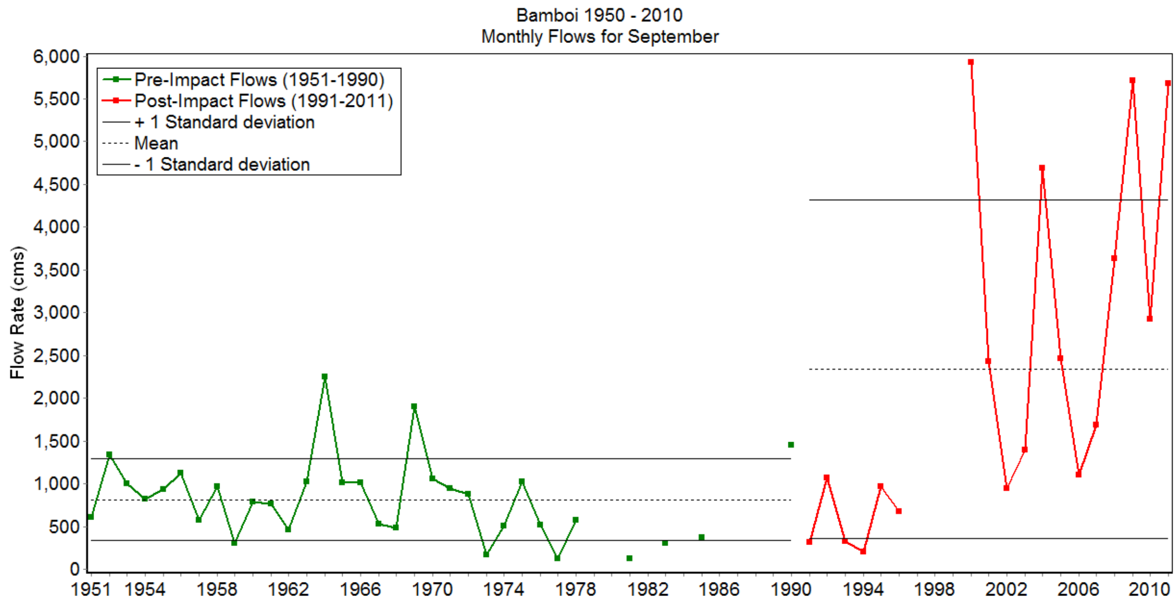


Figure 28: Monthly flow for September at Bamboi

The minimum monthly gauge flow of about 16m^3/s occurs at Lawra and the maximum of 52m^3/s occurs in Bamboi for the basin. This shows that there are untapped water resources in the basin which could be harnessed for productive uses to improve livelihoods.

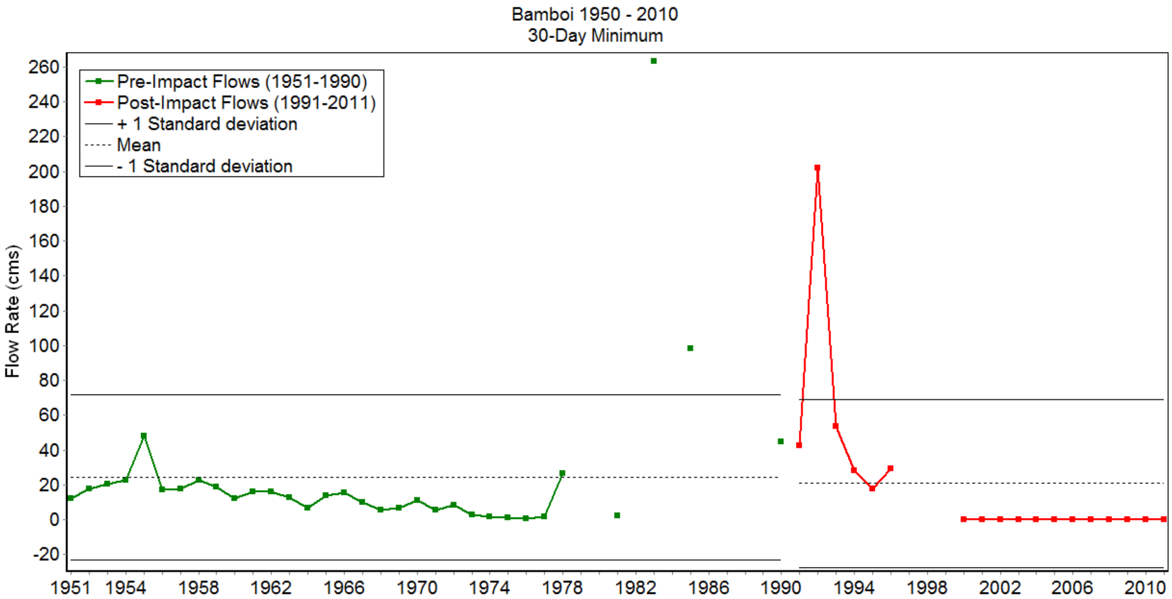


Figure 29: 30-day Minimum flow at Bamboi

3.4.2 *Surface Water Quality*

Continuous monitoring of the surface water quality is hardly carried out in the Black Volta basin. Monitoring is done by specific projects for their own purposes and this is not sustained when they end. The latest water quality assessment report available is dated 1996. This was carried out by Larmie and Annang but the data is from 1976 to 1978[28]. Water quality data for the basin is therefore very limited and since it is not continuous can hardly be used for any meaningful analysis.

Institutions that generate water quality data in Ghana include the Architectural and Engineering Services Limited (AESL) Hydro Division, Ghana Water Company Limited (GWCL), Water Research Institute (WRI), The Ghana Atomic Energy Commission (GAEC), The Ghana Standards Board (GSB), Environmental Protection Agency (EPA), Water Resources Commission (WRC), Private Laboratories, Universities and Research Institutes[18].

Table 3 shows the results of the water quality test carried out for the Volta basin. The one for the Black Volta was sampled from the station at Bamboi. The water in the Black Volta is suitable for Agriculture and portable water supply[19]. However this is also confirmed by the table 3 although the data is obsolete.

---

[28] VOLTA BASIN - HYDROLOGICAL INFORMATION ON WATER QUALITY. INTERIM REPORT (1996)

Table 4: Summary of Water Quality in the Volta basin[29]

Parameter	Oti River at Sabare (Nov 76 to Feb 78)		White Volta at Daboya (Aug 77 to Feb 78)		Black Volta at Bamboi (Aug 77 to Feb 78)		Lower Volta at Amedeka (Apr 77 to Mar 78)	
	mean	std dev	mean	std dev	mean	std dev	mean	std dev
pH	6.9	0.5	6.9	0.4	7.0	0.5	7.1	0.3
Conductivity	280	213	194	156	201	154	520	245
Dissolved Oxygen	9.9	2.4	10.6	3.8	11.2	3.1	8.0	2.0
BOD	2.7	1.3	1.5	0.5	3.8	2.3	2.8	2.2
Alkalinity	35.3	11.5	42.6	16.5	53.8	23.6	44.8	6.4
Chloride	5.4	2.8	13.6	8.6	7.0	0.8	4.6	2.5
Calcium	4.8	2.0	6.8	2.0	10.1	2.9	5.3	1.4
T Hardness	22.9	10.8	30.4	2.8	44.1	18.6	17.4	7.3
Magnesium	4.3	2.2	5.8	0.8	8.3	4.1	2.5	1.9
Ammonia-N	1.0	1.5	1.6	2.9	1.5	2.4	0.4	0.5
Phosphate	0.9	0.4	0.7	1.0	0.6	1.9	0.2	0.3
Nitrate	0.2	0.1	0.5	0.6	0.2	0.1	6.6	10.9
Nitrite	0.08	0.02	0.06	0.08	0.1	0.1	0.6	1.3
Sulphate	5.7	6.6	8.9	10.7	7.0	8.4	1.2	0.8

3.5 Groundwater

3.5.1 *Groundwater Assessment*

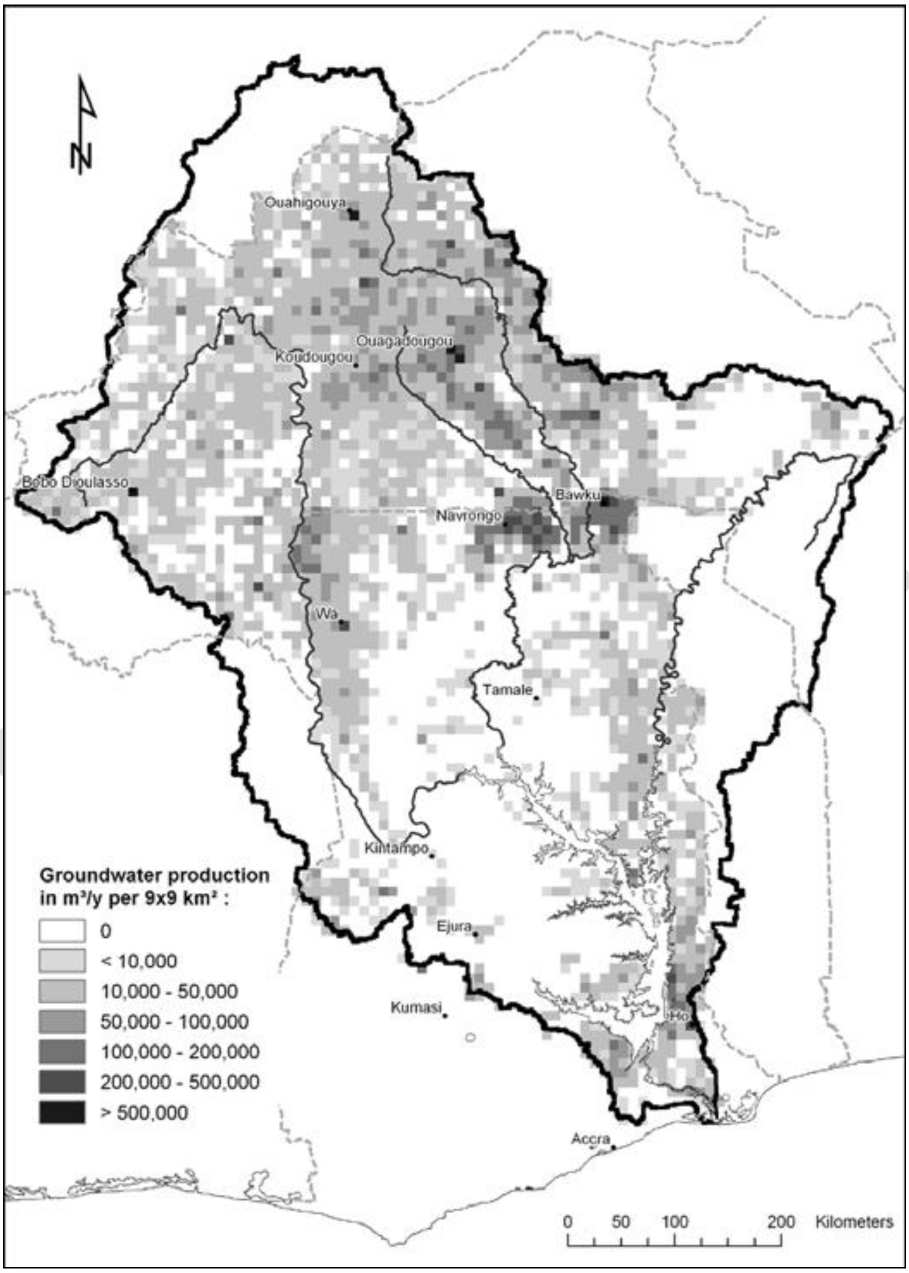
Most streams in the Volta basin are ephemeral and dry up by March/April. This makes it extremely difficult to find portable water in most parts of the Basin Systems during the dry season[30]. Groundwater resources then seem to be the most probable way out.

Table 5: Groundwater characteristics in the Volta basin[31]

Basin	Runoff Co-efficient %	Borehole Yield (m3/h)	Mean Borehole Yields (m3/h)	Specific Capacities (m3/h/m)	Depth to Aquifer (m)	Mean Depth to aquifer (m)	Depth of Boreholes (m)	Mean Depth of Borehole (m)
White Volta	10.8	0.03-24.0	2.1	0.01-21.1	3.7-51.5	18.4	7.4-123.4	24.7
Black Volta	8.3	0.1-36.0	2.2	0.02-5.28	4.3-82.5	20.6	-	-
Oti	14.8	0.6-36.0	5.2	0.06-10.45	6.0-39.0	20.6	25.0-82.0	32.9
Lower Volta	17.0	0.02-36.0	5.7	0.05-2.99	3.0-55.0	22.7	21-29.0	44.5

[29] Volta Basin - Hydrological Information on Water Quality. Interim Report (1996)
[30] Kortatsi (1997). Information Build Block – Geology and Groundwater
[31] Water Audit Update study, 2012

On the average, the mean annual groundwater recharge of the Volta River system is about 5-12% of annual precipitation in weathered rocks. Only rainfall values exceeding 380mm/annum in these weathered rocks recharge the groundwater system[32]. Figures 30 and 31 show the Groundwater production and groundwater consumption estimated for the Volta basin respectively.



[32] Martin and van de Giesen (2005). Spatial Distribution of Groundwater Production and Development Potential in the Volta River basin of Ghana and Burkina Faso. IWRA, Water International, Volume 30, Number 2, June 2005

Figure 30: Spatial distribution of groundwater production in m³/y per 9x9 km² cell[32]

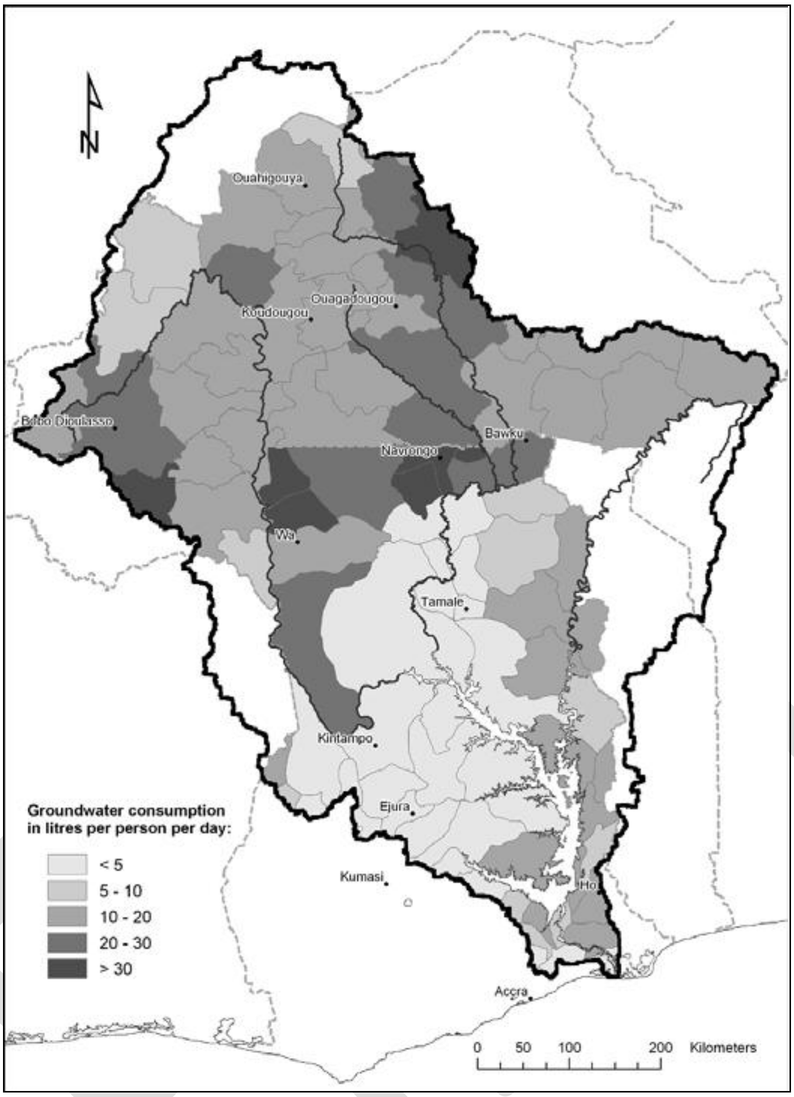


Figure 31: Average daily per person of groundwater consumption by district[33]

3.5.2 *Groundwater Quality*

Monitoring of groundwater quality is somewhat better than surface water quality due to the fact that the Black Volta is predominantly rural (about 70%) and their domestic demands are satisfied with groundwater. Apart from hardness, groundwater quality seems to be ok as shown in Table 6. The potential problems with groundwater are largely fluoride excesses and iodine deficiencies (i.e. less than 0.005 mg/l)[34].

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[33] MARTIN AND VAN DE GIESEN (2005). SPATIAL DISTRIBUTION OF GROUNDWATER PRODUCTION AND DEVELOPMENT POTENTIAL IN THE VOLTA RIVER BASIN OF GHANA AND BURKINA FASO. IWRA, WATER INTERNATIONAL, VOLUME 30, NUMBER 2, JUNE 2005

[34] GROUNDWATER QUALITY IN GHANA. WATERAID WORKING DOCUMENT. PUBLISHED BY BRITISH GEOLOGICAL SURVEY

Table 6: Summary Groundwater Quality for the Volta Basin[35]

Parameter	Geologic Formation				
	White Volta-Granite (East)	Black Volta-Granite (Central)	Black Volta-Granite (West)	White Volta-Metamorphic Rock or Birrimian East	Black Volta-Metamorphic Rock or Birrimian West
pH	Range 6-9.3 avg. 7.4 Majority have pH 7.0 Alkaline in nature	Range 6,1-7,4 avg. 6.8 not very acidic	Range 5.5-8,1 Majority have pH > 7.0 avg. 6.6 generally acidic	Range 6.2 to 6.8 Acidic	Range 6.1 to 8.8 Avg 7.3
Hardness	Generally moderately hard Temporary Hardness	Generally moderately hard Temporary Hardness	Moderate	very hard water	generally hard
Bicarbonate	High above 100mg/l	High above 100mg/l	High	high concentration up to 382mg/l	high concentration
Fluoride	High concentrations detected. Few wells up to 3.8mg/l	Small concentration detected in wells	All have concentration less than 1.5mg/l	high value detected in several wells up to 3.8mg/l	low concentration less than 1.5mg/l
Iron and Manganese	Less than 12% have concentration above 0.3mg/l	Few wells have concentration above 0.3mg/l	Majority (>50%) have concentration above 0.3mg/l	Few wells had concentration greater than 0.3mg/l	very high values detected in few wells up to 4.5mg/l
Silica	Range up to 90mg/l	Fluctuating between high and low	Not very high, range up to 60mg/l	not very high values for most of wells	not very high values for most of the wells
Nitrate	High concentration found in several wells	concentration up to 13mg/l detected in few wells	very high concentration noted in particular wells up to 123mg/l	considerable number of wells up to 12mg/l	up to 7.9mg/l detected
Phosphate	High values detected in several wells	Low concentration detected	All have concentration less than 1mg/l	generally low less than 1.0mg/l	low

35 VOLTA BASIN - HYDROLOGICAL INFORMATION ON WATER QUALITY. INTERIM REPORT (1996)

3.6 **Limitations of Water Resources Assessment in the Black Volta Basin**

3.6.1 *Meteorological Stations*

Each portion of the sub-basins of the Black Volta in Ghana has at least one meteo. station within 30km radius (shown in Figure 32) covering an average area of about $3700km^2$. It is evident from the figure that large portions of the basin are not covered.

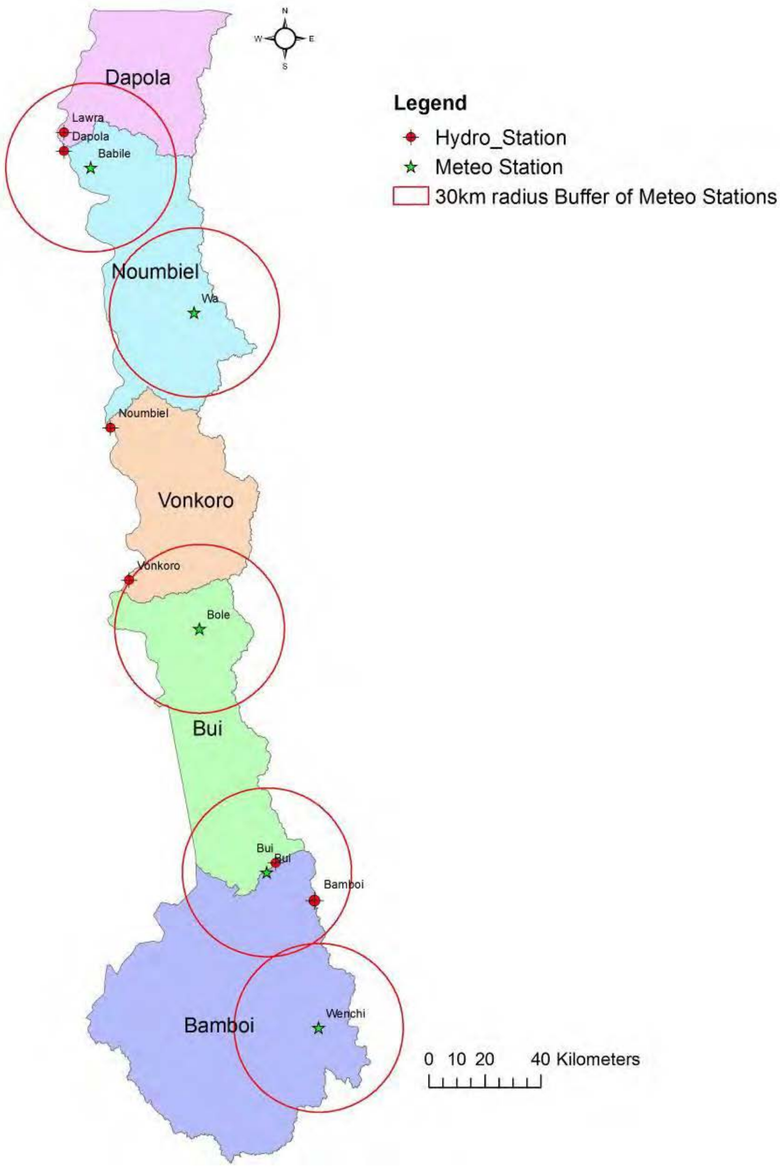

Figure 32: Hydro and Meteo Stations in the basin key for Ghana's water resources assessment

3.6.2 *Hydrological stations*

The current hydrological stations in the basin within Ghana are sufficient for general water resources assessment at larger scales. For detailed water analyses for smaller watersheds within the basin there would be the need to install more hydro stations. The key stations for Ghana's water resources assessment are shown in Table 7.

Table 7: Gauge Stations of Interest to the Black Volta Basin in Ghana

STATION	Latitude	Longitude	COUNTRY	RIVER
Dapola	10.570	-2.920	BF	Black Volta
Lawra	10.630	-2.920	GH	Black Volta
Noumbiel	9.680	-2.770	BF	Black Volta
Vonkoro	9.190	-2.710	CI	Black Volta
Bui	8.281	-2.238	GH	Black Volta
Bamboi	8.150	-2.030	GH	Black Volta

4. WATER DEMAND IN THE BASIN

Water use in the basin is mostly for agriculture, domestic purposes, fishing, livestock, the environment and currently mining (legal and galamsay).

Portable water supply to the populace in the basin within Ghana is done largely by the GWCL for urban coverage and the Community Water and Sanitation Agency (CWSA) for rural water supply. The GWCL operates mainly by using surface water resources and sometimes wells and boreholes. It has 208 pipe borne water systems, 8000 boreholes with hand pumps, 10,000 hand-dug wells to supply water to urban towns including Wa Municpality[36]. CSWA uses mostly the small town water supply system with a mechanized borehole often as the source of supply.

4.1 Current and Projected Water demands and its potential Impacts

4.1.1 *Agriculture water demand*

Most farmers in the Black Volta basin in Ghana are peasant farmers who do compound farming. Irrigation is largely done using small reservoirs hence its water demand is met by small reservoirs. The only large irrigation scheme in the basin within Ghana is the Bui irrigation which has an estimated water use rate of 20,000m^3/ha/year and a projected irrigable land of about 800ha by 2030 under cultivation[37].

Table 8: Projected irrigable lands for rice cultivation as per country in the Volta Basin[27]

Country	Sub-basin	Irrigation site	Irrigable land areas and projections (ha)					Water use rate m^3/ha/year
			2010	2015	2020	2025	2030	
Benin	Oti-Pendjari	Porga	10,503	10,503	10,503	10,503	10,503	15,000
Burkina Faso	Black Volta	Samendeni	2,500	5,000	7,500	8,900	10,500	15,850
		Sourou	3,360	3,710	4,090	4,520	4,990	20,000
	White Volta	Bagre	3,380	7,680	8,980	10,280	11,580	20,000
Cote d'Ivoire	Black Volta	Nord-Zanzan	138	16,781	17,292	17,818	18,361	15,000
Ghana	White Volta	Tono	1,432	1,699	1,966	2,233	2,500	20,000
		Vea	850	887	925	962	1,000	20,000
	Black Volta	Bui	50	600	700	750	800	20,000
Mali	Black Volta	Sourou	9,000	10,750	11,050	11,175	11,300	18,000
Togo	Oti	Dapaong	5,056	6,080	7,389	9,500	12,400	18,000

[36] ADOM (1997). GHANA WATER RESOURCES MANAGEMENT STUDY. INFORMATION BUILDING BLOCK. MAIN REPORT – URBAN WATER SUPPLY

[37] WATER AUDIT UPDATE STUDY, 2012

4.1.2 *Crop water requirements*

4.1.2.1 Rainfed Farming

Rainfed farming affects runoff generation in the basin. If lands under rainfed farming increase, runoff decreases. This is therefore already inherent in the river flows since the runoff is excess precipitation after infiltration and evapo-transpiration while taking into account changes in storage.

4.1.2.2 Irrigated farming

As explained in the previous section, apart from Bui, large irrigation schemes do not exist currently and by the year 2030 in the basin. Medium scale irrigation schemes are served by small reservoirs which are considered as demands in this study. Hence satisfying the demands of small reservoirs will satisfy the demands of all these irrigation schemes.

Some communities engage in groundwater for irrigation. However these are very few and survey conducted in the present study shows that the land size under irrigation is mostly under 0.4ha per community of the GWI project area but also for the basin within the Upper West region in general.

Table 9: Cropped area for major crops in the Upper West Region of Ghana – 2011 in Hectares[38]

	CROPS							
DISTRICTS	MAIZE	RICE	MILLET	SORGHUM	YAM	G/NUTS	COWPEA	SOYABEAN
Wa West	5440	1523	6838	6462	5027	19030	4608	4460
Wa East	8730	788	6476	3920	5294	12495	5292	4720
Wa Municipal	7580	462	6600	6108	4641	15320	4296	4730
Lawra	5380	116	12190	39496	0	15790	4680	188
Sissala East	10560	206	4343	985	2651	10980	10368	157
Sissala West	9340	378	4619	8492	2580	7850	11100	170
Jirapa-Lambussie	7420	1095	13754	17853	1275	21320	11960	399
Nadowli	12900	263	9086	18123	4834	29820	23652	806
REGIONAL TOTAL	67350	4829	63906	101439	26302	132605	75956	15630

38 SOURCE: STATISTICS, RESEARCH AND INFO. DIRECTORATE (SRID), MIN. OF FOOD & AGRIC.JAN, 2012

Table 10: Rainfall and Length of Growing seasons[39]

Agro-ecological zone	Mean annual rain (mm)	Growing period (days) Major season	Minor season
Rain forest	2,200	150-160	100
Deciduous forest	1,500	150-160	90
Transitional	1,300	200-220	60
Coastal	800	100-110	50
Guinea savanna	1,100	180-200	-
Sudan savanna	1,000	150-160	-

4.1.3 *Livestock Watering*

Livestock water from the main Black Volta river and its tributaries, and small reservoirs and dugouts. This usually serves as water source for large ruminants including cattle. However, small ruminants like goat and sheep often source their water needs from dugouts, wells and boreholes for which reason a trough is built at the water facility. Data collected by MOFA for 2010 shows that goat is the predominant livestock kept in the Upper West region. Herds of animals in the Upper West region is over 600,000. A detail of the livestock population and the water requirement is given in Tables 11 and 12.

Table 11: Livestock count in the Upper West Region[40]

	Livestock population (herd)					
District	Cattle	Sheep	Goats	Swine	Donkeys	Horses
Jirapa-Lambussie	20442	18486	43173	20318	1949	1
Lawra-Nandom	11696	13528	31201	14761	341	1
Nadowli	11539	15666	41295	12694	124	4
Sissala East	22459	8481	15055	487	726	7
Sissala West	15829	9069	14222	2390	1558	2
Wa East	14502	4383	13580	1829	20	0
Wa Municipal	7100	9368	15455	3418	385	230
Wa West	18601	17156	34941	14085	378	1
TOTAL	122168	96137	208922	69982	5481	246

"Tropical Livestock Unit" (TLU) has been developed by the Food and Agricultural Organization to harmonize and standardize the different compositions[41]. The Camel was used as the basis for this assessment and all other livestock compared to camel. 1 TLU = Camel 1.0.

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[39] Volta Basin Profile, Baseline Report No. 8. Volta River Basin: Enhancing Agriculture Water Productivity through Strategic Research (2005)

[40] Source: Statistics, Research and Info. Directorate (SRID), Min. of Food & Agric.- Jan, 2012

[41] http://www.fao.org/ag/againfo/programmes/en/lead/toolbox/Mixed1/TLU.htm

Assuming a demand of 35 l/TLU/day, an annual water demand has been estimated for the livestock in Table 11 for the Upper West Region. The annual growth rate for livestock has been estimated as 2.3% per annum[42].

Table 12: Livestock Water demand in the Upper West Region of Ghana

	Cattle	Sheep	Goats	Swine	Donkeys	Horses
No of Herds	122168	96137	208922	69982	5481	246
TLU/Livestock	0.7	0.1	0.1	0.2	0.4	0.7
Total	85518	9614	20892	13996	2192	172
Water demand (Mm^3)/year	1.092	0.123	0.267	0.179	0.028	0.002

4.1.4 *Domestic water demand*

Rural domestic water demand is estimated as 50l/c/day while that of urban population in the basin is estimated at 120 l/c/day.

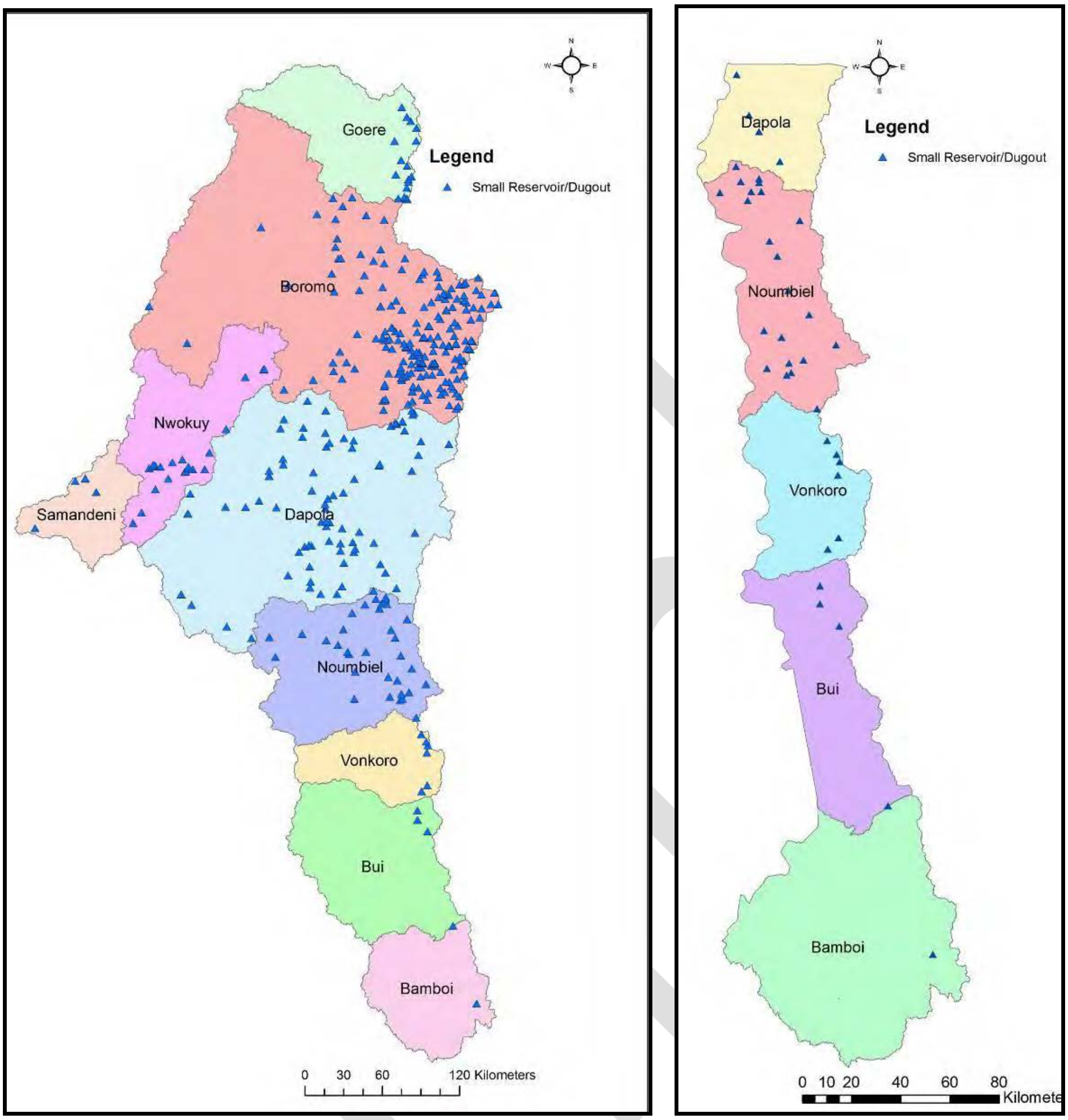
4.1.5 *Industrial demand (Mining)*

A range of industries are located in the Black Volta Basin including those in the mining sector. However, viable data on their water abstractions could not be assessed. This should be pursued in subsequent studies since mining activities seems to be on the rise in the basin.

4.1.6 *Small Reservoirs and Dugouts*

A number of small reservoirs are dotted in the Volta basin especially in the White Volta basin. This is very much utilized in the White Volta unlike in the Black Volta. The distribution of reservoirs in the Black Volta basin is given in Figure 33. The total annual water demand is estimated at $102Mm^3$ for the entire Volta basin. In the Upper West Region of Ghana in the Black Volta basin alone, the annual water demand for small reservoirs was found to be $4.2Mm^3$ representing about 4% with respect to small reservoir demand for the entire Volta basin.

[42] VOLTA WATER AUDIT STUDY, 2012



(a) (b)

Figure 33: Distribution of Small Reservoirs and Dugouts in (a) the Black Volta basin and (b) portion of the Black Volta basin within Ghana

4.1.7 *Environment*

Environmental flow is considered to be the minimum flow required to sustain habitat in rivers. It is considered in this study as the 25 percentile flow since detailed study has not been carried out yet on environmental flow requirement for the basin. In previous studies it was assumed to be 0.05 m^3/s [43].

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[43] WATER AUDIT UPDATE, 2012

5. CHALLENGES REGARDING USE OF WATER IN THE BLACK VOLTA BASIN OF GHANA

5.1 Conditions of Dams, Dugouts and Boreholes

There are about 1630 boreholes in the Ghana portion of the Black Volta basin. These are shown in Figure 34. Distribution in the sub-basins is given in Table 13.

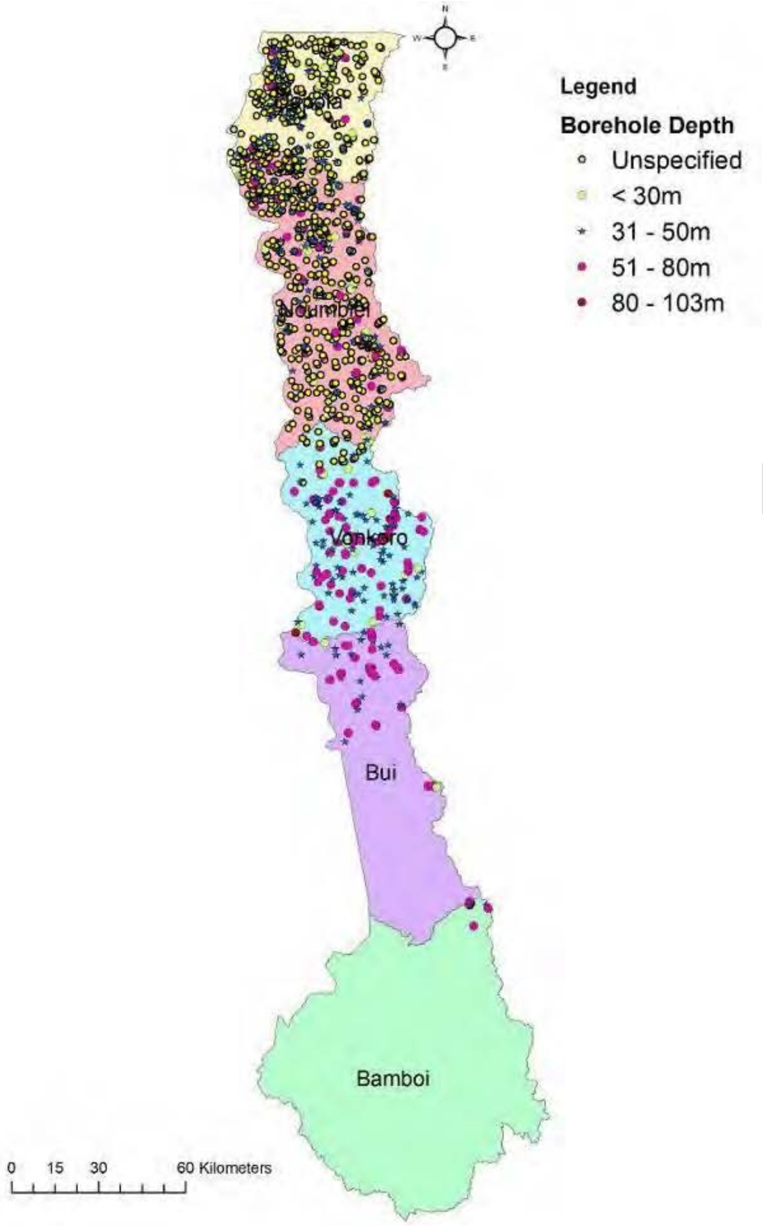

Figure 34: Boreholes within the Black Volta basin in Ghana[44]

[44] DATA FROM THE WRC HAP PROJECT (2011) WAS USED TO PRODUCE THE MAP

Table 13: Boreholes and Reservoirs in the sub-basins of the Black Volta

Black Volta Sub-basin	No. of Boreholes	No. of Small Reservoirs / Dugouts
Dapola	447	4
Noumbiel	777	22
Vonkoro	214	6
Bui	62	3
Bamboi	9	2

Most communities in the Black Volta are supplied with boreholes for their domestic water needs. Unfortunately minor routine maintenance and operations such as chlorination is not carried out. Whereas management mechanisms are operational through monthly levy and contributions from members who patronize the facility for the purpose of maintenance, other communities have adopted the pay as you fetch approach. The former was found to be faced with the challenge of effective collection and thus less sustainable.

Some communities have been provided with Small Reservoirs or Dugouts. However, no intensive large scale irrigation is carried out downstream of these facilities with the exception of the one in Bui. Most of these dugouts also dry up in the dry season when it is needed most for dry season vegetable gardening and livestock watering. This is primarily due to the fact that they are silted or have seepage problems. Regular desilting is not carried out by community members because they claim it is difficult to do when even some of the communities have been provided with the tools to be used by organizations like GWI.

5.2 **Cropping Patterns in Sub-catchments**

Crops grown are mostly cereals like Maize, Sorghum and rice in the rainy season and mostly vegetables including pepper; tomatoes and onions in the dry season. The yields of these crops are low because of poor soil fertility. Women are most often given poor lands in terms of soil fertility to farm on. This discrimination does not promote gender equity and poverty alleviation among women and household food security, in general.

The rainfall pattern is becoming more and more erratic and poses a major challenge in the basin as most farmers do rain-fed farming. This contributes to the low yields especially for the early maize and millet. There is the need to therefore shift towards efficient and productive irrigation where farmers could make up for their losses.

Crop production in the Upper West region seems to be increasing. However, there is no corresponding increase in yields. So there is intensification of farming without necessarily improving productivity. This does not encourage the young folks in the communities to engage in active farming hence leads to migration of the youth to big cities in the countries for non-existent jobs.

Figures 35 and 36 show the yields and annual production of crops from the year 2005 to 2011 for the Upper West region respectively.

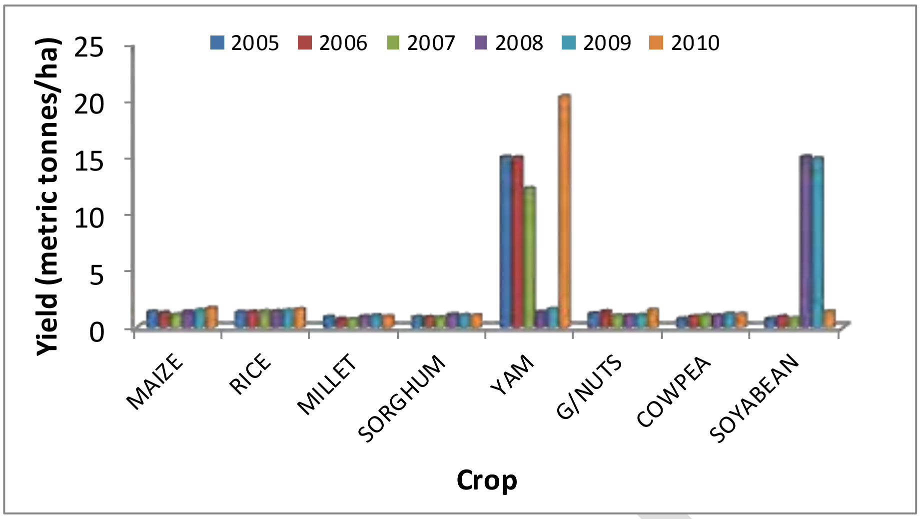

Figure 35: Yield trends in the Upper West Region of some major crops[45]

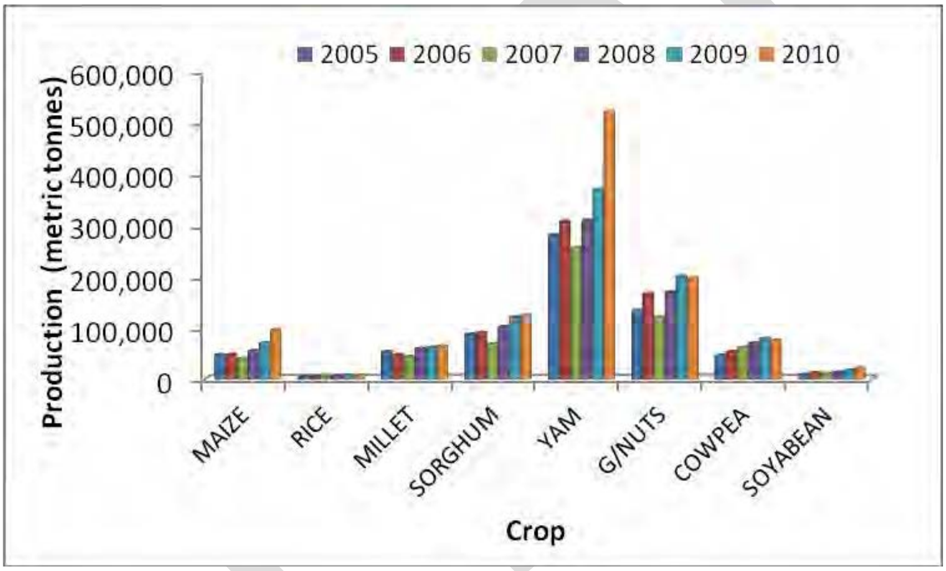

Figure 36: Annual Production of crops in the Upper West Region[35]

5.3 **Landuse and management of Sub-catchments**

Traditional roles of men as heads of family put them at a vantage position with regards to access to productive resources especially land for farming. Lands are managed by the Tindanis/Tindanba. Access to lands for farming is authorized by these family heads. By the cultural setting, men mostly take the very arable lands which are also closer to water sources for farming leaving women with very little choice but the lands with low soil fertility. These cultural

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[45] SOURCE OF DATA USED: STATISTICS, RESEARCH AND INFO. DIRECTORATE (SRID), MIN. OF FOOD & AGRIC.- JAN, 2012

settings make women disadvantaged and will have to be looked at for necessary adjustments. This calls for advocacy and gender mainstreaming.

5.4 **Farm Operations and Maintenance Culture**

Application of water in farms is mostly done with buckets and ropes or watering cans. This is somewhat inefficient and tiresome when large areas of lands are to be irrigated. Those who use water pumps also complain of high cost of fuel to run their pumps. Providing solar pumps with tight security could be an option out of this problem. GWI, CWSA and other organizations have introduced solar pumps to run community water supply systems which seem to be efficient. This could therefore be looked at in more detail through benefit-cost analysis.

Water use in communities in managed by a committee mostly the WATSAN or WUA. This happens in communities with small reservoirs most often. The committee allocates water on a rotational basis and is in charge of the maintenance of the canals and irrigations systems. They receive some support from GIDA and MOFA and from other organisations such as GWI and SARI (AGRA).

5.5 **Training and Advocacy on rainfed farming and irrigation**

There is a need to train the youth in most communities in non-farm based income generating activities or trades to supplement the income they generate from farming. This is needed to ensure that they do not migrate to cities which mostly ends up in hardships.

Productivity of irrigation or farming is low and so is water application. With poor soils and intensified agriculture low yields seems to be the only result. Farmers need to be educated on sustainable irrigation technologies and farming practices which would improve their crop yields. This cannot stop there! There is the need to train them also on micro-financing so they can be more productive and shift gradually from subsistence to commercial farming and livestock rearing.

Access to Markets is not a major problem since markets for food stuff and livestock are within 5km distance from most communities. In other communities farmers have to either walk or ride bicycles/motors over distances of at least 25km to sell their farm produce. There is a need to engage farmers in innovative ways of marketing their goods to ensure market queens do not monopolise the market as is currently practiced.

Good book or record keeping is essential for farmers so they can track their progress. Currently this is not done so it is difficult for farmers to quantify their productions and profit margins. They need to be taught how to carry out basic cost-benefit analysis and proper book keeping.

5.6 **Transboundary Issues**

Communities in the basin see communities in neighbouring countries as their relatives since they inter-marry and trade with them. Goods and services are easily sent across the Black Volta. This could be good because it opens up market but worrying because customs/duties could be evaded. Plates 1-2 show examples of goods being sent from Burkina to Ghana.

Plate 1: Transport of Goods across borders

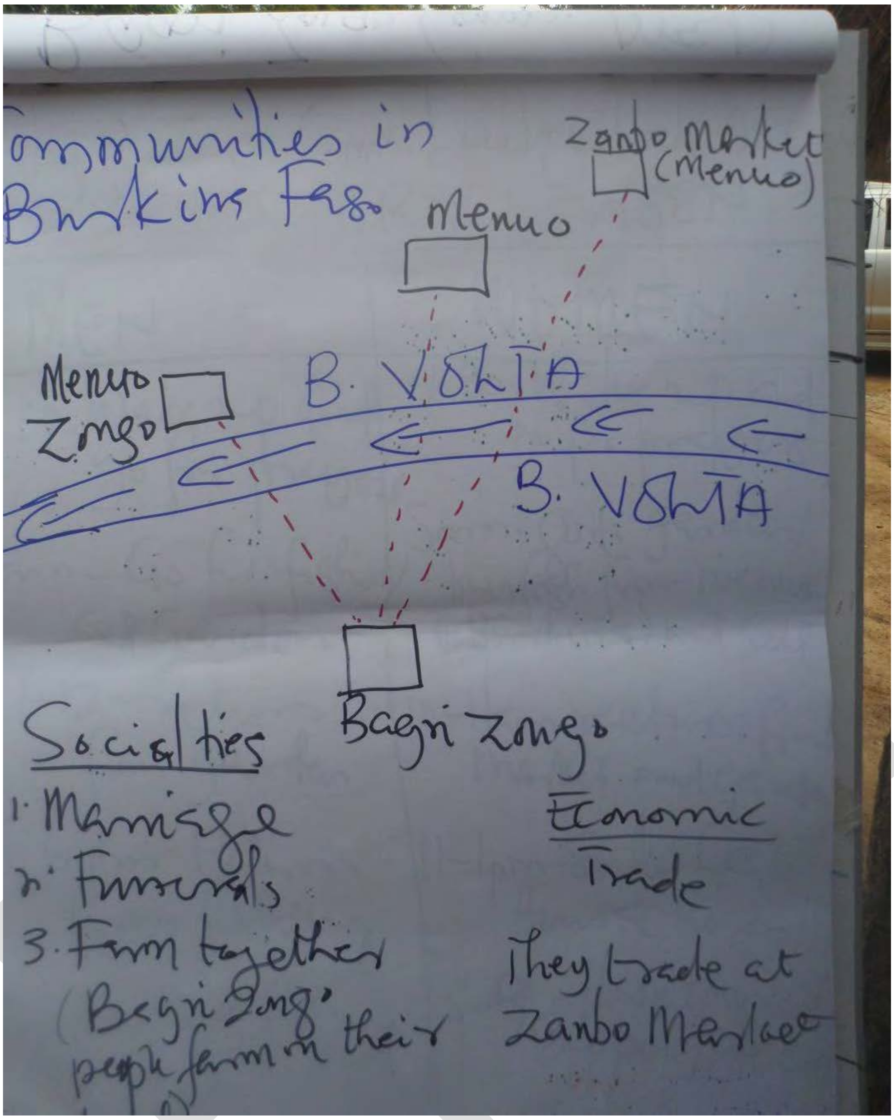

Plate 2: A picture showing the interactions between neighbouring communities along the Black Volta

The main transboundary issue in the basin has to do with the nomads also known as the "fulanis" who cause a lot of problems for the indigenes. Some of the issues raised include:

- Destruction of crops by their livestock
- Use of limited quantity of water in dugouts meant for the livestock of the indigenes
- Illegal possession and occupancies of lands meant for indigenes
- Raping of women
- Arm robbery
- Etc

It is purported that, these fulani's are hosted by some chiefs who benefit directly from them by either getting some herds of cattle or employing the Fulani to work for them. The problem with the latter is that, in that case, the herds of cattle belong to an indigene which makes the social mix complex.

Another transboundary issue to be addressed in the basin is the issue of flooding where upstream releases from dams is purported to cause flooding downstream. This has to be studied critically with some hydrological (flood) models.

The basin platform and subsequently the basin board to be formed will have to find a novel way to address this pressing issue taking into account existing traditional institutions and norms.

6. SUSTAINABLE WATER ALLOCATION

6.1 Water demand and allocation for various uses

The Water Allocation model developed for the update of the Volta Water Audit Update in 2012 was adapted in this study. The parameterization was the same, except that demands were disaggregated for the Black Volta basin in the Upper West region of Ghana. This was the focus for the modeling since that was the area where GWI was concentrating its' core activities. This was done due to the fact that the smaller watersheds in the Upper West Region of the Black Volta basin were ungauged and therefore difficult to calibrate. A scaling down approach was therefore seen to be the best option. Hence the Dapola, Noumbiel, Vonkoro and Bui subbasins of the Black Volta basin were used for the scaling down.

A brief description of the parameterization and scenarios on climate change is given in the next section however, a more detail one is described in the Volta Water Audit Update (2012) report.

Basically the Bui hydropower requirement, Environmental flow and four consumptive uses were considered in the model. The consumptive uses included;

- Domestic water use for urban populations
- Small Reservoirs water requirements
- Livestock Water requirements
- Irrigation

However, in the Upper West region, no major irrigation scheme apart from Bui was mentioned during the field visit and from the literature reviewed. Most of the irrigation done is either through small reservoirs hence satisfying the water requirements of small reservoirs will invariably satisfy those demands.

Livestock also water sometimes from small reservoirs/dugouts in addition to boreholes and rivers/streams. The model was constructed with this in mind.

6.1.1 *Parameterisation and Scenarios used in the WEAP Model for the Upper West Region*

The basin considered was only the portion of the Black Volta Basin in Ghana. Hence flows considered are flows from only the Ghana portions of the catchment.

The model was developed using climate (Rainfall, relative humidity, net evaporation, temperature, cloudiness fraction) hydrological (monthly stream flow) and demographic data sets including population and landuse.

Demands have been shown as red dots, catchments as green dots and groundwater objects as green box. Figures 37 and 38 shows the various demands considered in the WEAP model developed.

Figure 37: The Schematic view of the WEAP Model for the Black Volta basin within the UWR of Ghana

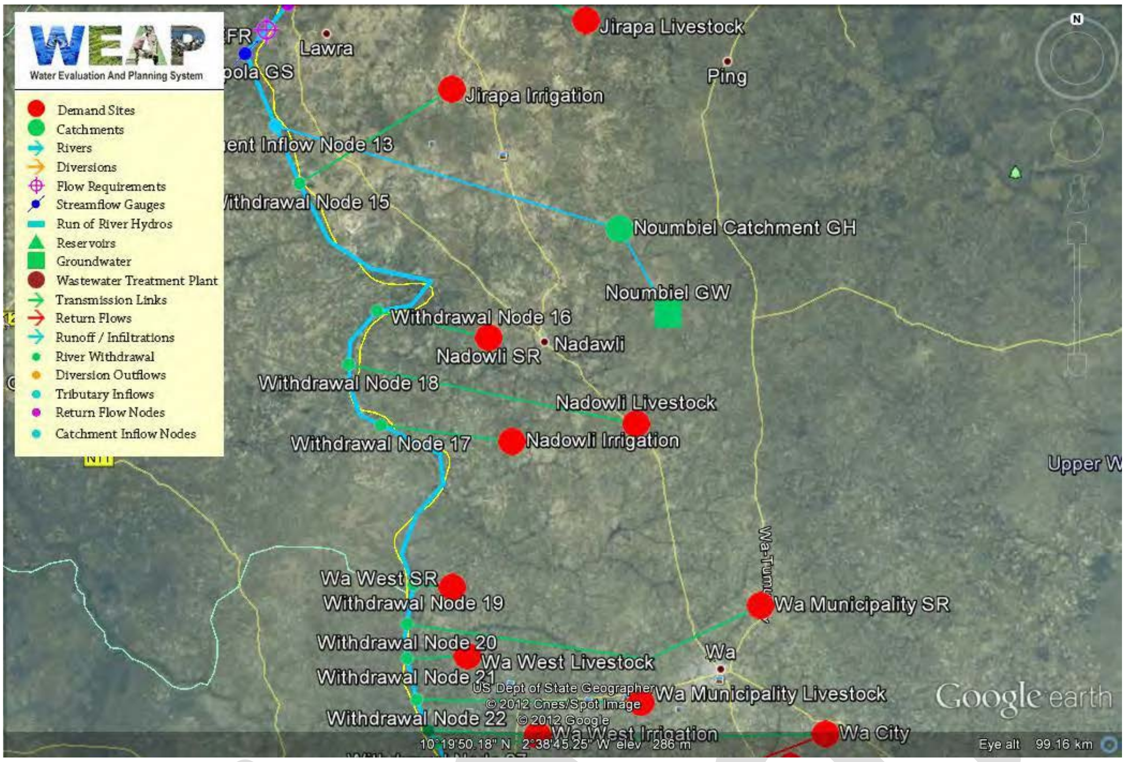

Figure 38: The Schematic view of UWR WEAP Model in Google earth

Since the model was adapted from the Volta Water Audit Update study, the climate change scenarios were maintained. 3 scenarios were developed in that study. Reference, Wetter climate and Drier climate scenarios. A temperature rise of 1^0C in the Volta Basin was considered over the simulation period.

For rainfall, three scenarios were considered:

- The "reference" situation where there was no change in precipitation levels relative to historical trends
- The "wetter" scenario where there is increase in precipitation relative to historical trends
- The "drier" scenario for which precipitation decreases relative to historical trends

These rainfall scenarios were achieved by shifting rainfall grids by 1 degree.

In the model, the increasing trends of water demands for domestic consumption coupled with population expansion in the basin were taken into account. Livestock and irrigation water demands were kept constant throughout the simulation period. This is how water has been accessed for current and future needs. Figures 39-42 show precipitation and runoff/infiltration in sub-basins within Ghana.

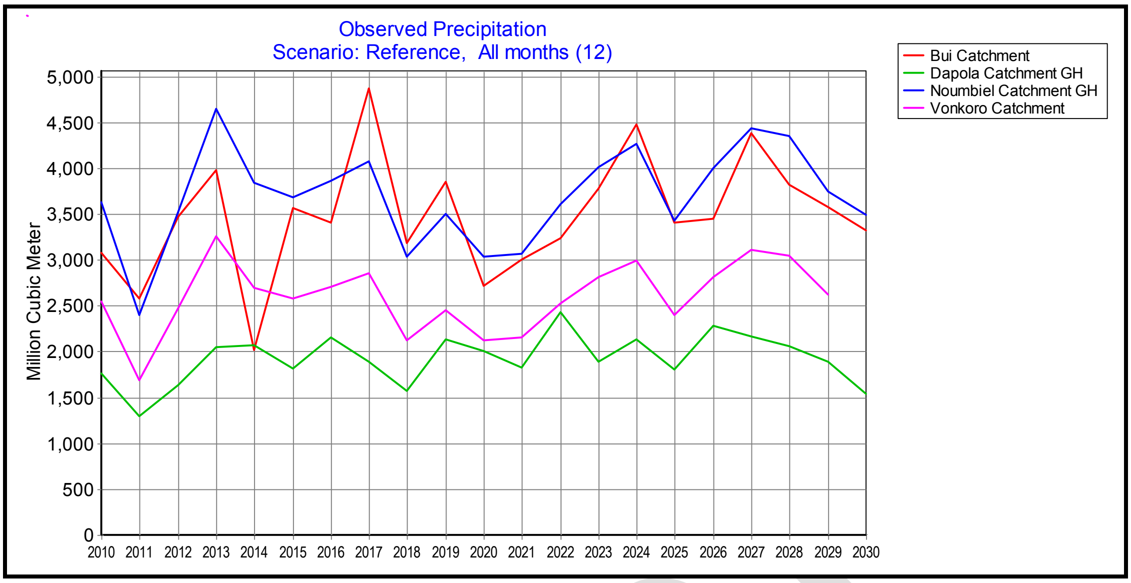

Figure 39: Annual Precipitation in the Black Volata subbasins within Ghana – Reference condition

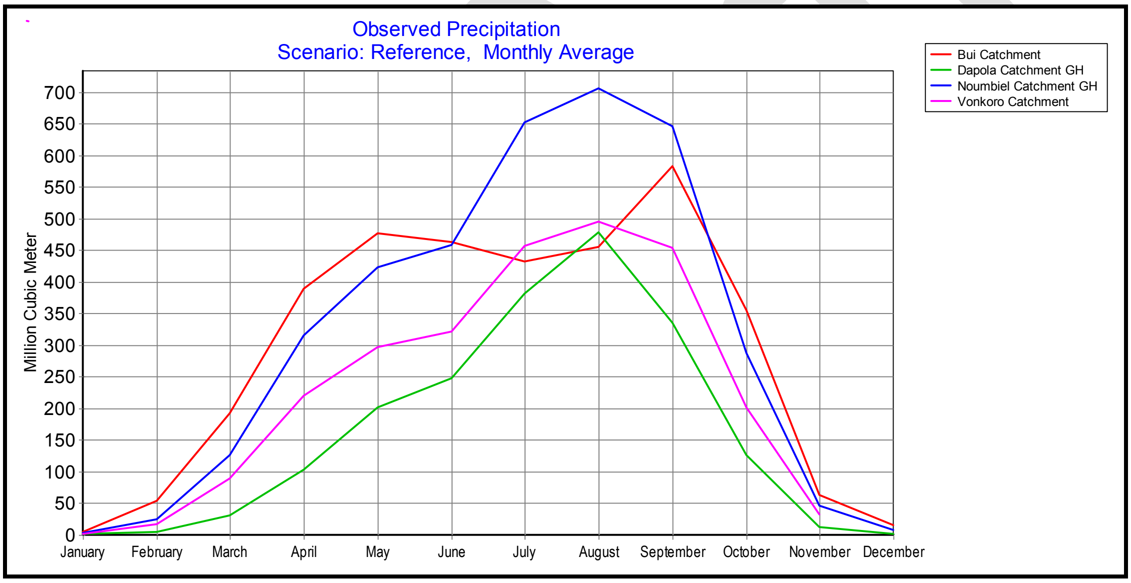

Figure 40: Monthly Average Precipitation in the Black Volta basins within Ghana – Reference condition

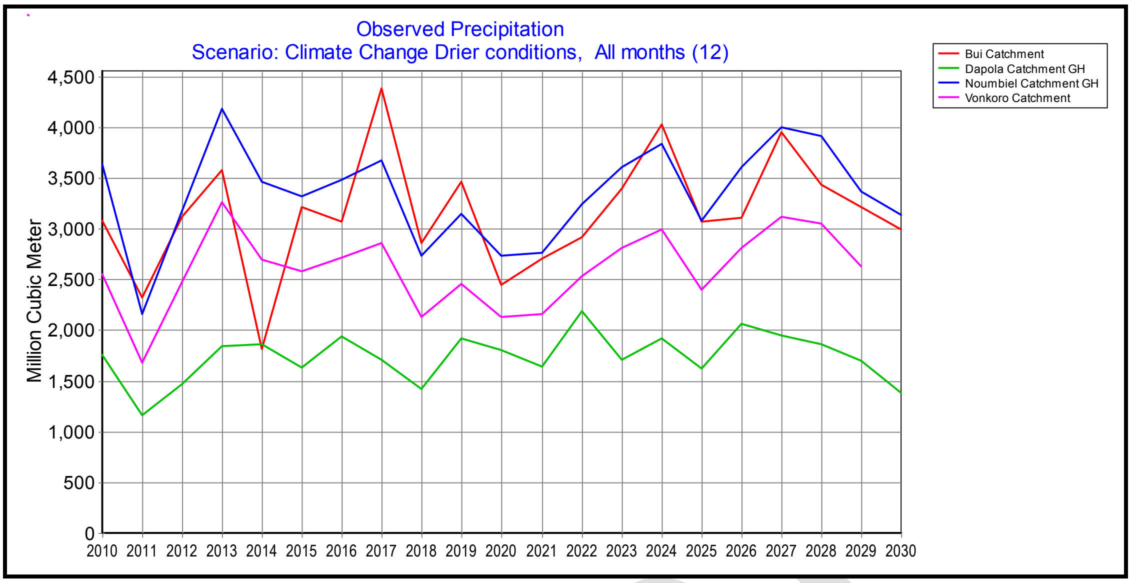

Figure 41: Annual Precipitation in the Black Volta basins within Ghana – Drier Condition

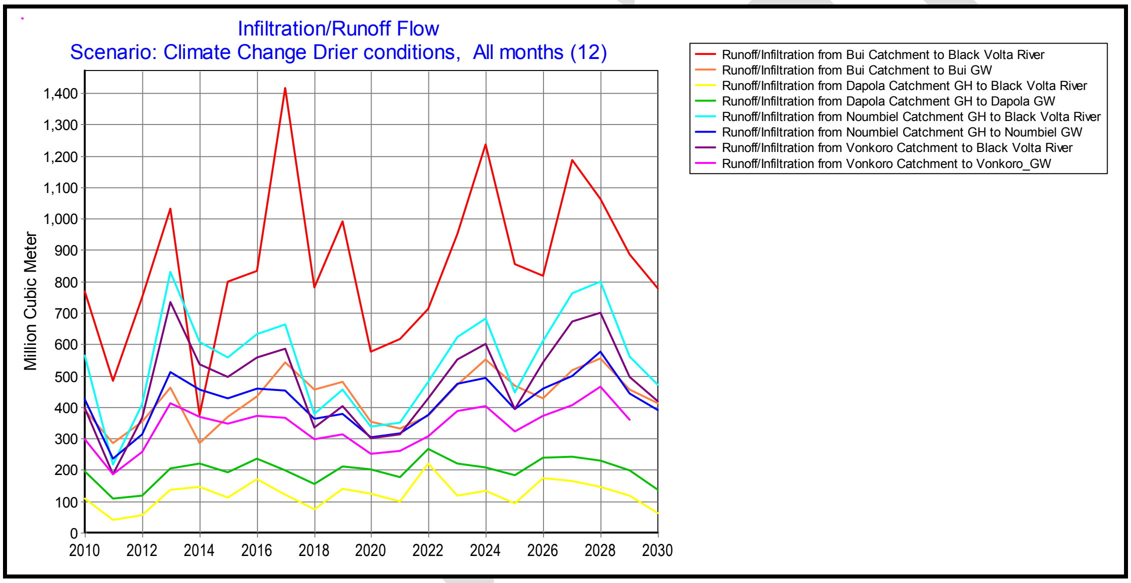

Figure 42: Runoff/Infiltration generated in the Black Volta sub-basins within Ghana – Drier condition

6.1.2 *Agriculture (Irrigation)*

Agriculture in the Upper West region is mainly rainfed. However in the dry season some farmers engage in dry season vegetable gardening. This is mostly done with small reservoirs and currently also boreholes. There are few farmers who do river irrigation at the moment.

In the model since the irrigation demands apart from Bui which requires 20,000m^3/ha/annum, small-scale irrigation demands are met with Small reservoirs;. However they were included so that stakeholders could build different scenarios and see how water availability to other users would be affected. Currently less than 2% of the irrigation area is put into use even though most of the reservoirs have been sited to meet 100% of the irrigation demands if all potential areas are cultivated in addition to making provision for livestock and other domestic uses such as dish and cloth washing, fishing and for construction purposes.

6.1.3 *Domestic purposes*

Most parts of the basin within the region are rural with domestic water requirements being met with groundwater resources. The current yields of boreholes is around 2.2m^3/h on the average. Urban water demands considered in the study include Jirapa, Lawra and Wa Municipal. The demands are given in Table 14.

Table 14: Urban Water demand in the within the Black Volta in the Upper West Region

District	2010 Population	% of Urban Population	Urban Population	Annual Water demand*(Mm3)
Wa Municipal	107,214	30%	32164	1.41
Lawra	100,929	14%	14130	0.62
Jirapa	88,402	5%	4420	0.19
* demand including losses				

The supply requirement for domestic water use in Wa is given in Figure 43 as an example of the variation of water requirements over the period of simulation.

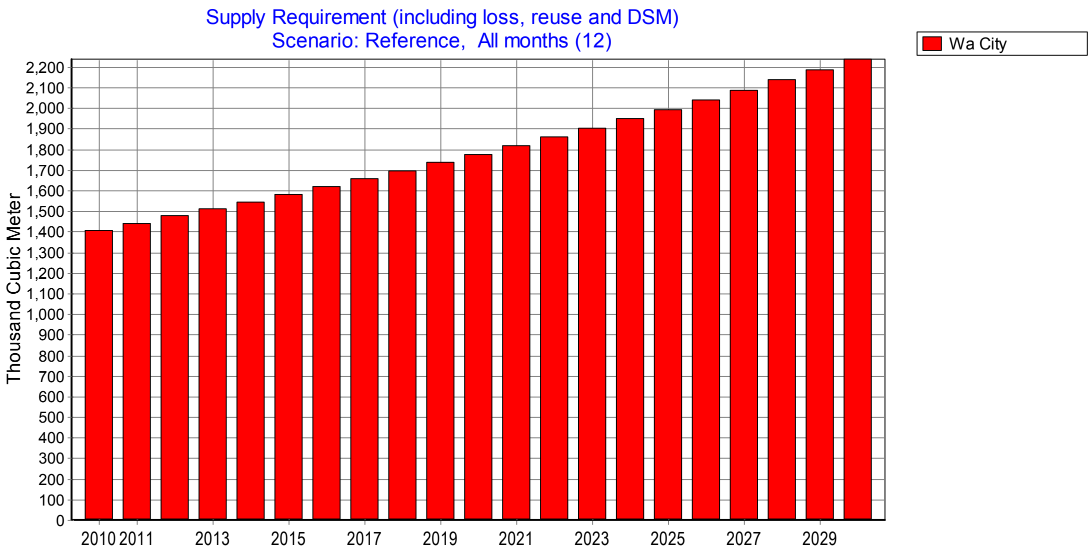

Figure 43: Water Supply requirement at Wa City

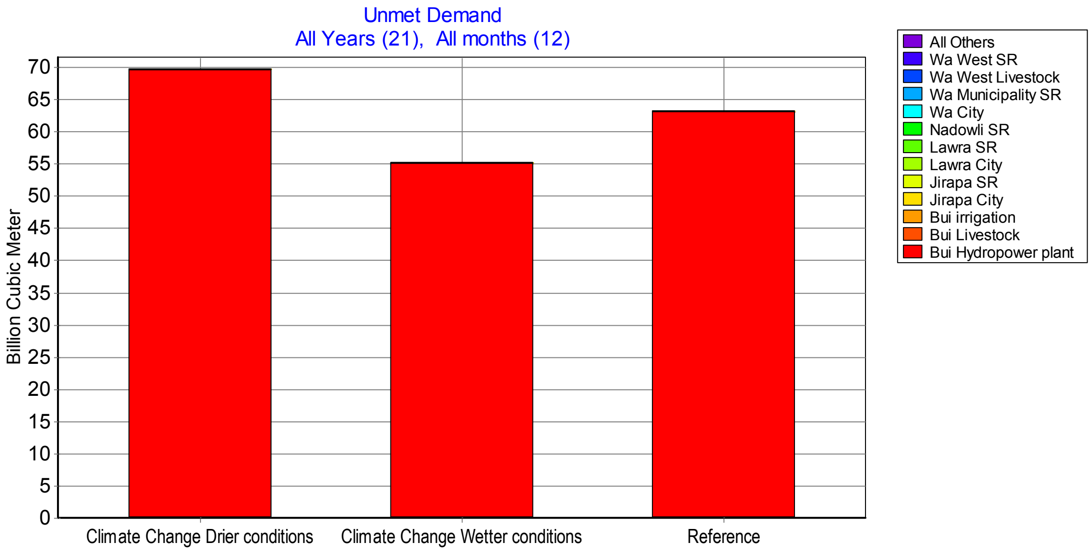

Figure 44: Unmet water demands for all scenarios and all years

It is shown in Figure 44, that water in the Ghana portion of the basin can meet all demands with the exception of the bui hydropower which is largely dependent on flows outside Ghana. The hydropower plant is also a critical resource for the country. This means that fostering good relations with riparian countries is a necessity.

6.1.4 *Fishing*

Fishing is considered to be a non-consumptive use although it is highly dependent on water levels in streams, rivers and reservoirs/dugouts. It was however not considered in the model. A current studyhas been carried out in the basin but the results were not available at the time of finalising this report.

6.1.5 *Livestock*

Livestock watering in the basin is done using either dugouts or small reservoirs. Occasionally rivers, streams and boreholes are used. Livestock watering in the model is considered to be from the river. Hence if this is unmet in the model, practical they will be met by the small reservoirs and dugouts. However Livestock requirements are met. This means that there is a high potential to increase livestock herds.

6.1.6 *The environment*

Environmental flow requirements are met however this is just based on quantity and not quality as shown in Figure 44.

6.2 Possible Impacts of the Bui dam on water resources in the basin

The Bui dam which is due to be operational in 2014 is a key water infrastructure for the country. While filling the dam, adjacent lands will get flooded and lead to a loss of biodiversity. However, the presence of the dam could regulate flow downstream and also reduce flood risk.

Upstream advantage of the dam is minimal unless water could be pumped upstream for domestic water supply purposes or irrigation.

7. WATER GOVERNANCE IN THE BASIN

7.1 Current state of water Governance in the basin including trans-boundary issues

Water is a vital resource which plays a major role in the developmental agenda of all the riparian countries of the Volta basin. There has been over exploitation and pollution of water resources base in the basin due to uncoordinated management and lack of water governance. Among the competing uses of water in each riparian state are irrigation, fishery, domestic water supply and livestock watering. There also exist competition over water by upstream and downstream countries notably among them is that between Ghana and Burkina Faso. In order to eradicate suspicion and build trust among the states sharing the common resource, it is important to work towards establishment of a coordinated effort of water management and institutionalization of pragmatic governance systems.

Governance to say is the most influential factor, as far as organizing framework for decision making is concerned. In order to achieve policy harmonization to guide effective coordination, a holistic/integrated approach to water management that views the basin as a unit is pre-requisite. If water governance is improved in the basin and integrated water resources management is adapted and implemented, conflicts over water resources can be curbed, if not alleviated or resolved. Utilization of collaborative and participatory mechanisms will help the riparian countries of the basin achieve their development goals in a sustainable way. It is in line with this that the Volta Basin Authority (VBA) was established in 2006 and based in Ouagadougou, Burkina Faso. Among the mandates of the VBA are to "promote and reinforce cooperation among the six countries in the management and development of the basin resources; and to harmonize national policies on integrated water resources management". Also among its roles is to "coordinate studies and research in the basin for the development of the water resources and to reinforce a system for the collection, processing, storage and dissemination of data for scientific research and planning"[46].

Over the years, riparian countries in their bid to harmonize the management of water resources of the basin have also created institutions which are charged with the responsibility of ensuring effective management of water and land resources. In order to achieve this, local and national level integration is of paramount importance not forgetting the critical role of inter-sectoral coordination[47]. At the national level, riparian countries have enacted laws that address environmental impacts and also integrate local communities in the process of water sector reforms. Shown in Table 15 are the various actions in terms of legislative reforms that are geared towards improving water governance at the country level in the basin.

[46] AFRICA RESEARCH BULLETIN, VOLUME 43, ISSUE 7 , 2006 (PAGE 17034A)

[47] ANDAH AND GICHUKI, 2005

Table 15: Some Important Legislative Reforms in the Basin

Riparian Country	Legislative Reform
Burkina Faso	Act No. 005/97/ADP. Act No. 0014/96/ADP of 23 May 1996.
Ghana	Act 46 of 1961 established VRA Act 462 of 1993 established DAs Act 490 of 1994 established EPA Act 522 of 1996 established WRC
Mali	No. 99-023 of June 11, 1999. No. 95-447/PM-RM.
Cote d'Ivoire	Law 98-755
Benin	Decree No. 82-435; December 30, 1982 Law No. 87-016 Law No. 98-030; February 12, 1999

Worthy of note, are also environmental concerns of loss of biodiversity (Figure 45), river pollution, reduction of fisheries resources, flooding and groundwater resources depletion[48]. These are as a result of biophysical and socio-economic factors. The biophysical factors include but not limited to spatial and temporal distribution of rainfall, drought and relief. The socio-economic factors consist of population pressure, unsustainable cultivation practices, deforestation, overgrazing, bushfires, improper use of agro-chemicals, poor mining practices, rapid depletion of soil nutrients without replenishment, lack of security in land tenure, migration and poverty. These issues are trans-boundary in nature and need to be taken into consideration if effective and sustainable water management is to be achieved in the basin.

Transhumance as stated in previous chapters and defined as the movement of cattle, sheep, and people across national boundaries, is common within the basin. This phenomenon has increased as a result of dam construction and new water and land management structures[49] usually accompanied by reckless destruction of vegetation and watering sources. The situation also creates social tension and disruption of socioeconomic activities, sometimes leading to conflicts.

[48] ANDAH AND GICHUKI, 2005
[49] YOUKHANA ET AL., 2006

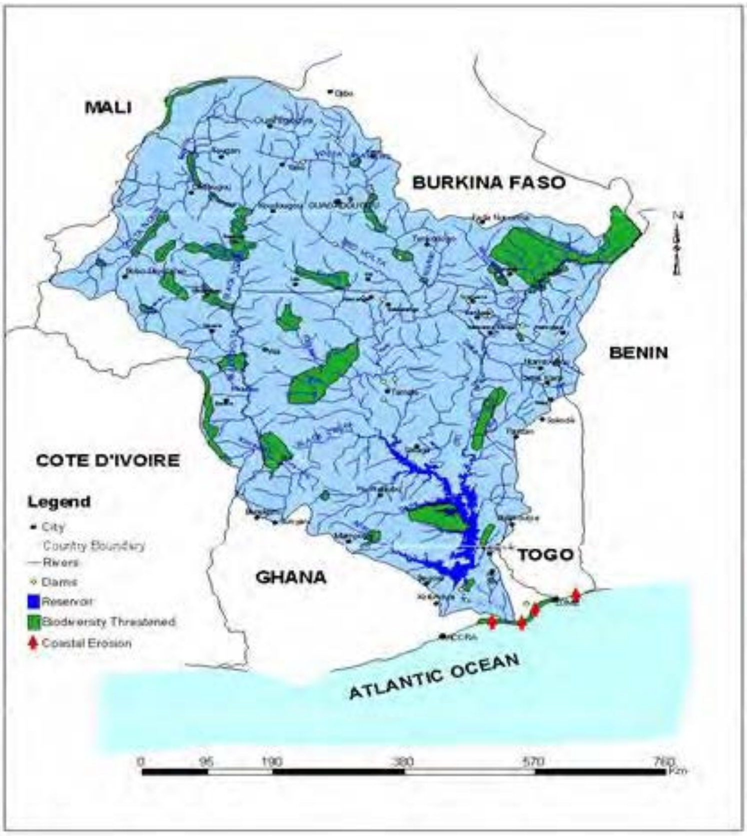

Figure 45: Biodiversity loss map of the Volta Basin[50]

7.2 Stakeholders involved in Water Resources Management

The main stakeholders involved in water resource management of the basin are the riparian countries. The riparian countries collaborate through the VBA Platform. This platform was borne out of series of consultations and agreement between all the riparian countries[51]. Since 2006, VBA has been the body spearheading the management of the Volta Basin. At the national levels, the countries have institutions that are mandated to ensure the effective management of water resources. In Ghana for instance, the Water Resources Commission which was established by Act 522 of Ghana's Parliament in 1996 is the main body mandated to regulate and manage the country's water resources and to coordinate government policies in relation to them. This body works hand-in-hand with research institutions such as CSIR-WRI, the HSD and GMet which also by Acts of parliament have been mandated to carry out focus led research in the area of water resources. Notably, similar institutions of state operate in the riparian countries including the Directorate General of Water Resources in Burkina Faso.

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[50] **ANDAH AND GICHUKI, 2005**

[51] **GHANA IWRM PLAN, 2012**

In the Black Volta basin in Ghana the activities of these organization is somewhat uncoordinated due to the absence of a platform for discussions and active engagements among these organizations.

Non-governmental organizations (NGOs), the private sector, research institutions and development partners however also play a significant role in the management of the basin resources. The GLOWA Volta project and PAGEV are some of the projects that have come about as a result of collaboration between riparian states and development partners[52]. Mentioned could also be made of the Volta River research project, Volta Basin research project and ADAPT Volta project all geared towards improving water resources in the basin[53]. At the local level, community members who are the end users of all water policies need also to be acknowledged.

7.3 Platforms on Integrated Watershed Management (IWM)

As far as IWM in the entire Volta basin is concerned, there have been a lot of efforts in rolling out platforms where issues pertaining to the management of water resources are dealt with. One of such platforms was the Volta water governance project (PAGEV) which operated from 2004-2007 (phase I) and continued until about 2011 with the second phase. This project was sponsored by IUCN in collaboration with Global Water Partnership (GWP) with the aim to improving water governance in the White Volta basin with particular focus on Ghana and Burkina Faso. The processes of the project accelerated the establishment of platforms across the border of the two countries, fostering consultations and joint planning. The PAGEV complemented the GEF supported Volta Basin Land and Water Management Programme, (GEF-Volta) involving all the six riparian countries, that aims to support coordination efforts in the eventual management framework for the Volta River Basin[54,55]. Another platform that has ensured the promotion of IWM is the GLOWA Volta project which was funded by the German Federal Ministry of Education and Research. The GLOWA-Volta initiative began the process of developing a scientifically sound Decision Support System (DSS) for the assessment, sustainable use, and development of the Volta Basin's water resources. This project is implemented in collaboration with established state institutions, such as the WRC of Ghana, within the White Volta Basin, during the period 2004 – 2006. The project was particularly seen as a way of generating and disseminating scientific information between Ghana and Burkina Faso and by so doing facilitating decision making on the management of the shared water resources[56].

However, in the Black Volta Basin there is no active platform for IWRM. GWI through CARE and CRS established a platform for Water Management but unfortunately it became a WASH platform. It was very active at the beginning but seems to have died off. It would be good to revive this platform and see how to broaden its scope within the proposed IWRM strategy to be implemented.

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52 **YOUKHANA ET.AL., 2005**
53 **ANDAH AND GICHUKI, 2005**
54 **IUCN, 2003**
55 **WRC, 2004**
56 **VAN EDIG ET AL., 2001**

7.4 Role of Institutions in fostering sustainable IWRM in the basin

By regulation, mandated water related institutions like the WRC, EPA, CWSA, GWCL, GIDA, MOFA, NADMO, NGOs and other organisations should enforce their policies regarding water resources management. State institutions together with development partners should work very closely with basin inhabitants. Integrating the views and opinions of end users during the planning and implementations phase of water resource planning will send signals of ownership and hence the sustainability of interventions[57]. The WRC is already doing very well in this regard and needs to look critically at the western corridor management of shared waters. GWI could therefore assist WRC to carry out its mandate as it has already started doing.

7.5 Integration of GWI interventions into the National IWRM strategic framework

7.5.1 *Integrating GWI Interventions into National IWRM strategic framework – Opportunities and Threats*

The WRC is the national institution mandated to regulate and manage water resources in the country and to coordinate government policies in relation to them. For all practical purposes WRC is yet to initiate on the ground, processes towards creation of a management structure to coordinate water related issues in the Black Volta basin. To manage effectively water resources in the basin and to respond to current priorities, it is important to adopt a holistic approach to water resources management and development. One approach that has gained recognition worldwide is Integrated Water Resources Management (IWRM), which has been adopted by WRC and used to develop action plans for basins where management structures have been established including the Densu and White Volta basins. This way, the GWI could assist WRC while playing her 'role' and to draw lessons from the IWRM processes in the field worth sharing with WRC.

Since the inception of GWI in the year 2008 in the Black Volta basin, interventions have been implemented in communities that do not derive roots from any national framework for the said basin. It is imperative therefore, to initiate integrated water resources management processes in strong collaboration with WRC so as to buttress basis for the interventions being delivered in the project area while ensuring feedbacks towards policy change.

While recognizing that GWI is a project with specific life span, association with WRC will seek to provide mechanisms for sustaining the interventions. Thus formalizing the relationship with the national institution is paramount in order to set pathways for influence and advocacy for practical solutions in the water and related sectors.

It is worth to note that financing of water resources development and management goes beyond the means of central government. The need to mobilize new sources of finance is pre-requisite

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[57] **Carius et al., 2004**

towards achievement of expectations of vulnerable communities. Further, integrated management of water resources will be facilitated and enhanced if appropriate partnerships are developed among stakeholders, and capacity built to enable them to function effectively.

To ensure sustainable development of these finite resources, water resources management should be considered within the context of the following two main areas:

- Conservation of water resources to sustain quality and availability, health of the people and to guarantee the integrity of the environment.
- Regulation and control of water use and waste disposal, to stay within the natural capacity of the water resource base, which must necessarily maintain its regeneration and self-purification characteristics. Advocacy could help in this regard.

The implementation of IWRM should be geared towards ensuring sustainability of water resource in the basin and this could effectively be achieved by adopting the following measures;

- Strengthening the regulatory and institutional framework for managing and protecting water resources for water security and enhancing resilience to climate change
- Enhancing public awareness and interest in water resource management issues
- Improving access to water resources knowledge base to facilitate water resources planning and decision making

A SWOT analysis based on an IWRM framework has been carried out for GWI in Wa. The Strengths(S) and Weaknesses(W) which are based on internal factors and the Opportunities(O) and Threats(T) which are also due to external factors for GWI is presented in Table 16. GWI has to build upon its strengths while minimising weaknesses and also seize its opportunties and reduce threats by careful and wholistic planning.

Table 16: A SWOT analysis of GWI in Wa

STRENGTHS	WEAKNESSES
• GWI has Young, energtic and professional employees who are willing to take up new challenges and be innovative • GWI is established in the Upper West region of Ghana and has created a strong community commitment and ownershiop of its previous projects so it will be easy for communties to identify/ associate with them • GWI has helped some communities to develop IWRM plans which could serve as a useful background document for the IWRM Platform • GWI has carried out a number of studies and interventions in the basin so it knows the major problems "in-and-out"	• Lack of coordination and linkages with other key stakeholders in the basin and even within the consortium • Beauraucratic processes which sometimes delay implementation and carrying out of planned activities • GWI has a lean project staff
OPPORTUNITIES	**THREATS**
• GWI has some financial support from the Howard G. Buffet Foundation to carry out some IWRM interventions in the basin • Innovative platforms have been setup by the CPWF Phase 2 – V2 project. This could serve as a learning alliance for both GWI and the CPWF project	• There are a number of communities which could be involved in the project but the problem is the limited amount of funds available. Criteria for selecting some communities among the lot could be a challenge • Effective cooperation/ collaboration with other key institutions/ stakeholders could be a long process which has to be pursued vigorously

8. VISION FOR THE SUSTAINABLE DEVELOPMENT OF THE BLACK VOLTA BASIN

8.1 **Increasing food security**

Agriculture practices in the Black Volta Basin vary from the transitional zone to the interior savannah. As mentioned in previous sections, agriculture is dominated by smallholder farms characterized by low input technologies and low yields and outputs. The major annual crops are classified as cereals, root crops, pulses and nuts and vegetables. The major cereals are maize, millet and sorghum. Maize is grown throughout the country with about 63% of food farmers involved in its cultivation. However, millet and sorghum are mainly grown in the savanna zone. Rice is a cash crop of importance especially in the Northern and Upper West Regions. Cassava is grown almost everywhere in the basin, however, in small scale in parts of the Upper West and Northern Regions. The cultivation of yam is concentrated mainly in the transition and Guinea Savanna zones. Groundnuts, Bambara nut and Beans are largely cultivated in the Upper West and Northern regions.

In order to ensure food security and improved livelihood of the inhabitants, measures should be introduced to ensure the judicious use of the available water resources. Surface water resources can also be developed employing strict sector policies so as not to deplete the resource base of the basin. In so doing, farmers will access water for their farming activities which will culminate into livelihood improvement.

Irrigation schemes developed around small reservoirs have not been utilized at all in the basin. Less than 2% of planned irrigable areas are under actual irrigation[58]. This situation has to change with the major setbacks resolved.

8.2 **Immediate "next" steps**

8.2.1 ***IWM Plans***

GWI partners (CARE, CRS and IUCN) have assisted some communities to draw strategic IWRM Plans. These plans have been reviewed and realised to be too ambitious. It is therefore necessary to review these plans with the communities and draw new plans and road maps that are easily implementable.

The plans drawn could be the basis for a master plan for the basin. It would be expedient to start from the 3 upstream basins namely Dapola, Noumbiel and Vonkoro. GWI is already well known in these basins and so could give a smooth start of planned activities.

Evidence based-learning is the way out. This means that GWI would have to use some communities as pilots to initiate IWRM interventions in the basin through participatory learning and not just advocacy. Advocacy is good but on its own cannot achieve the intended objectives.

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[58] DATA FROM GIDA, UPPER WEST REGION

For instance what advocacy can one do in a community that has unreliable and very low rainfall without a reservoir, dugout or a borehole to improve upon their livelihoods and alleviate their poverty? Talks alone would not materialise, the talks must be followed with actions on the ground. That is the only way the commitment of the community (grassroot stakeholders) can be gained. This could be out-scaled when they are successful.

8.2.2 *Action plan*

IWRM plans without action plan is less useful. GWI and its partners would have to set up a basin platform to review plans drawn or to be drawn and provide concrete activities (action plans) towards implementing those IWRM plans.

8.2.3 *Road Map and Roles of Key stakeholders*

For effective and decentralized IWRM, it would be important to anchor the IWRM platform to national institutions and most especially the district assemblies for the regulation and monitoring of activities. The platform should be well structured and represented with key stakeholders selected at a workshop with all stakeholders present so they themselves could choose institutions to be represented on the platform. Criteria for selection should be discussed at the workshop so as to sustain the platform including financing arrangement. How early the platform could be established depends on the firm commitment of partners including WRC. Thus liaising with WRC in the setting up of this platform is vital to ensure continuity and sustainability, leading to the eventual establishment of the Black Volta Basin management Board.
An organogram for the platform has not been produced because the consultant considers this to be a bottom-up approach instead of a top-down approach. There should be a decision making capacity for the people at the grassroot for the setting up of this platform. This is the only way people would identify with the process towards ownership and therefore give full commitment and be self-motivating.

Interaction with community members is important but the issue as to which communities to engage with is a key step which needs to be addressed. A buffer of 3km to the left bank (Ghana Side) of the main Black Volta river in Ghana (shown in Figure 46) already gives up a lot of communities requiring consultations/collaborations on transboundary issues. This is an opportunity but could also be a threat with regards to mobilisation of resources.

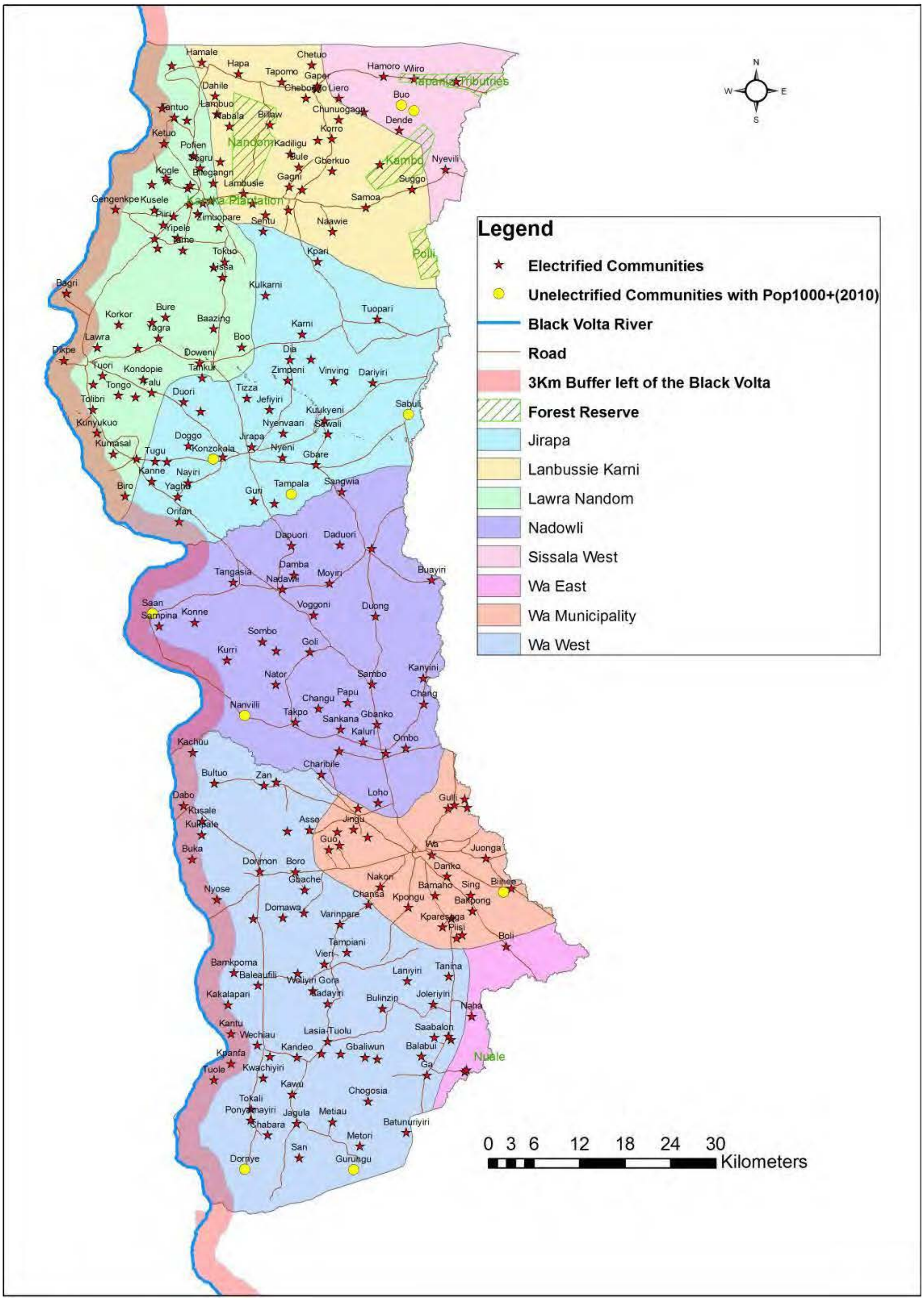

Figure 46: Communities in the Black Volta basin in Ghana with a 3km buffer from the left bank of the Black Volta River

8.2.4 *Communication Strategy and Products that can promote IWRM in the basin*

Most often IWRM awareness is created without any baseline study. It is important for GWI to conduct a baseline study to enable it measure the impact of its activities.

Communication of IWRM Plans, activities, strategies and results could be done in a number of ways. Most notable among these are the use of radio and TV programs in local dialects, Newsletters, brochures, National and Private Newspapers, Symposiums, Quizzes, use of sign boards (attractive advertisements/education) among others.

At the local communities, Video-vans can be sent occasionally to show documentaries that will educate and motivate the inhabitants to continue with their IWRM activities.

District water quality indices could be published quarterly to motivate the district assemblies to carry on with their IWRM activities. Rewards or awards could also be given to the best districts and individuals and advertised to motivate others to do likewise. T'shirts and Cups/hats could be printed with Key IWRM messages on them and given to people as souvenirs.

Giving regular talks on IWRM issues in Primary, Secondary and Tertiary education institutions could also be another avenue to educate people on IWRM issues. These schools visited could be given the souvenirs mentioned above to take home which might generate discussions of these subjects at the homes of these students.

8.2.5 *Vision of IWRM in the basin*

Interactions with key stakeholders in the basin suggested their vision for the basin to be the following: A basin with

- Harmonized buffer zone policy
- Healthy river water
- Groundwater for irrigation
- All water bodies fully utilized
- Green Environment
- Water Security
- Properly managed waste water systems
- Rivers protected from siltation

Stakeholders at the validation workshop then together came up with a vision for the UWRWAS as "***Sustainable Use of Resources for Food Security and Economic Growth by All for All by 2025***" with a mission to "ensure food security and economic growth through the development and effective utilisation of resources in the Black Volta Basin in an equitable and sustainable manner for the present and future generations".

9. CONCLUSIONS AND RECOMMENDATIONS

9.1 Conclusions

The following conclusions have been drawn from the study:

- The Black Volta Basin in Ghana is delineated into five (5) sub-catchments with three 93) Water Audit Sections to facilitate its management.

- The water resources of the Black Volta have been assessed. Almost all populations depend on groundwater for their domestic water requirements. The water available in the basin could meet the water demands of the various uses by 2030 except for Bui hydropower which would benefit largely on flows from outside Ghana.

- A number of small reservoirs and dugouts in the Upper West Region are not being used productively owing to its silted conditions thereby reducing their storage capacities. Due to the poor construction of some dugouts /reservoirs, the water stored dries up when the water is needed most. Moreover, management of the water facilities is still a challenge.

- There is high potential to increase the cropping areas within the basin in Ghana owing to the suitability of land. Sustainable farming practices are howwver required to forestall biodiversity in the basin, and therefore the protection of reserved areas.

- There is no platform for IWRM in the basin. Activities of water related technical institutions and/or high-level stakeholders are very much uncoordinated. There is a need for basin framework on IWRM and coordination to ensure coherence.

- The value chain approach with associated platforms is hardly used in the basin in Ghana with the exception of the seedlings platform being managed by MOFA and SARI under the auspices of UNDP in Wa. This could provide opportunities for all stakeholders to meet and discuss ways of solving existing problems efficiently and effectively.

- The use of TV and Radio programs with phone-in sections in local dialects and English, Newspapers, brochures, sign boards, souvenirs, public lectures, talks, symposia, and publishing of Water Quality Index (WQI) of districts quarterly, in the media with awards are some of the most promising communication strategies identified.

9.2 **Recommendations**

- Integrated watershed management with trans-boundary orientation is key in the basin and should be pursued with neighboring countries.

- Advocacy on agriculture especially irrigation is good but has to be done together with evidence based learning with some infrastructure and demonstrations to enhance the likelihood of adoption.

- Farmers should be productive, improve their yields and also be able to feed their livestock by growing a mixture of cereals and legumes including groundnut and vegetables in the dry season. The residues from these crops can be used to feed animals as supplementary feeds.

- GWI has started a platform for pastoralists and should continue to facilitate innovative ways to address issues with cattle herdsmen in the basin within Ghana taking into account international water laws and existing international relations and treaties between riparian countries.

- Platforms for IWRM must be established at the basin level through consultative process. The composition shall be determined by the stakeholders in close collaboration with the Water Resources Commission. The entire process of setting up the IWRM platform should be monitored, evaluated and documented.

- In the future, it is imperative to establish formal collaborative arrangements with state institutions such that the project would operate with the scope of the national orientation, ensuring feedbacks of lessons learned, towards influence and policy change while ensuring sustainability.

- Since the report on fisheries in the Black Volta Basin comissioned by the Bui Power Authority was not available at the time of finalising this study, it is proposed that the next study should look at fisheries in the Black Volta River in detail.

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APPENDICES

Annex 1 – TOR

The Global Water Initiative
A Partnership Funded by the Howard G. Buffett Foundation

IUCN

TERMS OF REFERENCE

STUDY OF THE HYDROLOGICAL STATE OF THE BLACK VOLTA BASIN IN GHANA

I. Introduction

The Global Water Initiative (GWI) is a worldwide program that is financed by the Howard G. Buffet Foundation. The long term goal of GWI is to generate lessons from Integrated Water Resources Management processes that inform policy change in the water sector, establishing platforms and frameworks that promote advocacy towards good governance of water resources. The program is implemented in thirteen (13) countries which are located in Central America, Eastern and Western Africa.

Initiated in 2007 and until 2012, GWI was implemented in five (5) West African States notably Burkina Faso, Ghana, Mali, Niger and Senegal. Presently, the programme is operating in the West African countries other than Senegal. In Ghana, the program is implemented by a consortium of CARE International, Catholic Relief Services (CRS) and the Regional Office for Central and West Africa of the International Union for Conservation of Nature (IUCN-PACO), based in Ouagadougou, Burkina Faso. The project Office is based in Wa in the Upper West Region of Ghana, and has engaged thirty-two (32) communities in the Nadowli and Lawra Districts.

The initiative has as its aim to support vulnerable groups and communities in arid and semi-arid regions with potable water supply and sanitation services delivery while ensuring equitable and sustainable management of water resources in an integrated manner. Nearly five years into the implementation of the initiative, the new orientation in the coming years is Water for Agriculture Initiative (WAI), following a meeting of the strategic committee of the initiative. This direction is intended to address water for sustainable agriculture development and increased food security.

Recognizing that a river basin is the unit for planning[59], it is necessary to increase our knowledge and understanding of the Black Volta basin in terms of the hydrology and water resource characteristics. Undoubtedly, the effective application of Integrated Water Resources Management (IWRM) concepts hinges on good knowledge of the basin in order to inform and

[59] GHANA NATIONAL WATER POLICY, 2007.

ensure sustainable mechanisms and processes that enhance feedbacks, building into national strategic frameworks.

With about 22% of primary stakeholders actively and effectively participating in IWRM interventions in the field[60], and with the responsibility to facilitate dialogue and advocate for practical approaches to IWRM implementation at higher level institutions of state, this study intends to chart a path of linking «local actions» to the national orientation, providing options for the sustainable management of the Black Volta Basin resources.

II. Objective of the study

II.1 General objective

The study aims to guide the future interventions of GWI in Ghana, characterise water resources (both current and future) of the Black Volta Basin, ascertain the reservoir storage, distribution and productive uses while highlighting sustainable operational mechanisms including constraints that govern water resources.

II.2 Specific objective

The study seeks to provide guidance to IUCN-PACO, and the consortium in general, to have a clear view of IWRM implementation in the Black Volta Basin while addressing specific objectives targeted at the following:

To assess the hydrological situation of the Black Volta basin, delineation and its extent and limits, the interaction with other hydrologic systems, and the trans-boundary zone with Burkina Faso;

To understand the stakes of water resources, the potential of surface water and groundwater systems, uses, and stakeholders (whose activities impact directly or indirectly), management constraints as regards exploitation and suitability;

To assess the state of dug-outs, dams, wells, and characterize the agricultural / irrigation water use (current and future) on one hand, and the cultivated areas around these water bodies: surface, types of crop, seasonal (or not) use of water, on the other hand;

To examine the ecosystem approach into river basin planning and management of the Black Volta.

III. scope of the assignment

The scope of the assignment shall include but not limited to the following;

Delimit the Black Volta basin and delineate the sub-catchments/basins while taking into account the demographic and political administrative settings;

Take inventory of, and state of water systems including reservoirs/dams, dug-outs and wells in terms of quantity of water available for exploitation, and if possible, surface water–groundwater interactions;

Assess the agricultural/irrigation land use around the water systems noted in point 2 above in each sub-catchments including the crops grown and cropping pattern;

Assess water use including irrigation agriculture and projected developments in the basin, assessing their impacts/threats on the water resource and land, and emphasizing the users whose activities impact directly or indirectly on the resources of the basin;

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[60] **DRAFT REPORT OF GWI WEST AFRICA CLUSTER MONITORING AND EVALUATION BASELINE STUDY, 2010.**

Examine the current state of water governance in the basin, prospects including trans-boundary mechanisms, and the processes that foster integration of GWI interventions into national IWRM strategic frameworks;
Make proposals that enhance better management of the water and other natural resources of the Black Volta Basin;
Formulate a clear vision for the sustainable development of the Black Volta Basin and clarify the intermediate results as they relate to the root causes of the problems identified by the study.
Establish the possible implications of the Bui dam project on the basin and its inhabitants.
Make proposals for communicating strategy/products of IWRM that highlight water education among primary stakeholders while informing secondary actors across scales of the hydrologic characteristics of the Black Volta;
Present the results of the study at a validation workshop to be organised by IUCN in collaboration with CRS and CARE International.

IV. product
The study is expected to produce a comprehensive report that highlights the options for improved food security in an integrated fashion, analyzing the strengths, weaknesses, opportunities and threats in linking GWI interventions to the overall national frameworks for Integrated Water Resources Management.

V. duration of work
The study is planned to commence in April, 2012 after a contract agreement is signed with the successful consultant. The consultant shall, based on the scope of work, make realistic implementation schedule and outline activities/tasks in a proposal including field work (stakeholder consultations) and writing of the study report. The details of the implementation schedule proposed by the consultant will be discussed and agreed upon by the parties involved.

VI. human and material resources
The assignment shall be carried out by a **consultant** recruited by IUCN in collaboration with CRS and CARE International. IUCN and partners in implementing GWI in Ghana shall provide technical backstopping to the consultant, making available staff in order to facilitate his/her field engagements and consultation processes.
In addition, a vehicle shall be made available to the consultant to facilitate collection of data in the field.

VII. profile and selection of the consultant
The consultant will need to have the expertise of hydrology and water resources, and familiar with national frameworks on Integrated Water Resources Management. He/she must demonstrate experience in similar studies.

The consultant shall submit a proposal of his offer to IUCN-PACO detailing the work to be carried out no later than 12th April, 2012. Upon evaluation of the bids, the successful candidate shall be consulted to agree on the terms of contract before he/she is engaged to conduct the assignment.

VIII. reporting

The consultant will be requested to present first findings at a workshop planned for the end of the first week of May 2012 in Accra. The consultant shall, after 10 days of the last day of field work, submit a draft report of the study to IUCN-PACO. Then IUCN-PACO will have to react within five (5) working days beginning on the day of reception and acknowledgment of receipt. Following submission of the comments/observation from IUCN and her partners, the consultant shall submit a final report within five (5) working days integrating the comments of the client.
The final report shall be presented as follows:
three printed copies, with all appendices included;
CD Rom containing an electronic version and the appendices.

List of stakeholders/partners of GWI
Traditional Authorities
Lawra Naa
Nandom Naa
Nanvilli Naa
Charikpomg Naa

Some Transboundary Communities
Bagre Zongo
Zupiiri
Methow-Yipaal

Some state institutions
Water Resources Commission (WRC)
Water Research Institute(WRI)
International Water Management Institute(IWMI)
Community Water and Sanitation Agency, Wa
Lawra district Assembly – District Planner and Coordinating Director
Nadowli district Assembly – District Planner and Coordinating Director
MoFA in Wa, Nadowli & Lawra
Environmental Protection Agency (EPA)
Forestry Services Division (FSD)
Ghana Irrigation Development Authority (GIDA)
Hydrological Services Department

Annex 2 – Population distribution by District/Province/Region in the Black Volta Basin[61]

Country	Admin Level	Admin Name	Capital	Pop in 2000	Area in Black Volta	Total Area in Country	% of Area in Black Volta	Pop Density 2000	Est. Pop in Black Volta in 2000
Burkina Faso	Province	Bougouriba	Diebougou	281910	6974	6974	100.0	40	281910
Burkina Faso	Province	Boulkiemde	Koudougou	466104	2861	4602	62.2	101	289771
Burkina Faso	Province	Comoe	Banfora	319012	2893	18030	16.0	18	51187
Burkina Faso	Province	Houet	Bobo-Dioula	742403	15398	16355	94.1	45	698961
Burkina Faso	Province	Kenedougou	Orodara	178636	2602	8307	31.3	22	55954
Burkina Faso	Province	Kossi	Nouna	424929	12777	13320	95.9	32	407607
Burkina Faso	Province	Mouhoun	DÚdougou	368488	10751	10751	100.0	34	368488
Burkina Faso	Province	Oubritenga	Ziniare	388308	84	4494	1.9	86	7258
Burkina Faso	Province	Passore	Yako	285656	2050	4005	51.2	71	146216
Burkina Faso	Province	Poni	Gaoua	300524	8788	9841	89.3	31	268368
Burkina	Province	Sanguie	Reo	277293	4972	4972	100.0	56	277293

[61] BASED ON UNEP POPULATION COUNT IN 2000

Faso									
Burkina Faso	Province	Sissili	Leo	312570	5259	13518	38.9	23	121601
Burkina Faso	Province	Sourou	Tougan	342164	9423	9701	97.1	35	332359
Burkina Faso	Province	Yatenga	Ouahigouya	684790	3410	12396	27.5	55	188378
Cote d'Ivoire	Department	Bondoukou		219263	4086	10538	38.8	21	85017
Cote d'Ivoire	Department	Bouna		167862	9018	21198	42.5	8	71412
Ghana	District	Berekum	Berekum	78310	451	955	47.2	82	36982
Ghana	District	Bole	Bole	85904	5006	9664	51.8	9	44499
Ghana	District	Jaman	Drobo	87042	882	1378	64.0	63	55712
Ghana	District	Jirapa Lambussie	Jirapa	82852	1865	2090	89.2	40	73933
Ghana	District	Kintampo	Kintampo	75749	41	6623	0.6	11	469
Ghana	District	Lawra	Lawra	72864	546	546	100.0	133	72864
Ghana	District	Nadowli	Nadawli	88335	1317	2605	50.6	34	44659
Ghana	District	Sissala	Tumu	59802	259	7458	3.5	8	2077
Ghana	District	Sunyani	Sunyani	98500	693	1268	54.7	78	53833
Ghana	District	Techiman	Techiman	104720	430	1135	37.9	92	39674
Ghana	District	Wa	Wa	135308	2034	5886	34.6	23	46758
Ghana	District	Wenchi	Wenchi	105115	4886	4991	97.9	21	102904
Mali	Region	Mopti		1629923	9775	90787	10.8	18	175494
Mali	Region	Segou		1682801	506	56523	0.9	30	15065
Mali	Region	Sikasso		1682800	365	77341	0.5	22	7942

Annex 3 – Detailed Soil Description by CSIR – SRI

Name	Unit	GEOLOGY	GROUP	General Description	Environment	Profile Description
Kagu	COMPOUND	SANDSTONE	Fluvisols	Fluvisols accommodate genetically young, azonal soils in alluvial deposits. The name Fluvisols may be misleading in the sense that these soils are not confined only to river sediments (Latin fluvius, river); they also occur in lacustrine and marine dep	Alluvial plains, river fans, valleys and tidal marshes on all continents and in all climate zones; many Fluvisols under natural conditions are flooded periodically	Profiles with evidence of stratification; weak horizon differentiation but a distinct topsoil horizon may be present. Redoximorphic features are common, in particular in the lower part of the profile
Kagu	COMPOUND	SANDSTONE	Leptosols	Leptosols are very shallow soils over continuous rock and soils that are extremely gravelly and/or stony. Leptosols are azonal soils and particularly common in mountainous regions. Leptosols include the: Lithosols of the Soil Map of the World	Mostly land at high or medium altitude and with strongly dissected topography. Leptosols are found in all climate zones (many of them in hot or cold dry regions), in particular in strongly eroding areas.	Leptosols have continuous rock at or very close to the surface or are extremely gravelly. Leptosols in calcareous weathering material may have a mollic horizon

Kagu	COMPOUND	SANDSTONE	Lixisols	Lixisols comprise soils that have a higher clay content in the subsoil than in the topsoil as a result of pedogenetic processes (especially clay migration) leading to an argic subsoil horizon. Lixisols have a high base saturation and low-activity clays	Regions with a tropical, subtropical or warm temperate climate with a pronounced dry season, notably on old erosion or deposition surfaces. Many Lixisols are surmised to be polygenetic soils with characteristics formed under a more humid climate	Nil
Kagu	COMPOUND	SANDSTONE	Vertisols	Vertisols are churning, heavy clay soils with a high proportion of swelling clays. These soils form deep wide cracks from the surface downward when they dry out, which happens in most years.	Depressions and level to undulating areas, mainly in tropical, subtropical, semi-arid to subhumid and humid climates with an alternation of distinct wet and dry seasons. The climax vegetation is savannah, natural grassland and/or woodland.	Alternate swelling and shrinking of expanding clays results in deep cracks in the dry season, and formation of slickensides and wedge-shaped structural elements in the subsurface soil. Gilgai microrelief is peculiar to Vertisols although not common

Kolingu	COMPOUND	GRANITE	Fluvisols	Fluvisols accommodate genetically young, azonal soils in alluvial deposits. The name Fluvisols may be misleading in the sense that these soils are not confined only to river sediments (Latin fluvius, river); they also occur in lacustrine and marine dep	Alluvial plains, river fans, valleys and tidal marshes on all continents and in all climate zones; many Fluvisols under natural conditions are flooded periodically.	Profiles with evidence of stratification; weak horizon differentiation but a distinct topsoil horizon may be present. Redoximorphic features are common, in particular in the lower part of the profile.
Kolingu	COMPOUND	GRANITE	Lixisols	Lixisols comprise soils that have a higher clay content in the subsoil than in the topsoil as a result of pedogenetic processes (especially clay migration) leading to an argic subsoil horizon. Lixisols have a high base saturation and low-activity clays	Regions with a tropical, subtropical or warm temperate climate with a pronounced dry season, notably on old erosion or deposition surfaces. Many Lixisols are surmised to be polygenetic soils with characteristics formed under a more humid climate	Nil

Kolingu	COMPOUND	GRANITE	Vertisols	Vertisols are churning, heavy clay soils with a high proportion of swelling clays. These soils form deep wide cracks from the surface downward when they dry out, which happens in most years.	Depressions and level to undulating areas, mainly in tropical, subtropical, semi-arid to subhumid and humid climates with an alternation of distinct wet and dry seasons. The climax vegetation is savannah, natural grassland and/or woodland.	Alternate swelling and shrinking of expanding clays results in deep cracks in the dry season, and formation of slickensides and wedge-shaped structural elements in the subsurface soil. Gilgai microrelief is peculiar to Vertisols although not commonly
Kunkwa	SIMPLE	ALLUVIUM	Arenosols	Arenosols comprise sandy soils, including both soils developed in residual sands after in situ weathering of usually quartz-rich sediments or rock, and soils developed in recently deposited sands such as dunes in deserts and beach lands.	From arid to humid and perhumid, and from extremely cold to extremely hot; landforms vary from recent dunes, beach ridges and sandy plains to very old plateaus; the vegetation ranges from desert over scattered vegetation (mostly	In the dry zone, there is little or no soil development. Arenosols in the perhumid tropics tend to develop thick albic eluviation horizons (with a spodic horizon below 200 m from the soil surface) whereas most Arenosols of the humid temperate zone

					grassy) to light forest	
Kunkwa	SIMPLE	ALLUVIUM	Fluvisols	Fluvisols accommodate genetically young, azonal soils in alluvial deposits. The name Fluvisols may be misleading in the sense that these soils are not confined only to river sediments (Latin fluvius, river); they also occur in lacustrine and marine dep	Alluvial plains, river fans, valleys and tidal marshes on all continents and in all climate zones; many Fluvisols under natural conditions are flooded periodically.	Profiles with evidence of stratification; weak horizon differentiation but a distinct topsoil horizon may be present. Redoximorphic features are common, in particular in the lower part of the profile.

Kunkwa	SIMPLE	ALLUVIUM	Leptosols	Leptosols are very shallow soils over continuous rock and soils that are extremely gravelly and/or stony. Leptosols are azonal soils and particularly common in mountainous regions. Leptosols include the: Lithosols of the Soil Map of the World (FAOûUNE	Mostly land at high or medium altitude and with strongly dissected topography. Leptosols are found in all climate zones (many of them in hot or cold dry regions), in particular in strongly eroding areas.	Leptosols have continuous rock at or very close to the surface or are extremely gravelly. Leptosols in calcareous weathering material may have a mollic horizon
Kunkwa	SIMPLE	ALLUVIUM	Lixisols	Lixisols comprise soils that have a higher clay content in the subsoil than in the topsoil as a result of pedogenetic processes (especially clay migration) leading to an argic subsoil horizon. Lixisols have a high base saturation and low-activity clays	Regions with a tropical, subtropical or warm temperate climate with a pronounced dry season, notably on old erosion or deposition surfaces. Many Lixisols are surmised to be polygenetic soils with characteristics formed under a more humid climate	Nil

Kunkwa	SIMPLE	ALLUVIUM	Vertisols	Vertisols are churning, heavy clay soils with a high proportion of swelling clays. These soils form deep wide cracks from the surface downward when they dry out, which happens in most years. The name Vertisols (from Latin vertere, to turn) refers to t	Depressions and level to undulating areas, mainly in tropical, subtropical, semi-arid to subhumid and humid climates with an alternation of distinct wet and dry seasons. The climax vegetation is savannah, natural grassland and/or woodland.	Alternate swelling and shrinking of expanding clays results in deep cracks in the dry season, and formation of slickensides and wedge-shaped structural elements in the subsurface soil. Gilgai microrelief is peculiar to Vertisols although not commonly
Pani-kupela	SIMPLE	ALLUVIUM	Arenosols	Arenosols comprise sandy soils, including both soils developed in residual sands after in situ weathering of usually quartz-rich sediments or rock, and soils developed in recently deposited sands such as dunes in deserts and beach lands.	From arid to humid and perhumid, and from extremely cold to extremely hot; landforms vary from recent dunes, beach ridges and sandy plains to very old plateaus; the vegetation ranges from desert over scattered vegetation	In the dry zone, there is little or no soil development. Arenosols in the perhumid tropics tend to develop thick albic eluviation horizons (with a spodic horizon below 200 m from the soil surface) whereas most Arenosols of the humid temperate zone

					(mostly grassy) to light fores	
Pani-kupela	SIMPLE	ALLUVIUM	Fluvisols	Fluvisols accommodate genetically young, azonal soils in alluvial deposits. The name Fluvisols may be misleading in the sense that these soils are not confined only to river sediments (Latin fluvius, river); they also occur in lacustrine and marine dep	Alluvial plains, river fans, valleys and tidal marshes on all continents and in all climate zones; many Fluvisols under natural conditions are flooded periodically.	Profiles with evidence of stratification; weak horizon differentiation but a distinct topsoil horizon may be present. Redoximorphic features are common, in particular in the lower part of the profile.

Pani-kupela	SIMPLE	ALLUVIUM	Leptosols	Leptosols are very shallow soils over continuous rock and soils that are extremely gravelly and/or stony. Leptosols are azonal soils and particularly common in mountainous regions.	Mostly land at high or medium altitude and with strongly dissected topography. Leptosols are found in all climate zones (many of them in hot or cold dry regions), in particular in strongly eroding areas.	Leptosols have continuous rock at or very close to the surface or are extremely gravelly. Leptosols in calcareous weathering material may have a mollic horizon
Pani-kupela	SIMPLE	ALLUVIUM	Lixisols	Lixisols comprise soils that have a higher clay content in the subsoil than in the topsoil as a result of pedogenetic processes (especially clay migration) leading to an argic subsoil horizon. Lixisols have a high base saturation and low-activity clays	Regions with a tropical, subtropical or warm temperate climate with a pronounced dry season, notably on old erosion or deposition surfaces. Many Lixisols are surmised to be polygenetic soils with characteristics formed under a more humid climate	Nil

Pani-kupela	SIMPLE	ALLUVIUM	Vertisols	Vertisols are churning, heavy clay soils with a high proportion of swelling clays. These soils form deep wide cracks from the surface downward when they dry out, which happens in most years.	Depressions and level to undulating areas, mainly in tropical, subtropical, semi-arid to subhumid and humid climates with an alternation of distinct wet and dry seasons. The climax vegetation is savannah, natural grassland and/or woodland.	Alternate swelling and shrinking of expanding clays in deep cracks in the dry season, and formation of slickensides and wedge-shaped structural elements in the subsurface soil. Gilgai microrelief is peculiar to Vertisols although not commonly
Siare-dagare	SIMPLE	ALLUVIUM	Arenosols	Arenosols comprise sandy soils, including both soils developed in residual sands after in situ weathering of usually quartz-rich sediments or rock, and soils developed in recently deposited sands such as dunes in deserts and beach lands.	From arid to humid and perhumid, and from extremely cold to extremely hot; landforms vary from recent dunes, beach ridges and sandy plains to very old plateaus; the vegetation ranges from desert over scattered vegetation	In the dry zone, there is little or no soil development. Arenosols in the perhumid tropics tend to develop thick albic eluviation horizons (with a spodic horizon below 200 m from the soil surface) whereas most Arenosols of the humid temperate zone

					(mostly grassy) to light fores	
Siare-dagare	SIMPLE	ALLUVIUM	Fluvisols	Fluvisols accommodate genetically young, azonal soils in alluvial deposits. The name Fluvisols may be misleading in the sense that these soils are not confined only to river sediments (Latin fluvius, river); they also occur in lacustrine and marine dep	Alluvial plains, river fans, valleys and tidal marshes on all continents and in all climate zones; many Fluvisols under natural conditions are flooded periodically.	Profiles with evidence of stratification; weak horizon differentiation but a distinct topsoil horizon may be present. Redoximorphic features are common, in particular in the lower part of the profile.

Siare-dagare	SIMPLE	ALLUVIUM	Leptosols	Leptosols are very shallow soils over continuous rock and soils that are extremely gravelly and/or stony. Leptosols are azonal soils and particularly common in mountainous regions.	Mostly land at high or medium altitude and with strongly dissected topography. Leptosols are found in all climate zones (many of them in hot or cold dry regions), in particular in strongly eroding areas.	Leptosols have continuous rock at or very close to the surface or are extremely gravelly. Leptosols in calcareous weathering material may have a mollic horizon
Siare-dagare	SIMPLE	ALLUVIUM	Lixisols	Lixisols comprise soils that have a higher clay content in the subsoil than in the topsoil as a result of pedogenetic processes (especially clay migration) leading to an argic subsoil horizon. Lixisols have a high base saturation and low-activity clays	Regions with a tropical, subtropical or warm temperate climate with a pronounced dry season, notably on old erosion or deposition surfaces. Many Lixisols are surmised to be polygenetic soils with characteristics formed under a more humid climate	Nil

Siare-dagare	SIMPLE	ALLUVIUM	Vertisols	Vertisols are churning, heavy clay soils with a high proportion of swelling clays. These soils form deep wide cracks from the surface downward when they dry out, which happens in most years.	Depressions and level to undulating areas, mainly in tropical, subtropical, semi-arid to subhumid and humid climates with an alternation of distinct wet and dry seasons. The climax vegetation is savannah, natural grassland and/or woodland.	Alternate swelling and shrinking of expanding clays results in deep cracks in the dry season, and formation of slickensides and wedge-shaped structural elements in the subsurface soil. Gilgai microrelief is peculiar to Vertisols although not commonly
Sirru	SIMPLE	ALLUVIUM	Fluvisols	Fluvisols accommodate genetically young, azonal soils in alluvial deposits. The name Fluvisols may be misleading in the sense that these soils are not confined only to river sediments (Latin fluvius, river); they also occur in lacustrine and marine dep	Alluvial plains, river fans, valleys and tidal marshes on all continents and in all climate zones; many Fluvisols under natural conditions are flooded periodically.	Profiles with evidence of stratification; weak horizon differentiation but a distinct topsoil horizon may be present. Redoximorphic features are common, in particular in the lower part of the profile.

Sirru	SIMPLE	ALLUVIUM	Leptosols	Leptosols are very shallow soils over continuous rock and soils that are extremely gravelly and/or stony. Leptosols are azonal soils and particularly common in mountainous regions. Leptosols include the: Lithosols of the Soil Map of the World (FAOûUNE	Mostly land at high or medium altitude and with strongly dissected topography. Leptosols are found in all climate zones (many of them in hot or cold dry regions), in particular in strongly eroding areas.	Leptosols have continuous rock at or very close to the surface or are extremely gravelly. Leptosols in calcareous weathering material may have a mollic horizon
Sirru	SIMPLE	ALLUVIUM	Lixisols	Lixisols comprise soils that have a higher clay content in the subsoil than in the topsoil as a result of pedogenetic processes (especially clay migration) leading to an argic subsoil horizon. Lixisols have a high base saturation and low-activity clays	Regions with a tropical, subtropical or warm temperate climate with a pronounced dry season, notably on old erosion or deposition surfaces. Many Lixisols are surmised to be polygenetic soils with characteristics formed under a more humid climate	Nil

Tanina	COMPOND	GRANITE	Fluvisols	Fluvisols accommodate genetically young, azonal soils in alluvial deposits. The name Fluvisols may be misleading in the sense that these soils are not confined only to river sediments (Latin fluvius, river); they also occur in lacustrine and marine dep	Alluvial plains, river fans, valleys and tidal marshes on all continents and in all climate zones; many Fluvisols under natural conditions are flooded periodically.	Profiles with evidence of stratification; weak horizon differentiation but a distinct topsoil horizon may be present. Redoximorphic features are common, in particular in the lower part of the profile.
Tanina	COMPOND	GRANITE	Leptosols	Leptosols are very shallow soils over continuous rock and soils that are extremely gravelly and/or stony. Leptosols are azonal soils and particularly common in mountainous regions.	Mostly land at high or medium altitude and with strongly dissected topography. Leptosols are found in all climate zones (many of them in hot or cold dry regions), in particular in strongly eroding areas.	Leptosols have continuous rock at or very close to the surface or are extremely gravelly. Leptosols in calcareous weathering material may have a mollic horizon

Tanina	COMPOND	GRANITE	Lixisols	Lixisols comprise soils that have a higher clay content in the subsoil than in the topsoil as a result of pedogenetic processes (especially clay migration) leading to an argic subsoil horizon. Lixisols have a high base saturation and low-activity clays	Regions with a tropical, subtropical or warm temperate climate with a pronounced dry season, notably on old erosion or deposition surfaces. Many Lixisols are surmised to be polygenetic soils with characteristics formed under a more humid climate	Nil
Tanina	COMPOND	GRANITE	Vertisols	Vertisols are churning, heavy clay soils with a high proportion of swelling clays. These soils form deep wide cracks from the surface downward when they dry out, which happens in most years.	Depressions and level to undulating areas, mainly in tropical, subtropical, semi-arid to subhumid and humid climates with an alternation of distinct wet and dry seasons. The climax vegetation is savannah, natural grassland and/or	Alternate swelling and shrinking of expanding clays results in deep cracks in the dry season, and formation of slickensides and wedge-shaped structural elements in the subsurface soil. Gilgai microrelief is peculiar to Vertisols although not common

					woodland.	
Wenchi-hilun	SIMPLE	GRANITE	Fluvisols	Fluvisols accommodate genetically young, azonal soils in alluvial deposits. The name Fluvisols may be misleading in the sense that these soils are not confined only to river sediments (Latin fluvius, river); they also occur in lacustrine and marine dep	Alluvial plains, river fans, valleys and tidal marshes on all continents and in all climate zones; many Fluvisols under natural conditions are flooded periodically.	Profiles with evidence of stratification; weak horizon differentiation but a distinct topsoil horizon may be present. Redoximorphic features are common, in particular in the lower part of the profile.

Wenchi-hilun	SIMPLE	GRANITE	Leptosols	Leptosols are very shallow soils over continuous rock and soils that are extremely gravelly and/or stony. Leptosols are azonal soils and particularly common in mountainous regions.	Mostly land at high or medium altitude and with strongly dissected topography. Leptosols are found in all climate zones (many of them in hot or cold dry regions), in particular in strongly eroding areas.	Leptosols have continuous rock at or very close to the surface or are extremely gravelly. Leptosols in calcareous weathering material may have a mollic horizon
Wenchi-hilun	SIMPLE	GRANITE	Lixisols	Lixisols comprise soils that have a higher clay content in the subsoil than in the topsoil as a result of pedogenetic processes (especially clay migration) leading to an argic subsoil horizon. Lixisols have a high base saturation and low-activity clays	Regions with a tropical, subtropical or warm temperate climate with a pronounced dry season, notably on old erosion or deposition surfaces. Many Lixisols are surmised to be polygenetic soils with characteristics formed under a more humid climate	Nil

Wenchi-hilun	SIMPLE	GRANITE	Vertisols	Vertisols are churning, heavy clay soils with a high proportion of swelling clays. These soils form deep wide cracks from the surface downward when they dry out, which happens in most years.	Depressions and level to undulating areas, mainly in tropical, subtropical, semi-arid to subhumid and humid climates with an alternation of distinct wet and dry seasons. The climax vegetation is savannah, natural grassland and/or woodland.	Alternate swelling and shrinking of expanding clays results in deep cracks in the dry season, and formation of slickensides and wedge-shaped structural elements in the subsurface soil. Gilgai microrelief is peculiar to Vertisols although not commonly