IWMI Working Paper 166

Water Resources Assessment of the Volta River Basin

Marloes Mul, Emmanuel Obuobie, Richard Appoh, Kwabena Kankam-Yeboah, Emmanuel Bekoe-Obeng, Barnabas Amisigo, Frederick Yaw Logah, Benjamin Ghansah and Matthew McCartney

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International Water Management Institute

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Project

This work was undertaken as part of the Water Infrastructure Solutions from Ecosystem Services Underpinning Climate Resilient Policies and Programmes (WISE-UP to Climate) project. The project is generating knowledge on how to implement mixed portfolios of built water infrastructure (e.g., dams, levees, irrigation channels) and 'natural infrastructure' (e.g., wetlands, floodplains, forests) that contribute to poverty reduction; water, energy and food security; biodiversity conservation; and climate resilience at a landscape scale. 'WISE-UP to Climate' aims to demonstrate the application of optimal portfolios of built and natural infrastructure developed through dialogue with stakeholders and decision-makers at multiple levels (local to national) to identify and find consensus on trade-offs. The project also seeks to link ecosystem services to water infrastructural development in the Volta River Basin (Ghana, principally, and also Burkina Faso) as well as the Tana River Basin in Kenya.

The project is led by the International Union for Conservation of Nature (IUCN) and involves the Council for Scientific and Industrial Research - Water Research Institute (CSIR-WRI); African Collaborative Centre for Earth System Science (ACCESS), University of Nairobi; International Water Management Institute (IWMI); Overseas Development Institute (ODI); University of Manchester; and the Basque Centre for Climate Change (BC3). This project is part of the International Climate Initiative. Bundesministerium für Umwelt, Naturschutz, Bau und Reaktorsicherheit (BMUB) (Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety), Germany, support this initiative on the basis of a decision adopted by the German Bundestag.

For further details about the project, visit: www.waterandnature.org or www.iucn.org/water_wiseup

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Contents

Summary

The Volta Basin is a transboundary basin shared by six riparian countries. In 2007, the Volta Basin Authority (VBA) was established and it was mandated to provide legal and institutional arrangements among the riparian countries for managing the water resources of the Volta Basin. The transboundary diagnostic analysis commissioned by the VBA has highlighted five key challenges that the basin faces: changes in water quantity and seasonal flows; degradation of ecosystems; water quality concerns; governance; and climate change. A key mandate of the VBA is authorizing the development of infrastructure and projects that could have a substantial impact on the water resources in the basin.

The water resources in the Volta Basin contribute significantly to the economic development of the six riparian countries. This is the case particularly for Burkina Faso and Ghana where more than 60% of the area of each country is located within the Volta Basin. The water resources are being utilized for agricultural production, domestic water use, livestock watering and hydropower production. Increasing demands on the resources have created competition between sectors and countries. Widespread construction of hydraulic infrastructure of different sizes and for different purposes has been developed over the years. Climate change and variability, and upstream water resources development have impacted the hydropower generation of Akosombo and Kpong dams, located close to the Volta Estuary. This comprises about 70% of the installed hydropower capacity of the basin.

The Volta Basin is also endowed with freshwater ecosystems which provide various ecosystem services that contribute to local livelihoods, and larger-scale basin objectives, by providing food, fuel and construction materials, regulating flows (reducing peak and increasing baseflows) as well as by providing habitats for animals, such as migrant birds, which may attract recreational activities.

Both natural and built infrastructure provide benefits. Some benefits such as hydropower are only provided by built infrastructure but others, such as water treatment and flood control, can be provided by both natural and built infrastructure. In addition, natural infrastructure supports the performance of built infrastructure, through providing water of a certain quantify and quality. Degradation of natural infrastructure is a key concern in the Volta Basin and may affect the performance of downstream dams. On the other hand, natural infrastructure may be affected by the development and management of built infrastructure, as is observed downstream of the Akosombo Dam.

Future water resources development in the Volta Basin requires an integrated approach towards built infrastructure development and investments in natural infrastructure to ensure optimal basin-wide benefits.

INTRODUCTION

The WISE-UP to Climate Change project focuses on identifying optimal configurations of natural and built infrastructure on landscapes within the Tana and Volta river basins. As part of the initial project implementation there is a paramount need to identify, describe, and develop a baseline of the biophysical characteristics and ecosystem services within each basin.

This document provides an overview of natural infrastructure and water resources in the *Volta River Basin.* Understanding the variety and distribution of natural infrastructure and water resources within the basin plays a critical role in developing appropriate land management and water use strategies. The report is divided into five parts.

- Part I. Assessment Background
- Part II. Basin Context
- Part III. Physical Geography
- Part IV. Water Resources and Use
- Part V. Ecosystem Services

1. ASSESSMENT BACKGROUND

1.1 Assessment Scope

The geographical scope of this assessment is restricted to the Volta River Basin. The technical scope of this assessment focuses on several broad themes: physical geography, water resources and use, and ecosystem services. Within each theme several focused topics are considered in detail where data are available.

1.2 Methodology

1.2.1 Desk Study

To address the constraints inherent when working in large basins, an initial desk study was carried out. Findings from the desk study are intended to supplement and support future field assessments, and will be expanded as additional field data are collected throughout the project. While every effort was made to ensure the veracity of statistics presented in this assessment, recent changes in government institutions and varied historical mechanisms for managing biophysical data mean that there may be gaps or inconsistencies among agencies in record keeping.

1.2.2 Remote Sensing

Remotely sensed data were used to explore landscape features, such as seasonally inundated areas and wetlands, reservoirs, irrigation structures, and communities. When possible we relied principally on Landsat, Shuttle Radar Topography Mission (SRTM), ASTER GDEM v.2, and Google Earth to identify features and verify information acquired from secondary sources.

1.2.3 Spatial Analysis

Geographic information system (GIS) data were collected from a variety of sources and some were subset from global data sets. New data were digitized from remotely sensed imagery and Google Earth when needed. In some cases, such as in the initial macro-level assessment of ecosystem services, spatial analysis methods were employed to generate new information from these data.

2. BASIN CONTEXT

2.1 The Volta River Basin

The Volta River Basin is located in West Africa and is shared between six countries, namely, Burkina Faso, Ghana, Togo, Côte d'Ivoire, Mali and Benin (Figure 2.1). The basin covers approximately 400,000 km^2 of the subhumid and semiarid savannah zones. The north-south extent of this transboundary basin stretches from approximately latitude 5^0 30' N in Ghana to 14^0 30' N in Mali, with the widest part stretching approximately from longitude 5^0 30' W to 2^0 00' E (Gordon et al. 2013). The basin becomes narrower towards the Gulf of Guinea coast. The proportions of the basin located within the six West African riparian nations are: 43% in Burkina Faso; 42% in Ghana; 6% in Togo; 3% in Benin; 3% in Côte d'Ivoire; and 3% in Mali (Barry et al. 2005) (Table 2.1).

TABLE 2.1 Distribution of the Volta River Basin in the riparian countries.

Country	Area of basin (km^2)	% of area of basin	% of country area in basin	% of basin population
Burkina Faso	171,105	42.95	62.4	47.6
Ghana	165,830	41.63	70.1	35.5
Togo	25,545	6.41	45.0	8.55
Benin	13,590	3.41	12.1	2.56
Mali	12,430	3.12	1.0	3.35
Côte d'Ivoire	9,890	2.48	3.1	2.13
Total	398,390	100.00		

Sources: Biney (2010, 2013).

The Volta River Basin has four major subbasins, namely (UNEP-GEF Volta Project 2013; Gordon et al. 2013):

- The Black Volta (covers an area of about 142,056 km^2), originates as the Mouhoun in Burkina Faso and drains western Burkina Faso, northwest Ghana and small parts of Côte d'Ivoire and Mali.
- The White Volta including its major tributary, the Red Volta (covers an area of about 106,742 km^2), originates as the Nakambe in Burkina Faso and drains northern and central Burkina Faso and Ghana.
- The Oti River (covers an area of about 72,778 km^2), originates as the Pendjari in Benin and flows through Togo.

- The Lower Volta (covers about 71,608 km^2), consisting of a series of small rivers flowing directly into Lake Volta (the world's largest man-made body of water created by the Akosombo Dam), and the portion of the river downstream from the Kpong Dam flowing into the sea.

Most of the generated runoff flows into Lake Volta, except the network of streams downstream of the lake. The Volta River empties into the Gulf of Guinea in the Atlantic Ocean through the Volta Estuary. The mean annual flow at the estuary is 40,400 Mm^3 yr^{-1} (McCartney et al. 2012).

The average mean altitude of the Volta River Basin is approximately 257 m, ranging between 0 and 920 m, with more than half of the basin in the range of 200–300 m. The global slope index is between 25 and 50 cm km^{-2} (Moniod et al. 1977). The basin is flanked by a mountain chain on the western side: the Akuapem ranges rise from the sea northeastwards followed by the Togo Mountain, Fazao Mountain, and Atakora Ranges in Benin. The Kwahu Plateau branches northwestwards after the Akosombo Gorge. The only other significant relief on the western part of the basin is the Plateau of Banfora located in the Black Volta Basin in Burkina Faso.

Of all the natural resources of the basin, water resources constitute the main stake around which development of the diverse sectors of the economy revolves. Unfortunately, this also means that water is the resource around which there are potential conflicts between different states and stakeholders. The major uses of water in the Volta Basin are irrigation, hydropower generation, fisheries, domestic water uses, industrial and mining water uses, livestock and water transport.

2.2 Historical Background

The water resources of the Volta River Basin are under severe stress due to competing demands on the resources by the riparian countries (van de Giesen et al. 2001). Factors such as population growth and increased economic activity have led to the widespread construction of hydraulic infrastructure of various types and sizes for water mobilization throughout the basin, particularly in Burkina Faso and Ghana. These hydraulic facilities include dams for hydroelectric power generation, large-scale irrigation systems, reservoirs for domestic water supply and numerous small-scale reservoirs mainly for domestic and agricultural purposes.

The Akosombo Dam in Ghana, built between 1961 and 1965 with an installed generating capacity of 1,020 megawatts (MW), is the most significant man-made structure in the Volta Basin. The construction of the dam resulted in the formation of the Volta Lake, covering an area of approximately 8,500 square kilometers (km^2) with a storage capacity of 148,000 million cubic meters (Mm^3), which gives an average residence time of 3.7 years for the reservoir (Barry et al. 2005). The lake covers about 4% of the total area of Ghana. The Kpong Reservoir, which covers an area of roughly 38 km^2 with a storage capacity of 2.5 Mm^3, was constructed between 1977 and 1982, downstream of the Volta Lake to produce 160 MW of electricity. The Kpong Reservoir is operated in tandem with Akosombo as a run-of-river system. The Bui Dam covering an area of 440 km^2 with a storage capacity of 12,350 Mm^3 was completed in 2013 to supply 400 MW of electricity. Hydroelectric power from the Akosombo, Kpong and Bui dams provides most of Ghana's total electricity requirements though the proportion fluctuates from year to year depending on water levels in the dams. Eight other proposed hydropower projects in the Volta Basin in Ghana are to be sited at: Juale on the Oti River; Pwalugu, Daboya, and Kulpawn on the White Volta River; and Koulbi, Ntereso, Lanka and Jambito on the Black Volta River (McCartney et al. 2012). The total proposed additional live storage is 23,000 Mm^3, which is expected to generate an extra 502 MW of electricity.

Lake Kompienga in Burkina Faso was created as a result of the construction of the Kompienga Hydroelectric Power Station in 1989 on the Ouale River (a tributary of the Oti River). The lake, with a storage capacity of 2,025 Mm^3 generates 14 MW of electricity. The Bagre Dam in Burkina Faso, with a total storage volume of 1,700 Mm^3 was completed in 1994 on the Nakambe (White Volta) River to generate 16 MW of electricity. Hydropower from these two dams supplies about 12.7% of Burkina Faso's electricity needs. Planned hydropower installations in Burkina Faso are to be sited at: Samendeni, Bonvale, Bontioli, Bon, Noumbiel and Gongourou, on the Black Volta River; Bagre Aval and Bandongo on the White Volta River; and Arli on the Oti River (McCartney et al. 2012). These additional dams are expected to generate a total of 146 MW of electricity. Benin has a hydroelectric power station on the Oti River, the Batchanga Dam, with a storage capacity of 350 Mm^3 with a capacity to produce 15 MW of electricity (Barry et al. 2005).

Irrigation development in Ghana began about a century ago, but serious irrigation efforts only started in the 1960s. Between its inception and the year 1980, approximately 19,000 hectares (ha) of irrigated land were developed. By 2007, the area under irrigation had expanded to 33,800 ha (Namara et al. 2011), which has remained largely the same to date. Of the irrigated land, slightly less than 9,000 ha were developed by the Government of Ghana, with the remainder being developed by the private sector. There are 22 public irrigation systems in Ghana out of which 15 are located in the Volta River Basin (Annex 1). Ghana's irrigation potential ranges from 0.36 to 2.9 million hectares (Mha) depending on the degree of water control (Namara et al. 2011). Further irrigation schemes are on the drawing board with an estimated area of 42,800 ha, which includes the Accra Plains Irrigation Project with an estimated 11,000 ha (MOFA 2013; McCartney et al. 2012).

In Burkina Faso there are a few large-scale public irrigation schemes in operation, with currently, an estimated 24,543 ha under irrigation, and plans are underway to add 12,800 ha (McCartney et al. 2012). The other four countries do not have large irrigation schemes established in the Volta Basin, although Togo is planning to develop two schemes on the Oti River with a total irrigable area of about 2,600 ha. The full potential of many of the irrigation projects has not been realized and the schemes are often poorly managed. Besides the public irrigation schemes, many private irrigation schemes are in existence across the basin, although exact numbers are not available and most are small.

Small reservoirs and dugouts, which are common in the northern part of the basin, are extensively used for livestock watering and sometimes for irrigation of small (0.4 to 1 ha) vegetable gardens (Johnston and McCartney 2010). Burkina Faso is one of the West African countries with the highest density of small reservoirs, and a continuous demand for building further reservoirs (Leemhuis et al. 2009). In Burkina Faso, most small reservoirs were constructed between 1974 and 1987, largely in response to the Sahel droughts of the early 1970s and 1980s (Venot et al. 2012; Sally et al. 2011). During the era of colonialism, the British constructed small dams to sustain year-round production in Northern Ghana. Considerable investments were also made in the development of small reservoirs following independence in the 1960s (Venot 2011). Construction of small reservoirs in Ghana slowed down in the 1970s and 1980s in favor of medium and large public irrigation systems (Venot et al. 2011). There were more than 1,700 small reservoirs and dugouts in Burkina Faso in 2009 (Andreini et al. 2009) and more than 1,000 in Ghana (Venot et al. 2012), though many were not functioning efficiently (Venot 2011).

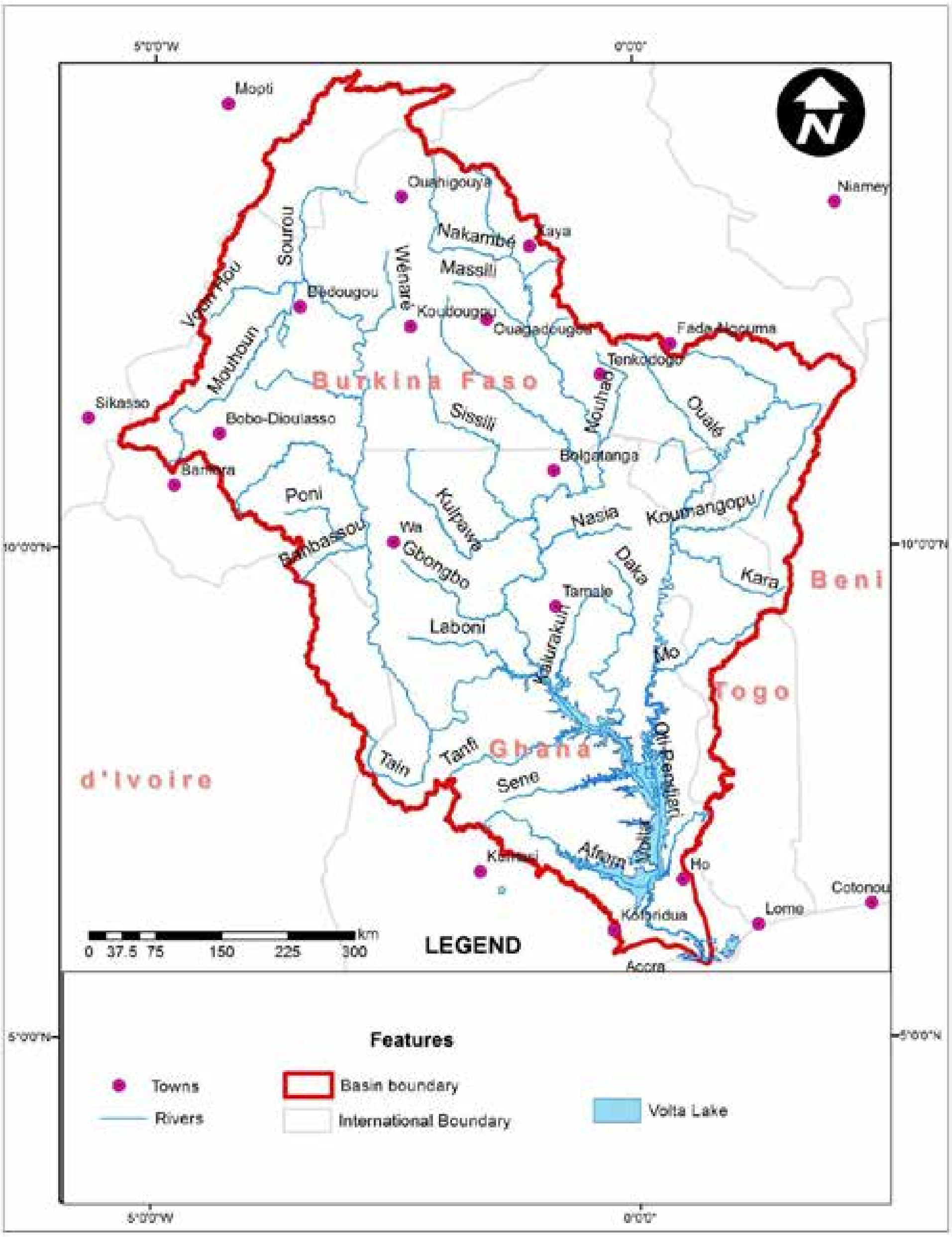
Groundwater supplies water to approximately 56% of rural communities in Ghana, though the proportion in some regions is higher (e.g., 78% in the Upper West Region) (CSIR-WRI 2009). It also plays an important role in domestic water supply in some urban areas in the basin, especially in the Upper East and Upper West regions of Ghana, where the water supply of more than 80%

of the urban population comes from groundwater sources (Martin and van de Giesen 2005). Over 80% of groundwater extractions in the basin are used for drinking and other domestic purposes (Johnston and McCartney 2010).

There were altogether 18,676 boreholes fitted with hand pumps in the Volta Basin by the year 2001 comprising 7,285 and 11,391 boreholes in Ghana and Burkina Faso, respectively (Martin and van de Giesen 2005).

The riparian countries of the Volta Basin are heavily reliant on its water resources for their socioeconomic development. To avoid or reduce improper exploitation of the Volta Basin resources, the Volta Basin Authority (VBA) was established to drive and coordinate proper water resources management throughout the basin. A description of the VBA and its functions is given in section 2.3.

FIGURE 2.1. Location of the Volta River Basin.



2.3 Administration and Policy

Many institutions in the riparian countries are charged with the responsibility of managing land and water resources in the Volta Basin, resulting sometimes in overlapping responsibilities. Coordination of activities among the institutions is generally weak and, in some cases, is only on an ad hoc basis, primarily during crisis situations. In many cases, the laws and regulations established for managing land and water resources appear to be weak and ineffective. In instances where the laws are adequate they are not adhered to, or enforced, due either to lack of institutional capacity or political commitment. The knowledge base of the state of natural resources, rate of depletion, and consequent future impacts poor, probably contributing to the weak political commitment on the part of governments. The resources of the basin are generally administered at each of the transboundary, national, subbasin and community levels.

2.3.1 Transboundary Water Governance Framework

In the past, each riparian state in the Volta River Basin managed its own resources independently. Cooperation between the riparian states may have originated in colonial times but no major joint initiatives were undertaken by the principal occupying powers (Great Britain, Germany, and France). Following the independence of Ghana and Burkina Faso, the two countries (as well as the other riparian countries) continued to pursue their own water-related agendas with little concern for impacts outside their states. Between 1957 and 1996, there were only two international agreements concerning the Volta's waters, and neither of them effectively integrated the water management and development plans of riparian countries. In 1962, an agreement was signed by Togo and Benin to purchase electricity (generated at the Akosombo Dam) from Ghana (Garané 2009). In 1973, an international agreement was signed by all the six riparian countries to control the spread of Onchocerciasis in the basin (UN 1984).

For many years, the Volta remained one of the few large transboundary river basins in Africa without formal legal and institutional arrangements among the riparian countries for managing its resources. Cooperation on the Volta's waters was largely initiated and driven by international donors, especially the World Bank, to satisfy lending conditions. Thus, the first existing agreement on water use on the Volta was between Ghana and Burkina Faso in 1996, and arose out of a 'no objection' request from Burkina Faso to Ghana for a water supply scheme: the Ziga Dam on the White Volta in Burkina Faso. The 'no objection' was required by financiers of the project and not out of the realization by Burkina Faso of a need to coordinate the use of the shared water resources (MWH 1998b).

Garané (2009) further reports that in the late 1990s, increasing pressure on the region's natural resources, in particular on water, and tension related to the increased incidence of floods and reduced water levels at the Akosombo Dam, led to a growing need for a closer and more coordinated approach to managing the basin resources. This brought the six riparian countries together and, with the support of international partners, led to a series of technical and political initiatives, which resulted in the following outcomes:

- The creation of the Volta Basin Technical Committee to prepare for the establishment of a Volta Basin Organization (March 2004).
- The signing of a Memorandum of Understanding by ministers of water resources of the riparian countries to create a Volta Basin Authority (VBA) (December 2005).

- The approval of Convention and Statutes for the VBA by the Ministers, with its headquarters in Ouagadougou, and the appointment of an Interim Executive Directorate (July 2006).
- The VBA Convention, signed by the first Assembly of the Heads of State (January 2007). As of January 2015, all the riparian states except Côte d'Ivoire have ratified the Volta Basin Authority Convention.
- The Statutes of the VBA signed by the first meeting of the Council of Ministers (November 2007).
- The coming into force of the VBA convention (August 2009).

(*Source:* http://www.abv-volta.org/about/historique [accessed on January 07, 2015]).

According to Article 6 of the Convention on the Status of the Volta River and Establishment of the VBA, the mandate of the Authority is to:

- Promote permanent consultation tools among the parties for the development of the basin.
- Promote the implementation of integrated water resources management (IWRM) and the equitable distribution of the benefits resulting from their various uses.
- Authorize the development of infrastructure and projects planned by the stakeholders, which could have substantial impact on the water resources of the basin.
- Develop joint projects and works.
- Contribute to poverty alleviation and the sustainable development of the Parties in the Volta Basin, for better socioeconomic integration in the subregion.

The statutory organs of the Authority are:

- The Assembly of Heads of State and Government.
- The Council of Ministers in Charge of Water Resources.
- The Forum of the Parties involved in the Volta Basin development.
- The Committee of Experts.
- The Executive Directorate of the Authority.

To ensure effective international cooperation, VBA has, in addition to the statutory organs, established a Technical and Financial Partners Consultative Group with the principal objective of promoting complementarity in the provision of technical and financial support to the VBA. The VBA is less than 10 years in existence and its main achievements so far are strengthening the institutional framework and performing a transboundary diagnostic analysis (UNEP-GEF Volta Project 2013). Cooperative management of the Volta Basin therefore lags behind that of many other basins in West Africa – notably the Senegal and Niger basins, which have basin authorities that were established decades ago.

2.3.2 National Water Governance Frameworks

Each riparian country has established an array of policies, laws and institutions covering sustainable water resources management. The states operate in different political-administrative

contexts, in part as a consequence of the influence of the former ruling political powers: Ghana inherited the British system of administration, while the other five riparian countries operate on the basis of French tradition. Below is a description of the water governance frameworks in Ghana and Burkina Faso.

Ghana

When Ghana gained independence (1957), various institutions were established to manage the water resources of the country.The first of these institutions was the Volta River Authority (VRA), in 1961, with a mandate to generate electrical power and maintain the Volta Reservoir. The next major water management institution created was the Ghana Water and Sewerage Corporation (GWSC), in 1965, charged with provision, distribution, and conservation of the nation's water resources for public, domestic, and industrial purposes. The institution was given priority over other water authorities, yet the VRA maintained exclusive rights over the Volta Lake and rivers (Mensah 1999; MWH 1998b). The Ghana Irrigation Development Authority (GIDA) was created in 1977 to develop irrigation schemes for farming, livestock improvement, and fish culture. There was little or no cooperation among the GIDA, VRA, and GWSC (Mensah 1999; MWH 1998a, 1998b). To solve this problem, an umbrella body, the Water Resources Commission (WRC) was formed in 1996.

Ministry of Water Resources, Works and Housing
Water resources management is currently under the jurisdiction of the Ministry of Water Resources, Works and Housing. The mandate of this ministry in the water resources sector is implemented through agencies established under it such as WRC, the Ghana Water Company Limited (GWCL), Community Water and Sanitation Agency (CWSA), and the Hydrological Services Department (HSD).

Water Resources Commission
The WRC was created through an Act of Parliament (Act 522 of 1996) to address the diffused state of functions and authority in the water resources sector. The commission is made up of 15 members including the Chairman, the Executive Secretary, a Chief and two other persons, one of whom is a woman. The rest are representatives of the following institutions: Ghana Water Company Limited; Organizations producing potable water; Hydrological Services Department; VRA; GIDA; Water Research Institute; Ghana Meteorological Agency; Environmental Protection Agency; Forestry Commission; and Minerals Commission.

The mandate of the WRC is to regulate and manage the utilization of water resources, and coordinate relevant government policies in relation to them. WRC represents Ghana on transboundary-related issues with their counterparts in the riparian countries, supported by the basin management boards that are mandated to implement its functions at the basin level. The basin management board coordinates water resources-related issues within the subbasins of Ghana. The management boards are not tied to administrative boundaries but rather to hydrological boundaries. Currently, for the Volta Basin, there is only a board for the White Volta Basin, which also covers the Black Volta and Oti. The White Volta Basin Board has representatives from the following institutions: a chairperson appointed by the WRC; one other representative of the WRC; and one person each from the following institutions: All the eight District Assemblies; Upper East Regional Coordinating Council; Ministry of Food and Agriculture; Ministry of Gender and Social Protection; Environmental Protection Agency; Community Water and Sanitation Agency;

Savannah Agricultural Research Institute; Regional House of Chiefs; and nongovernmental organizations (NGOs).

Ghana Water Company Limited (GWCL)

GWCL was established in 1999, following the conversion of Ghana Water and Sewerage Corporation (GWSC - established in 1965) into a state-owned limited liability company. GWCL is in charge of potable water supply for towns with populations above 20,000.

Community Water and Sanitation Agency (CWSA)

CWSA is the core government agency at the regional level concerned with the provision of potable water and related sanitation services to rural communities and small towns. The CWSA was carved out of the then GWSC, now GWCL, under the National Community Water and Sanitation Program (NCWSP) which was launched in 1994. At the district and community levels, the CWSA is assisted by the District Water and Sanitation Team (DWST), and the Water and Sanitation (WATSAN) Committee, to implement its mandate at the local level.

Hydrological Services Department

The Hydrological Services Department is an agency with responsibility for programming and the coordinating coastal protection works, the construction and maintenance of storm drains countrywide, and the monitoring and evaluation of surface water bodies in respect of floods.

Other Government and Para-Government Agencies

Apart from the Ministry of Water Resources, Works and Housing, other government and para-government agencies with major stakes in water resources development and management in Ghana include: the GIDA; Ministry of Fisheries and Aquaculture Development (MOFAD)/ Fisheries Commission; Ministry of Local Government and Rural Development; Ministry of Health/ Ghana Health Service; Environmental Protection Agency (EPA); VRA; Forestry Commission; Minerals Commission; Traditional Authorities; The District Water and Sanitation Teams; Research Institutions; Donor Organizations; NGOs; and International Research Organizations.

Volta River Authority (VRA)

The VRA, through the construction of a dam and creation of a lake/reservoir, is responsible for the generation, transmission and supply/distribution of electrical energy for industrial, commercial and domestic use in Ghana and neighboring countries. Act 46 also enjoined the VRA to manage the water resources of the Volta Lake to promote tourism; lake transport; irrigation; inland water fishery; and aquaculture (cage/pen fishery).

As part of the effort to encourage private-sector participation in the energy sector, the Volta River Development (Amendment) Act 2005 (Act 692) legislation revised the VRA mandate. The transmission component of the original mandate was entrusted to a new National Grid Company (GRID Co.). VRA is now a purely power-generation company.

Ghana Irrigation Development Authority (GIDA)

Irrigation started in Ghana in the early 1960s under the Land Planning and Soil Conservation Unit of the Ministry of Agriculture. The Irrigation Development Authority (IDA) was set up in 1977 under the SMC Decree 85. The Authority is wholly owned and financed by the Government of Ghana. It is primarily responsible for identifying possible irrigation projects, and is, in some instances, involved in the management and maintenance of irrigation schemes.

Water User Associations (WUAs)
The WUAs are responsible for small reservoirs developed for the communities and their members are made up of the irrigators, fishermen and livestock owners. In most instances, the irrigators double as fishermen and/or livestock owners. The executive is elected by the members and is responsible for ensuring the following:

- Protection of the reservoir, irrigable area and catchment areas upstream of the reservoir to prevent siltation.
- Irrigation water delivery and control of valves.
- Maintenance of the dam, valves, canals and drains.
- Collection of water levies for maintenance of the system.
- Conflict resolution.

GIDA often provides supervision and takes care of the maintenance of headworks, pumps, primary canals and other major structures.

Burkina Faso

The first water-related institution to be formed in Burkina Faso (Upper Volta) was the Colonial Society of Energy, created in 1954 to handle the development and allocation of energy and electricity. Its name has now been transformed to the National Water Society and the National Water Office. Next to be created in 1965 was the Center for Hydraulic and Rural Supply (DHER), to extend water supplies for domestic use (MEE 2001). The National Office of Dams and Irrigation (ONBI) was then created in 1976, with the aim of harnessing the irrigation potential of the country. Several water research institutions were formed as well, but just like Ghana, Burkina Faso's water management displayed a lack of coordination. Following the droughts of the 1970s, Burkina Faso's water policies have been oriented toward ensuring basic supply for all and minimizing vulnerability during periods of low precipitation (MEE 2001). Current institutional arrangements for water resources management are described below.

Ministry of Agriculture, Hydraulics and Fishing Resources
Water resources management is under the jurisdiction of the Ministry of Agriculture, Hydraulics and Fishing Resources, established in 2002 to replace the former Water and Environment Ministry. The mandate of this ministry relating to water resources management is implemented through the following directorates and organizations.

- *General Directorate for Inventory of Hydraulic Resources (DGIRH)* is responsible for collecting, processing and assessing hydrometric data, as well as all data concerning water-related activities and interventions in Burkina Faso. Its general mission is to ensure the development, coordination and application of policies for drinking water supply, water provision for agricultural use and the protection of the national water resources.
- *General Directorate of Water Resources Management (DGRE).* It's mission is to manage water resources in a better way and put in place an adequate information system.

- *General Directorate for Fishery Resources (DGRH)* is in charge of the sustainable exploitation of the country's fish resources and ensures the effective management of the fishing industry. It is also entrusted with preserving and protecting aquatic ecosystems.
- *General Directorate of Rural Engineering (DGGR)* is responsible for the conceptualization of national water policies and coordinates implementation and application in the domains of agricultural and pastoral hydrology, and the exploitation and protection of water resources for agricultural, pastoral and fisheries production.
- *Regional Directorate of Agriculture, Hydrology and Fishery (DRAHRH)* is in charge of the coordination of Provincial Directorate of Agriculture, Hydrology and Fishery (DPAHRH) which implements development activities at the provincial level.

Basin Management Committee (CGB)
The basin management committee is a consultation and decision-making organ. The composition, structure and the functions are specified in statutory guidelines. The Basin Management Committee has the following tasks:

- Identification and evaluation of water resources within the basin.
- Provision of operators for the coordinated management of water resources.
- Identification, prevention and resolution of possible disputes which might arise apropos sharing water resources with Ghana.
- Identification of issues pertaining to the basin's water resources, and disseminating them to competent authorities.

The basin management committee is composed of members of the following organizations with equal representation:

1. Users' representatives
2. Local community representatives
3. State representatives

Basin Agency
The Basin Agency is a public establishment endowed with legal authority and financial autonomy for water management at the basin level. Its composition, domain of competence, structure and functioning are specified by a statute. The Basin Agency has the general mission of technical and economic intervention, of water resources monitoring and supervision of dependant areas and addressing water users and their impact. The Basin Agency is the executive body, implementing the decisions made by the Basin Management Committees, which have a more administrative task. The specific tasks of a Basin Agency are to:

- Implement Water Development and Management Plan (SAGE) and Water Development and Management Master Plan (SDAGE) projects and supervise them.
- Coordinate the implementation of SDAGE and SAGE.
- Provide economic interventions through water users' financial contributions and support granted to public and private owners.

- Provide technical advice (advice, expertise, communication, technical training for owners).
- Disseminate information to basin water users on water use and the natural environment.
- Support activities for all the commissions of the basin management committee.
- Resolve conflicts and grant resources.
- Participate in the management of shared water.

Local Water Committees (CLEs)
Depending on the acuteness of the problems related to the development and management of subbasins, aquifers, rivers, urban agglomeration and waterworks, local CLEs are formed to conform to SDAGE. The composition, structure and function of CLEs are specified by statute.

National Water Council (CNE)
The CNE is an established unit at the national level for consultative water management, involving the State, local communities, the private sector and civil society in its various components. The main objective in the formation of the CNE was to establish consultation between actors in the water sector. Such a permanent, structured, productive consultation, involving all actors, differs from the usual approach which involves the State simply informing the other actors in the water sector of developments. It is consulted on national issues on water, notably the action plan for IWRM (SDAGE, SAGE), the intervention programs of basin agencies, essential legislative and statutory laws in the domain of water or having an important effect on water, as well as on any other matter in the water domain that will be submitted by the government or that CNE will address. This council supervises via its permanent secretariat (Steering Committee of PAGIRE) with a permanent secretariat under the administration of the Cabinet Minister responsible for water.

Technical Water Committee (CTE)
The technical committee for water is responsible for proposing fundamental water resources development options. It consists of an administrative body that coordinates the sectorial policies of different ministries. The administrative body is composed of ministerial general secretaries (or their representatives) involved in water, health, agriculture, animal breeding, fishing, forestry, environment, urban development and housing. This framework allows the State to have a harmonized perspective on questions related to water within the National Water Council.

The National Water and Sanitation Office (ONEA)
ONEA is a government company with the mission to create and manage infrastructure for drinking water in urban and peri-urban areas. ONEA is under the administrative supervision of the Directorate of Drinking Water Supply and Sanitation (DAEPA). It is partly privatized and supported by Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH and KfW.

National Wells and Boreholes Office (ONPF)
The mandate of ONPF is to supply drinking water to rural areas throughout the country.

Other Government and Para-Government Agencies
Other government and para-government institutions in the water resources management sector include: Rural Water and Equipment Fund (FEER); Sourou Valley Development Authority (AMVS); Bagre Mastery (MOB); Burkina Faso Electricity Society (SONABEL); Traditional

Authorities; and Research Institutions; Donor Organizations; NGOs; and International Research Projects.

2.4 Modern Challenges

Following the establishment of the VBA, the United Nations Environment Programme - Global Environment Programme (UNEP-GEF) under the Strategic Action Programme (SAP) instituted a six-year project to address transboundary concerns in the Volta Basin and its downstream coastal areas. This project ended in December 2013. The Volta Basin Transboundary Diagnostic Analysis (TDA) identified three clusters of transboundary problems and two priority cross-cutting concerns. The transboundary problems are: changes in water quantity and seasonal flows; degradation of ecosystems; and water quality concerns. Governance and Climate Change are the major priority cross-cutting concerns. A brief review of these transboundary problems is presented in the sections below and detailed analyses relating to causes, environmental impacts and socioeconomic consequences are described in UNEP-GEF Volta Project (2013).

2.4.1 Changes in Water Quantity and Seasonal Flows

Changes in the availability of water across the basin have socioeconomic and cultural impacts. Most of the rivers in the basin have great seasonal and/or temporal variations under natural conditions. Many are naturally dry for lengthy periods, and flooding occurs naturally. However, changes in the overall aggregate volume available, and changes in the temporal and seasonal distribution of water availability have been observed over the past. Changes due to increased population pressure and use of water for agricultural, industrial, and electricity-generating purposes have also been observed (Gordon et al. 2013). Increasingly, over recent decades, water shortages have become more intense and less predictable. It is expected that climate change will aggravate the situation, affecting the amount of rainfall, increasing temperatures and disproportionally affecting the water resources (Roudier et al. 2014).

2.4.2 Degradation of Ecosystems

Coastal erosion downstream of the Volta River Basin

The coastal ecosystem near the mouth of the Volta River is a function of its water supply, the incoming water quality, and the supply of sand and other beach nutrients. As these inputs have changed in response to changes in the natural environment and human activities, in particular the construction of the Akosombo Dam, the ecosystem has also changed. As a consequence of this, Ghana and Togo have been experiencing severe coastal erosion problems at various points along their coastline. The most severe and internationally known areas are located in the Volta Estuary Basin, mainly at Ada (where the Volta River flows to the Atlantic Ocean) and Keta (including its extension to Lome in Togo). The ocean claims 1.5 to 2 m of the 560 km Ghana coastline annually, with Ada Foah and the Eastern parts of Keta, recording 4 m (Appeaning-Addo 2009). In 2009, waves covered about one kilometer of a tarred road along the Keta coastal area, affecting several villages which are all about 100 m away from the seashore.

Invasive aquatic species

The growth of aquatic weeds is an increasing problem in the Volta River Basin. This has been of particular concern in some of the tributaries, especially to the Volta Lake, Oti, Pendjari and Lower Volta. These invasive plant species colonize and alter, and even take over the natural aquatic ecosystems and undermine ecosystem functions. The Mou River, a tributary of the Black Volta in Burkina Faso has been infested with *Eichhornia crassipes* (water hyacinth) (Petr 2000). Areas of the Volta Basin within Ghana (especially Kpong), Benin and Togo are also witnessing a proliferation of invasive aquatic plants such as *Pistia stratiotes* (water lettuce), *Salvinia molesta* (giant salvinia or Kariba weed) and, most significantly water hyacinth. In some places the water lettuce is knitted together with *Scirpus cubensis* (Cuban bulrush). In the Volta River and lake system, *Vossia cuspidate* (hippo grass) growing along the edges of the water has increased alarmingly over the years. In some areas it has formed large floating islets that interfere with water transport and fishing (Petr 2000). Other invasive aquatic plants such as *Neptunia oleracea* (water mimosa), *Cyperus papyrus* (papyrus sedge), *Limnocharis flava* (yellow velvet leaf) and *Azolla africana* (water fern) have been reported. *Pistia stratiotes* is also common in ponds and lagoons in the basin and in the mangroves. *Typha australis* (bulrush or cattail), is found in almost every area of the basin and usually colonizes marshy ponds (UNEP-GEF Volta Project 2013).

Loss of soil and vegetative cover

Land degradation in the Volta Basin encompasses soil degradation, intense erosion and desertification. The basin's population is heavily dependent upon the land resources of the region for subsistence agriculture and livestock production. This leads to both environmental and economic challenges. However, statistics on the loss of soil and vegetative cover in the Volta Basin are scarce.

Forest resources in the Volta Basin have experienced extensive degradation in recent decades and this has led to serious loss of vegetative cover. In Togo, across the country, forest cover disappears at an annual rate of 15,000 ha yr^{-1} (UNDP 2006). The extent of natural vegetation declined from 43 to 13% of the total basin area in Burkina Faso between 1965 and 1995, whilst the cultivated areas increased from 53 to 76% and the area of bare soil nearly tripled from 4 to 11% (Droogers et al. 2006). Across the country in Côte d'Ivoire, forest cover was estimated to be 14.5 Mha in 1900, reduced to 9 Mha in 1965 and to 2.5 Mha in 1992 (Oszwald 2005). The 2010 Global Forests Resources Assessment revealed that in Ghana there was a 2% (135,000 ha) loss of forest annually from 1990 to 2000 (FAO 2010). The Forestry Commission of Ghana estimates the rate of deforestation in Ghana at 65,000 ha yr^{-1} (Opoku et al. 2005).

Increased sedimentation in the river courses

Sediment yield in the Volta River catchment includes soil erosion from agricultural fields, hill slopes and settlements. Factors that influence fluvial sediment loads include the various land uses and cultural practices that take place in these areas. The Volta Basin River courses are affected by sedimentation and specifically the life span and storage capacity of small reservoirs and dams are affected by sediment depositions. Unfortunately, data on sediment yield in the riparian countries are limited owing to lack of logistic support for systematic sediment sampling activities. In Ghana, the mean annual specific suspended sediment yield for the Oti, White Volta and Black Volta subbasin for the Volta River Basin system are 63.26, 32.56 and 28.05 t $km^{-2}yr^{-1}$, respectively (Akrasi 2011).

2.4.3 Water Quality Concerns

There are no widespread, severe water-quality problems. However, some localized problems exist especially near large industrial sites, urban areas, and mining areas. The major problem affecting surface water is deterioration in water quality as a result of the presence of phosphates and nitrates from agriculture (UNEP-GEF Volta Project 2013). This deterioration is generally more prevalent in the north of the basin than in the south because of the effects of dilution in the south due to the ever-increasing water supply from upstream downwards. Groundwater in the Volta Basin is generally of good quality.

2.4.4 Governance

The UNEP-GEF Volta Project undertook an analysis of the governance – policy, legislative and institutional constraints to effective water resources management of the basin, at both the national and the basin level. The six riparian countries share many constraints relating to the frameworks for knowledge management; information and communication; individual and institutional capacities; human and financial resources; and governance mechanisms, at the national level. At the basin level, the most important constraints relate to the absence of effective institutional and legislative mechanisms to ensure good basin-wide governance. Table 2.2 and Table 2.3 summarize the challenges faced by managers of the basin's resources at both the national and basin levels.

TABLE 2.2. Summary of policy and legislative constraints.

Level	Type of constraint	Description
National	Knowledge management, Information, Communication	• Insufficient knowledge, data, reliable information and tools for decision support. • Ineffective communication (dissemination, extension, etc.) of legal texts and monitoring their implementation. • Inadequate procedures and sustainable generation of information and scientific data on climate change and extreme weather events. • Insufficient legislation on multilateral environmental agreements. • Insufficient awareness by many on the issue of climate change.
	Individual and institutional capacities	• Inadequacy of texts and obsolescence of certain texts in force. • Noncompliance with current legislation and culture of impunity and weak enforcement of existing legislation. • Excessive delays and cumbersome process for adopting laws and implementing regulations. • Weaknesses of the processes for initiating and drafting texts (inadequate participation and integration of customary law in modern law). • Inadequate procedures for formal strategic environmental assessment. • Absence of a binding legal framework for the implementation of compensatory measures and compensation. • Insufficient capacity of those responsible for negotiating agreements and nonmastery of the tools to access the carbon market and financing under the clean development mechanism (CDM). • Weak consideration of international provisions into national laws and weak enforcement of international conventions.

(Continued)

TABLE 2.2. Summary of policy and legislative constraints. (Continued)

Level	Type of constraint	Description
	Human and financial resources	• Inadequate human resources (quantity and quality) to ensure the development, and then implementation of environmental policies. • Predominance of individual goals and interests to the detriment of public goals and majority interests. • Insufficient financial resources for the implementation of adaptation actions. • Low financial resources and inefficient funding mechanisms. • Weaknesses of economic incentives, financial and budgetary measures.
	Governance	• Absence of a development vision that sufficiently takes into account two imperatives: the imperative of socioeconomic development and the need for sustainable use of natural resources (the poor are not immune from excessive dependence on natural resources). • Large gap between the political will for an integrated and participatory management of natural resources and on-the-ground reality. • Dualism and ambivalence between traditional land tenure law enforcement and modern land law. • Legal vacuum on the measures for social protection in the case of damage caused by natural disasters. • Inadequacy of management and resolution of conflicts between users of natural resources. • Low recognition of the gender aspect. • Transparency and accountability/responsibility. • Insufficient security and respect for individual property rights.
Volta Basin	Governance	• Absence of a coordinating framework for the overall management of natural resources and ecosystems. • Inadequate development of environmental policies and strategies. • Insufficient harmonization of policies and legal frameworks for natural resources management – and of synergy in the implementation of multilateral environmental agreements. • Inadequate coordination of the implementation of strategies, action plans and regional programs. • Inadequate standards for controlling water quality. • None of the countries of the Volta Basin are members of the Convention relating to the assessment of environmental impacts across borders. • Absence of specific national legislation to manage the national portions of the Volta Basin.

Source: UNEP-GEF Volta Project 2013.

TABLE 2.3. Summary of institutional constraints.

Level	Type of constraint	Description
National	Knowledge management, Information, Communication Individual and institutional capacities	• Increasing pressure on medicinal and economic plants due to population growth. • Insufficient exploitation of existing scientific knowledge. • Low technical and financial capacities of municipalities to assume their duties and powers • Instability of the institutional anchoring, structural instability and organizational weaknesses. • Absence of several mechanisms or bodies announced in legal texts, inadequate institutional support. • Inadequate organization of certain structures or institutions. • Weak capacities of the state, private sector and civil society.
	Human and financial resources	• Ineffective transfer of skills and resources, which does not allow a true local governance of natural resources. • Insufficient skilled resources and qualified personnel in specific areas. • Overreliance on international financial partners.
	Governance	• Multiplicity of decision centers without leadership, poor coordination and consultation (fragmentation of responsibilities, inconsistency and lack of synergy in the field). • Conflicts of competence or leadership between ministries and between sectoral policies. • Confusion in the roles and responsibilities of the many structures and institutions. • Ineffectiveness of many forums for dialogue (national and local). • Incomplete decentralization. • Poor integration of traditional authorities, the private-sector and civil-society organizations in the formal governance structures. • Low involvement of traditional authorities and insufficient integration of traditional law. • Development of corruption at various levels.
Volta Basin	Governance	• Noncompliance with conventional procedures on the environment. • Absence of specific national institutions to manage the national portion of the Volta Basin. • Non-ratification of the VBA charter by some countries. • Organizational failure and cooperation across the basin at different levels.

Source: UNEP-GEF Volta Project 2013.

2.4.5 Climate Change

Global climate change has led to changing temperatures, rainfall patterns and frequency, and intensity of storms in West Africa. Climate change is likely to be a driver of natural resource degradation across the basin, and adaptation to climate change is therefore essential to the long-term sustainable development of the basin and to the utilization of its resources. Changing climate patterns are one of the root causes of environmental problems in the region.

2.5 Strategic Action Programme (SAP)

Based on the findings of the TDA and extensive consultation, a Strategic Action Programme (SAP) (UNEP-GEF Volta Project 2014) was drafted that identified specific actions and investments needed to:

- Ensure water availability.
- Conserve and restore ecosystem functions.
- Ensure adequate water quality.
- Strengthen governance and information management in the basin.

These actions address the key identified threats to water and related natural resources in the region in terms of the sustainability of their use for socioeconomic development. The prioritized actions are summarized below (UNEP-GEF Volta Project 2014):

Component A: Ensuring water availability

This component is addressing the issue of changing water quantity and seasonal flows (transboundary problem 1, UNEP-GEF Volta Project 2013). The seven actions identified focus on improving water availability as well as optimizing its use in the Volta Basin (UNEP-GEF Volta Project 2014). They aim to better understand the basins, hydrology in order to better respond to changing conditions and improve adaptation to risks related to water availability (Table 2.4).

TABLE 2.4. Actions for Component A: Ensuring water availability.

Action No	Title	Environmental quality objective
A.1	To identify and promote techniques of adaptation to climate variability and climate change in the Volta Basin	
A.2	To protect all the springs that contribute to the basic permanent flow of the Mouhoun River	
A.3	To develop irrigation infrastructure in the Sourou Basin	Water is optimized among primary users (domestic, agricultural, ecosystem and hydroelectric power) so that they receive adequate and sustainable supplies
A.4	To update and increase the density of monitoring networks of water resources (surface water, groundwater and water quality) in the national parts of the Volta Basin	
A.5	To develop surface-water allocation models for sustainable water use in the Volta Basin	
A.6	To set up an early-warning system for droughts, floods, inundations and diffusion of pollution in the Volta Basin	
A.7	To identify appropriate adaptations as a response to climate change impacts on the water resources of the Volta Basin	

Source: UNEP-GEF Volta Project 2014.

Component B: Conserving and restoring ecosystem functioning

This component is addressing the issue of ecosystem degradation, which includes coastal erosion, invasive aquatic species, increased sedimentation of river courses and loss of soil and vegetative cover (transboundary problem 2, UNEP-GEP Volta Project 2013). Actions in this component focus on physical actions and investments to ensure the sustainable exploitation of the ecosystems in the Volta Basin (Table 2.5; UNEP-GEF Volta Project 2014).

TABLE 2.5. Actions for Component B: Conserving and restoring ecosystem functioning.

Action No	Title	Environmental quality objective
B.1	To stabilize the coast between Ada and Keta in Ghana	The coast between Ada and Keta will be stabilized by 2025
B.2	To promote sustainable management and development of coastal ecosystems in the Volta Estuary	
B.3	To implement a regional program to combat invasive aquatic species in the water bodies of the Volta Basin	The proliferation of invasive species is contained, especially in five priority biodiversity hot spots
B.4	To design and implement a regional program for the protection and restoration of the river banks and gallery forests upstream of Lake Volta	Sedimentation in five key hot spots is reduced by 20% by 2025
B.5	To create, rehabilitate and secure transhumance and livestock corridors	Critical ecosystem functions are conserved. restored and managed for sustainable use in at least five selected areas
B.6	To restore the vegetation cover of the forests of Samory and Ségué	
B.7	To preserve and restore the slopes and mountainsides of the Pendjari-Oti Region	
B.8	To protect the wetlands of the Volta Basin	
B.9	To create biodiversity conservation zones in the Sourou-Mouhoun area	
B.10	To make an inventory of, and develop a monitoring system for, biodiversity in the aquatic ecosystems of the Volta Basin	

Source: UNEP-GEF Volta Project 2014.

Component C: Ensuring adequate water quality

This component is addressing the issue of water quality concerns (transboundary problem 6, UNEP-GEF Volta Project 2013). The actions in this component directly aim to protect water quality and to improve capacity of national water quality laboratories to obtain accurate information on the status of the quality of water in the Volta Basin (Table 2.6; UNEP-GEF Volta Project 2014).

TABLE 2.6. Actions for Component C: Ensuring adequate water quality.

Action No	Title	Environmental quality objective
C.1	To control pollution in highly polluted areas of the Volta Basin	
C.2	To promote productive reuse of treated wastewater	Water of sufficient quality is available to support ecosystem needs at four pollution hot spots
C.3	To safeguard the shallow freshwater aquifers from salinization along the coast of Ghana and Togo	
C.4	To reinforce the capacities of national water-quality laboratories	

Source: UNEP-GEF Volta Project 2014.

Component D: Strengthening governance and improving the quality of information for resource management.
This component is addressing one of the cross-cutting concerns on governance (UNEP-GEF Volta Project 2013). It aims to reinforce institutional frameworks for sustainable management of the environmental and water resources of the Volta Basin (Table 2.7; UNEP-GEF Volta Project, 2014).

TABLE 2.7. Actions for Component D: Strengthening governance and improving the quality of information for resources management.

Action No	Title	Environmental quality objective
D.1	To prepare the Water Charter of the Volta Basin	
D.2	To prepare the Master Plan of the Volta Basin	
D.3	To make an institutional assessment of the Volta Basin Authority	The legal and institutional framework within the Volta Basin is strengthened
D.4	To support and reinforce transboundary and regional cooperation for water resources management across the Volta Basin	
D.5	To improve and harmonize the safety standards and regulations of the dams in the Volta Basin	
D.6	To protect and apply regulations to watercourses and wetlands	
D.7	To support the Volta Basin countries to implement the institutional aspects of their IWRM plans	
D.8	To reinforce a mechanism of transboundary governance of the water resources of the Sourou Basin shared by Mali and Burkina Faso	
D.9	To reinforce public awareness and knowledge on laws relating to water and the environment in the Volta Basin	
D.10	To support the operationalization of the Volta Basin Observatory	
D.11	To assess the economic values of environmental capital and ecosystem functioning within the Volta Basin	
D.12	To carry out a social anthropological study in the Volta Basin on the relationships between water uses and the environment	

Source: UNEP-GEF Volta Project 2014.

It is anticipated that achieving the aims of the actions outlined in the SAP will contribute to protecting human health, decreasing poverty levels, and conserving and protecting water resources in the Volta Basin, as well as protecting biodiversity and ecosystem functions that are recognized worldwide as important.

2.6 Demographics

The major population areas in the Volta River Basin include Ouagadougou, Tamale and Bolgatanga in the White Volta Subbasin; Bobo Dioulasso in the Black Volta Subbasin; Kara Region of Togo in the Oti Subbasin; and the lower reaches of the Lower Volta Subbasin in southern Ghana

(UNEP-GEF Volta Project 2013). The populations of the countries in the basin are growing at an average rate of 2.7% per annum, one of the fastest in the world (Table 2.8). Biney (2010) projected that the total basin population will grow from an estimated 18.6 million in 2000, to 33.9 million in 2025, an increase of 80% over a 25-year period. The current population growth, apart from having an impact on available infrastructure and facilities, also poses a problem to sustainable natural resources use, especially water resources.

Population density within the riparian countries varies with the highest found in Togo (125 persons km^{-2}) and the lowest in Mali (13 persons km^{-2}) (Barry et al. 2005). Ghana, Benin, Côte d'Ivoire and Burkina Faso have population densities of 114, 92, 64 and 62 persons km^{-2}, respectively (Table 2.8). The population densities also vary within a country. For example, the population density of Ghana's Upper East, Upper West and Northern regions are 118.4, 38 and 35.2 persons km^{-2}, respectively (GSS 2012). The average population density in the Volta Basin of Burkina Faso is 29 persons km^{-2}, with a high population density (79 persons km^{-2}) on the Central Plateau and sparsely populated eastern and western regions (10 persons km^{-2}) (Obuobie and Barry 2010).

The basin area experiences population migration which is influenced by a number of factors such as poverty, increasing population pressure, and environmental degradation. In addition, people continue to move to urban areas in search of better opportunities. The decline in fishing activities in the downstream areas of the Volta Lake due to the creation of the Lake has resulted in people moving upstream to settle in the immediate surroundings of the lake for their livelihood (UNEP-GEF Volta Project 2013). People in the Savannahs and Kara regions of Togo who migrated to the southern regions of the country before 1990 are now returning because of socio-political unrest (Obuobie and Barry 2010). The population of Burkina Faso also experiences an important migration at both internal and external levels. It is estimated that 71.2% migrate inside the country and 28.8% abroad (Obuobie and Barry 2010). The state of the environment also contributes to the issue of migration in the basin. Such factors are known to include movements induced by bushfires, floods, pastures, droughts and famines.

TABLE 2.8. Population dynamics in the Volta Basin.

	Population (2013) (millions)	Population density (people/km)	Population growth rate (annual %)	Population; ages 0–14 (%)	Population; ages 15–64 (%)	Population; ages >65 (%)
Benin	10.3	92	3	43	54	3
Burkina Faso	16.9	62	3	46	52	2
Côte d'Ivoire	20.3	64	2	41	55	3
Ghana	25.9	114	2	38	58	3
Mali	15.3	13	3	47	50	3
Togo	6.8	125	3	42	55	3

Source: World Bank 2014.

2.7 Livelihoods

The riparian countries of the Volta Basin are generally poor with weak economies based mainly on the export of primary commodities. The 2014 Human Development Report (UNDP 2014) classified all, except Ghana, in the Low Development bracket with the Human Development

Index of below 0.5. Per capita gross domestic product (GDP) in the riparian countries ranges between USD 1,858.2 (in Ghana) and USD 636.4 (in Togo) (World Bank 2014). High poverty rates also lead to extensive migration to resource-rich areas, which itself contributes to the increasing pressure on productive agricultural lands. About half of the population in each of the riparian countries is in the age group of 15–64 years, which forms the majority of the labor force (Table 2.8). Among the six basin countries, Ghana has the largest labor force (15.02 million), followed by Côte d'Ivoire (11.2 million), Burkina Faso (8.8 million), Mali (7.7 million), Benin (5.6 million), and Togo (3.7 million).

Between 64 and 88% of the basin population is rural (Barry et al. 2005) and depends directly on natural resources, which is a challenge for their sustainable management (Biney 2010). The Volta River and its tributaries are important sources of water for the inhabitants. Water plays a vital role in the livelihoods of people in the basin and in the promotion of economic growth. Major livelihood activities in the basin include crop production, livestock-rearing, fishing, industry, and commerce.

2.7.1 Agriculture

Agriculture, including livestock, fisheries, and forestry contributes to a large share of the GDP in the riparian countries and is therefore the most important livelihood activity in the basin. Agriculture, which generates about 40% of the basin's economic output, is heavily reliant on available water resources (Biney 2010). The majority of economically active persons (men and women) are engaged in commercial or subsistence agriculture. The agriculture sector employs the largest share of the labor force (60–92%). In Côte d'Ivoire, agriculture accounts for 54% of male employment and 72% of female employment (Obuobie and Barry 2010).

The farming system is a combination of crop rotation and mixed cropping. There are also monocropping systems, especially rice along river valleys and streams. In the headwater catchments, farmers use contour bunds, stone bunds, and grass bunds for conservation of land and water to improve production. Farmers mostly maintain parkland agroforestry systems, characterized by the deliberate retention of mainly economically valuable and multipurpose trees such as Shea (*Vitellaria paradoxa*), Dawadawa (*Parkia biglobosa*) and Kapok (*Ceiba pentandra*) on farmlands (Poudyal 2009). Generally, farming is characterized by the use of simple tools and fire for clearing vegetation. The low level of technology intrinsically limits the total possible area cultivated. Animal traction is utilized heavily in certain parts of the basin but hoes and machetes are the main farming implements in the basin. The use of tractors for land preparation is gradually increasing.

There is heavy dependence on the inherent fertility of the soil, and fertilizer applications are low both in terms of quantity per hectare and frequency of application. Soils are therefore poor and the pressures on agricultural lands have reduced fallow periods. In general, cropping is done in the wet season but there are many small-scale irrigation facilities such as dams, dugouts and small reservoirs for dry-season farming. Crops grown in the basin include maize, millet, sorghum, rice, yam, groundnut, Bambara beans, cowpea, soybean and vegetables like tomato, onion, cabbage, pepper and okra. Common cash crops cultivated in the basin include cotton, coffee and cocoa. Estimates of average yield for different crop types are provided in Table 2.9.

TABLE 2.9. Estimated crop yields for Ghana.

Crop	Yield ($tons ha^{-1}$)
Maize	1.4-1.7
Rice	1.9-2.6
Millet	0.7-1.1
Sorghum	0.7-1.3
Cassava	>12
Yams	13.4-15.7
Cocoyams	6.5-7.2
Plantains	9.4-10
Legumes	0.8-1.5

Source: UNEP-GEF Volta Project 2010.

Forested areas are cut to provide additional land for agriculture, and to provide firewood and charcoal for local populations. Forests in many parts of the basin have been severely overexploited, and are threatened (see section 2.4.2). Population pressures in the basin induce unsustainable use of forest and land resources.

2.7.1 Livestock-Rearing

In addition to crop cultivation, the production of livestock is an important source of rural livelihoods in the northern parts of the basin. The prevalence of tsetse flies and the spread of trypanosomiasis throughout the tropical part of the basin have kept the level of animal production very low in the south. Animal-rearing is therefore found especially in Burkina Faso and Northern Ghana. The rich savannah grassland provides good fodder for livestock production. Almost every farmer has some animals. Livestock is a source of income to farmers in addition to serving as insurance against crises when immediate cash may be needed. The method for rearing livestock is basically free-range except during the rainy season when some of the animals are confined to prevent destruction of crops. The predominant livestock reared by farmers comprise cattle, sheep, goats, pigs, fowls and guinea fowls. In Burkina Faso, animal husbandry, just like crop production, occupies an important place in the farming system in all the regions. McCartney et al. (2012) estimated livestock populations in the Volta Basin from government ministries in Burkina Faso and Ghana, and estimated possible future populations based on current growth trends (Table 2.10).

TABLE 2.10. Livestock population estimates in the Volta Basin.

	Livestock population			
Sub-catchment	1983	2000	2025	2050
Black Volta	2,261,061	3,440,472	6,378,442	11,825,275
Lower Volta	2,139,129	3,274,039	6,034,475	11,187,580
Oti	1,495,889	2,443,472	4,219,896	7,823,449
White Volta	4,620,441	7,161,981	13,034,242	24,164,750
Total Volta Basin	10,516,520	16,319,964	29,667,055	55,001,054

Source: After McCartney et al. 2012.

2.7.3 Fishing and Fish Marketing

Fishing is an important activity for many inhabitants of the basin. It is a year-round activity; however, individual fishing methods and targeted species vary greatly during the year. Fishing activities are usually undertaken by men using either manual or motorized canoes. Apart from the natural fish resources in the basin, aquaculture development, particularly caged fish production, is also increasing in popularity, especially in Lake Volta and downstream reaches of the river. Fresh fish is landed on a daily basis and is either sold wholesale for cash or given on credit to women fish processors and traders. In other cases, especially on market days, fishermen may sell off their own fresh catch. The principal processing methods are smoking, salting, sun-drying and fermentation. Processing is done predominantly by women. Wholesale traders travel to fishing villages to purchase processed fish and return to the lakeside market within 2-3 days with the fish already prepared for the journey to urban centers. Inland fisheries are major sources of livelihood to many communities along the Volta River. Fish provides about 60% of the total protein requirements of Ghana and inland fisheries and aquaculture contribute about 20% of Ghana's total production. Total production from the inland fisheries is estimated at 87,500 tyr^{1}, of which 98% comes from the Volta Lake (UNEP-GEF Volta Project 2010).

2.7.4 Industry

The most significant industrial development in the basin is hydropower generation, though this does not offer direct employment to the majority of the population in the basin. In Ghana, there are a few textile factories located near the Akosombo Dam such as the Juapong Textiles Limited and Akosombo Textiles Limited. There are also tomato and cotton-processing factories in the northern part of the basin in Ghana. Apart from these, industries in the basin in Ghana are generally small-scale, and use local raw materials, employing typically between two and six workers. In Burkina Faso, a number of industries are located in the basin that use large quantities of water and emit waste into waterways. These include agro-processing (breweries, slaughterhouses, cotton, and soap factories), chemicals (pesticides), and textiles (tanning and sewing).

The industrial sector of the micro economy is highly underdeveloped. This sector is dominated by women as the main actors. Areas of operation include Shea butter production, groundnut oil production, *pito* (local beer) brewing, parboiling of rice, spinning and cloth-weaving, basket-weaving, pottery, and leather works.

Mineral resources such as phosphate, uranium, gold, and iron abound in the Volta River Basin, but few have been developed. Small-scale gold mining is being practiced in the Upper East section of the basin in Ghana and in several areas of Burkina Faso, including Kaya, Bittou, and Yako. Apart from the destruction to the land and vegetation, water quality is also severely affected due to the use of mercury. Most of these mining activities are illegal. Artisanal iron production is also common in Togo.

Tourism remains underdeveloped in the basin even though there are many natural and cultural attractions. The most important attractions are national parks such as the Pendjari National Park in Benin, the Comoé National Park in Côte d'Ivoire, and the Mole National Park in Ghana.

2.7.5 Commerce

Another form of livelihood diversification practiced is petty trading (selling drinks, cooked food, sugar and other essential supplies). In particular, petty trading involves large numbers of women (either full-time or part-time) and concerns a large variety of products (selling of cooked

food, home-made drinks/alcoholic beverages derived from agricultural products or wild fruits, retailing of gardening products, etc.). The commercial sector is constrained by poor transport services coupled with an inadequate road network, limited communication facilities, and poor market infrastructure.

3. PHYSICAL GEOGRAPHY

3.1 Geology

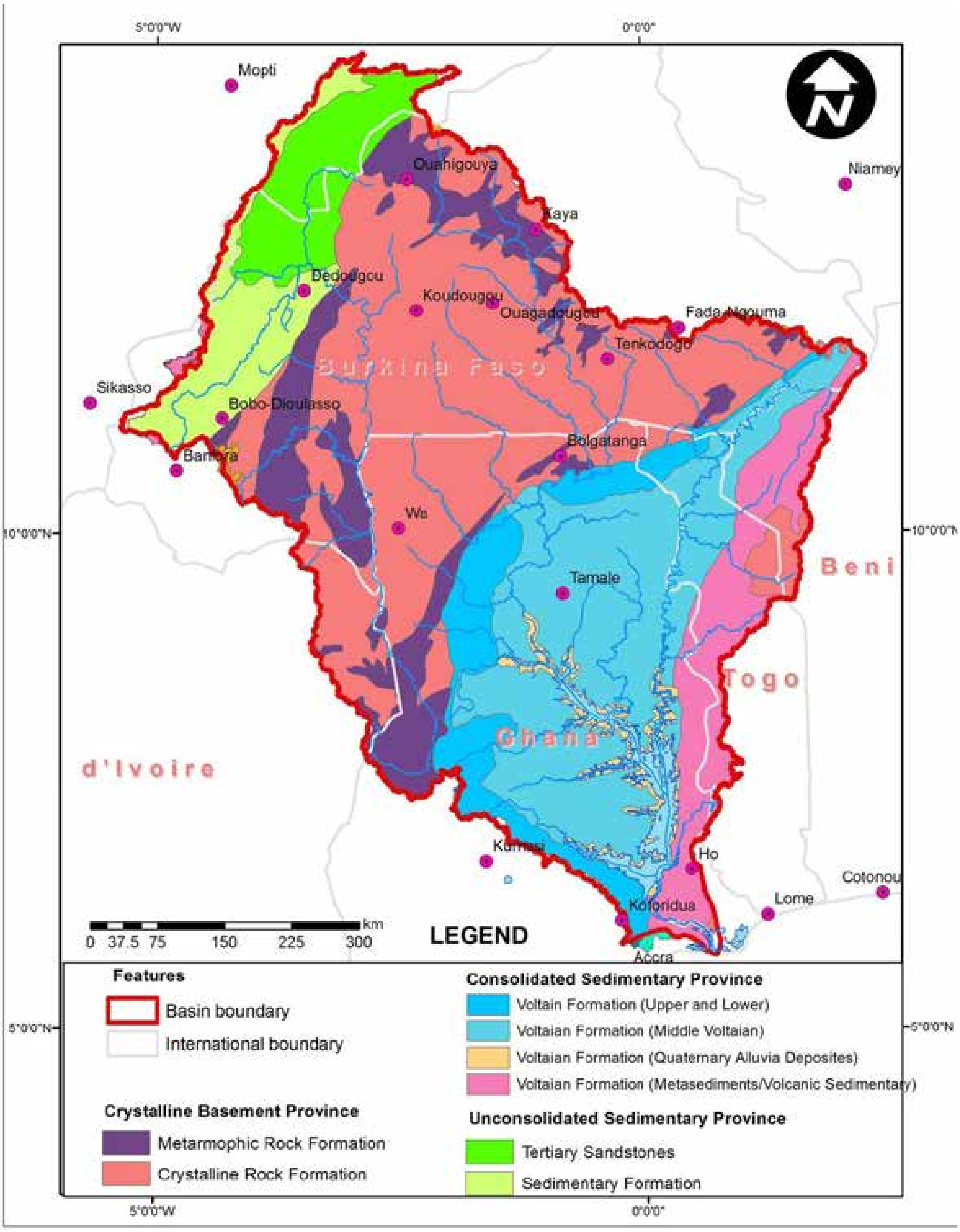
The Volta Basin is underlain by two main geological formations: the basement crystalline rocks of Precambrian age associated with the West African Craton, and the consolidated sedimentary formations (commonly known as Voltain formation) of Proterozoic to Paleozoic ages. These two geological formations underlie over 90% of the Volta Basin (Figure 3.1). The rest of the geology consists of the Proterozoic to Paleozoic sedimentary rocks (zone sedimentary zone - Gres, Clacaire) that consist of thick layers of sandstones, schists, conglomerate and dolomite, and the recent tertiary sedimentary rocks (Continental Terminal), which consist mainly of sandstones (Martin 2006; Obuobie and Barry 2012; Sandwidi 2007). Both the sedimentary formation and Continental Terminal underlie the northwestern portions of the basin in Burkina Faso.

The crystalline basement and the consolidated sedimentary formations are usually overlain by a weathered layer of varying thickness and lithology, sometimes referred to as the regolith (Martin 2006; Carrier et al. 2006). Generally, the thickness of the regolith is influenced by lithology, structural characteristics, topography, vegetation cover, erosion, and climate. Information on the thickness of the regolith is very scanty but observations from previous studies show the regolith for the basement crystalline formation can be up to 140 m in the central parts of the basin (northeast and west of Ghana) even though it is generally less than 30 m (Dapaah-Siakwan and Gyau-Boakye 2000; Apambire et al. 1997; Apambire 1996) and ranges from 15 to 40 m (can be up to 100 m) in the north (Palacky et al. 1981; Groen et al. 1988). The thickness of the regolith in the Voltaian formation is usually less than that of the crystalline basement and ranges from 4 to 20 m in the southern portions of the Voltaian (Acheampong 1996).

3.1.1 Crystalline Basement Rocks

The basement crystalline rocks are the most dominant geological formation in the Volta Basin and underlie mainly the northern, central, extreme east, and southwestern areas of the basin. It is an important geological feature as it underlies about 40% of the total land area in sub-Saharan Africa (Carrier et al. 2006). In Burkina Faso and Ghana, the crystalline basement rocks, underlie 80 and 54%, respectively (MEE 1998; Bilan D'eau 1993; MWH 1998a). They consist of strongly deformed metamorphic rocks, igneous rocks, granite-gneiss-greenstone rocks, and anorogenic intrusions (Key 1992; Martin 2006; BRGM 2003; BGS 2002; MAHRH 2003). According to Apambire (1996), the structural trend in these rocks may be influenced, to a great extent, by the principal tectonic stress orientation (West/North West-East/South/East) and thus follow a northeast-southwest axis (Carrier et al. 2006). Fracture patterns may develop along the same axis (sub-vertical fractures) in addition to the upper part of the bedrock (sub-horizontal fractures from isostatic uplift) and on the fringe of large intrusions (sub-vertical fractures parallel to margins). The crystalline province is commonly categorized into the Birimian super group (with associated granitoid intrusion), Dahomeyan formation, Togo formation and the Buem formation (Martin 2006).

FIGURE 3.1. Geology of the Volta River Basin.



Source: GLOWA Volta Project.

3.1.2 Consolidated Sedimentary Formation

The consolidated sedimentary formation (Volta formation) dominates the geology of the central-west and southwestern areas of the basin. The rock types are mainly sandstones (with intercalated formations such as politic schist, dolomitic limestone and conglomerate), shales, arkose, mudstones, sandy and pebbly beds, and limestone (MWH 1998a). These are usually well cemented or recrystallized (MacDonald and Davies 2000). On the basis of lithology and field relationships, the Voltaian system can be grouped into the upper, middle and lower Voltaian. The upper Voltaian consists of massive and thin-bedded quartzite sandstones, which are interbedded with shale and mudstones in some areas. The middle Voltaian (Obusum and Oti beds) mostly consists of shales, sandstones, arkose, mudstones, and siltstones. The lower Voltaian consists of massive quartzite sandstone and grit (MWH 1998a). Geological formations in the northwestern part of the basin consist of thick layers of sandstones, schist and carbonates of the Sedimentary zone and sandstones of the tertiary continental terminal (Martin 2006).

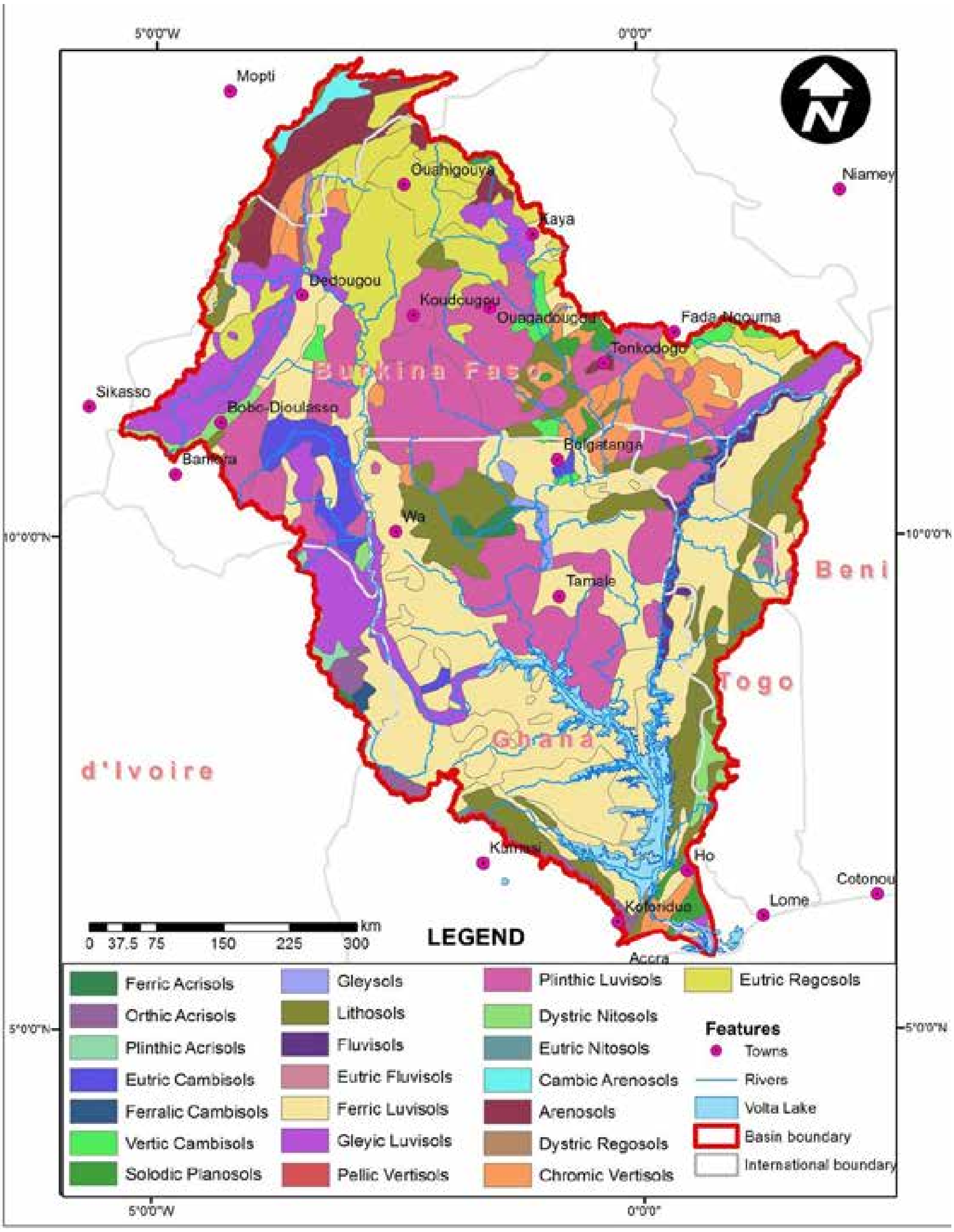
3.2 Soils

Soils in the Volta Basin have been formed from weathered parent materials of the mid-Palaeozoic age or older (Andah et al. 2003) and have been leached over a long period (Benneh et al. 1990). Based on the FAO-UNESCO (1974) soil classifications legend, 12 major soil types can be identified in the Volta Basin (Figure 3.2). By far, Luvisols are the dominant soil type and occur everywhere in the basin except for the areas in the extreme north where Regosols and Arenosols dominate. The Luvisols found in the Volta Basin, particularly those in the north, have low nutrient content and unstable soil structure, thereby making them prone to slaking and erosion on sloping land.

Besides the Luvisols, Regosols and Arenosols are the other dominant soils found in the north of the basin (Burkina Faso). The Regosols were formed from unconsolidated materials and are coarse-textured. They are sensitive to erosion due to low coherence of the soil matrix material (Mando 1997) and have high permeability and low water-holding capacity. These make them sensitive to drought. Arenosols are found in the upland areas and have high clay content. They have low fertility and low water-holding capacity which limit their ability to produce high yields of crops.

In the southern parts of the basin (Ghana), Lithosols are the most important soils after Luvisols. These soils are mostly well to moderately well-drained, gravelly with a light-textured matrix. Generally, Lithosols found in the north of Ghana have low cation exchange capacity, low aggregate stability, low organic content and fertility compared with those found in more humid climatic conditions in the southeast which are rich in organic matter and have high fertility. Additionally, the Lithosols in the north of Ghana have root-zone limitation due to surface layers of plinthite, ferruginous concretion or ironpan, and surface sealing under the effect of rains resulting in increased runoff.

FIGURE 3.2. Soil map of the Volta River Basin.



Source of data: FAO-IIASA-ISRIC-ISS-CAS-JRC 2012.

3.3 Climate

The climate of the Volta Basin is dominated by the rain-bearing southwesterly tropical maritime air mass and the dry, northeasterly tropical continental air mass (Dickson and Benneh 1988). The two air masses meet at the Inter-Tropical Convergence Zone (ITCZ) forming a quasi-frontal zone of low pressure which migrates across West Africa (Anyadike 1993). The ITCZ is therefore

characterized by vigorous frontal activity and its movement controls the amount and duration of rainfall. At any location, the rainy season begins when the ITCZ has passed overhead moving north and ends with its southwards retreat. Consequently, there is a general tendency for rainfall to decrease from the south to the north.

Between May and August (i.e., the West African Monsoon), the ITCZ moves to the north, and the basin countries lie under the influence of the tropical maritime air mass. Normally, from December to February, the front lies across the Gulf of Guinea and the dry *harmattan* a hot, dry usually dusty wind, that blows from the northeast or east in the southern Sahara (Kasei 2010), prevails over all the countries across the Volta Basin. Between March and November, the ITCZ moves across the basin in a complex fashion crossing some areas twice, resulting in a distinctly bimodal rainfall pattern, more significant in Ghana than in the rest of the basin countries. At higher latitudes the interval between the two peaks decreases until at the limit only a single peak is evident (Laux 2009).

The climate of the Volta River Basin is therefore highly variable, both spatially and temporally. A clear climatic gradient occurs from humid conditions in the South to semiarid conditions in the North. It is also characterized by high temperatures throughout the year. In addition to seasonality, interannual variability is considerable. This was previously thought to be associated with anomalous displacements of the ITCZ, but more recent work has indicated that the causes are in the structure of the complicated zonal winds that form over West Africa in the summer (Nicholson 2005).

The Volta Basin stretches across four climatic zones:

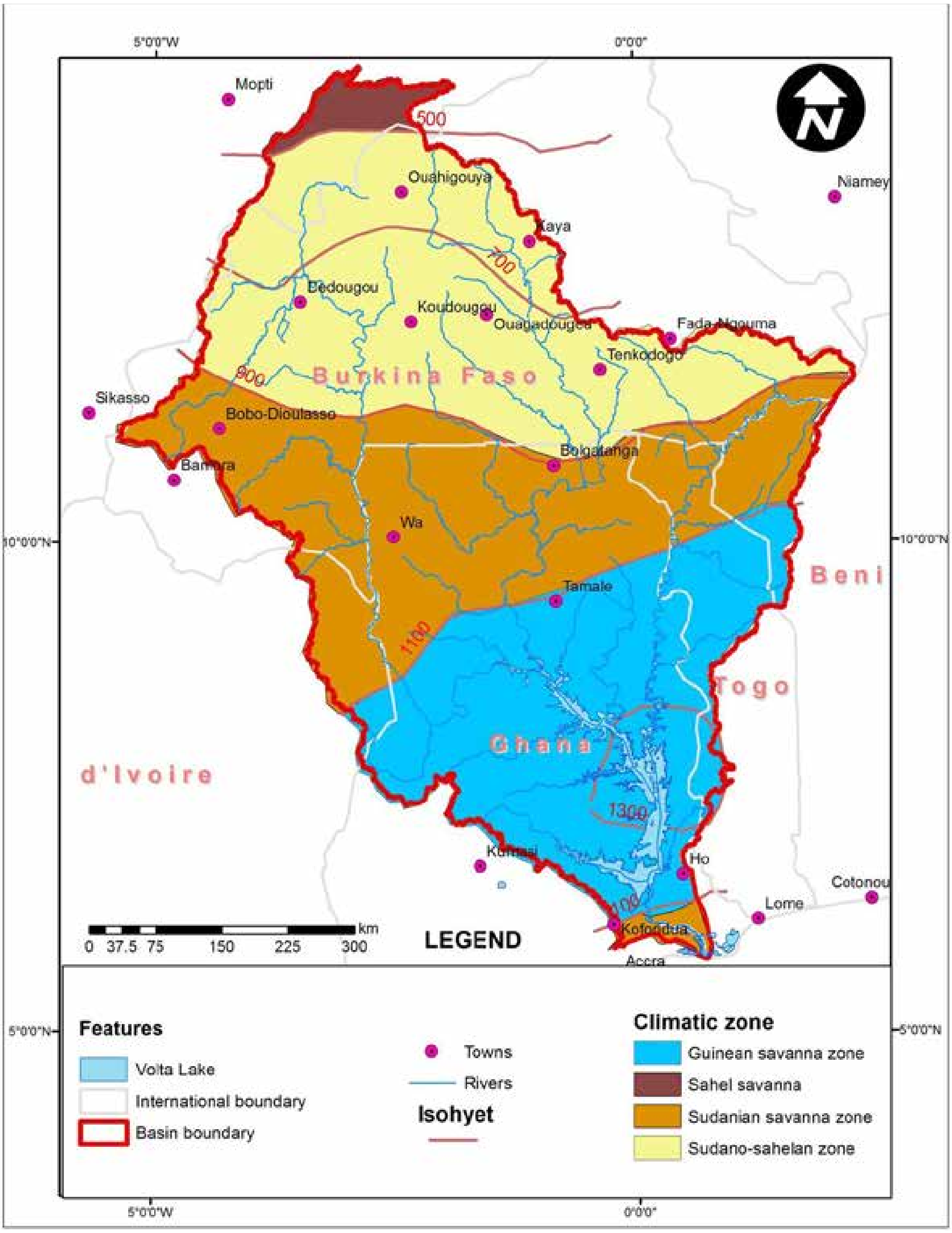
1. The Guinean Zone extending from approximately 8° N to 11° N (Kranjac-Berisavljevic et al. 1999).
2. The Sudan Zone located below 11° 30’ N parallel.
3. The Sudano-Sahelian zone located between the 11° 30’ N and 14 °N parallels.
4. The Sahelian Zone located above the 14° N parallel (Barry et al. 2005).

The spatial distribution of rainfall has been used to define agro-climatic zones in the basin (Figure 3.3).

3.3.1 Rainfall

The rainfall in the basin is highly variable, both spatially and temporally. The Sahelian Zone located in the northern part of the basin receives an annual rainfall of less than 500 $mmyr^{-1}$. The Sudano-Sahelian Zone, which covers the greater part of Burkina Faso, receives rainfall of between 500 and 900 $mmyr^{-1}$. The Sudanian Zone comprises the northern part of Ghana and some parts of Côte d’Ivoire, Benin and Togo and receives rainfall between 900 and 1,100 $mmyr^{-1}$. The Guinean Zone covers the southern part of Ghana and receives rainfall between 1,000 and 1,300 $mmyr^{-1}$ (Kranjac-Berisavljevic et al. 1999). In the Sahelian Zone, the rainy season lasts for about 3 months; it lasts 4 to 5 months in the Sudano-Sahelian Zone; and 6 to 7 months in the southern part of the Sudan and Guinean Zone (Barry et al. 2005). Nearly 70% of annual rainfall in the basin occurs during the three months of July, August and September, with little or no rainfall between November and March over most parts of the basin.

FIGURE 3.3. Climatic zones of the Volta Basin.



Source of data: Lemoalle and de Condappa 2009.

The major rainy season in the south of the basin begins in April/May and the minor one occurs in September/October. The peak rainfall periods are June/July and September/October for the major and minor seasons, respectively. In the north, a single rainfall season occurs between May/June and September/October, with the maximum monthly rainfall normally occurring in September.

The mean annual rainfall volume in the basin is 500 km^3yr^{-1} and it has been estimated that 340 km^3yr^{-1} of rain must fall on the catchment before runoff occurs at significant levels (Andreini et al. 2000). Martin (2006) found out that the annual recharge for the Volta River system ranges from 13 to 16% of the mean annual precipitation. There is also an observed medium-term variability in rainfall of a decadal order, for example, the 1930s, 1950s and 1960s were relatively wet while the 1940s, 1970s and 1980s were drier (UNEP-GEF Volta Project 2013). According to Opoku-Ankomah (2000), since the 1970s there have been a number of changes in the precipitation patterns in some sub-catchments in the basin, with a corresponding rainfall and runoff reduction. Areas which hitherto had a bimodal rainfall pattern now have only one rainfall season, with the second minor season becoming very weak or nonexistent. Although rainfall decreased by only 5% from 1936 to 1998, runoff decreased by 14% (Andreini et al. 2000). Lacombe et al. (2012) reported that significant rainfall changes occurred in Ghana from 1960 to 2005, resulting in a reduction in the number of rainy days with totals less than about 20 mm of rainfall, during the wet season, between latitudes 6 and 9.5 °N. Although these changes were confined to the central part of Ghana, they are significant at the country level.

3.3.2 Temperature and Humidity

Generally, there is a gradual increase of temperature from the south to the north of the Volta Basin. The mean annual temperature ranges from 27 °C in the south to 36 °C in the north (Oguntunde 2004). Daily temperatures can be as high as 44 °C, whereas night temperatures can be as low as 15 °C. A diurnal temperature range of 6–8 °C is observed along the coast and 10–13 °C is observed further north. Due to the proximity of Ghana, Côte d'Ivoire, Togo and Benin to the equator, the mean temperatures never fall below 24 °C. In Burkina Faso and Mali, the mean temperature in the Sahel Zone is always higher than 29 °C while in the Sudano-Sahelian Zone it lies between 28 and 29 °C and in the Sudan Zone below 28 °C (Barry et al. 2005).

The seasonal variation in temperatures is characterized by four periods: two extremely hot periods and two relatively cool periods. The first hot period is in March-April with average maximum temperatures of 37, 39 and 41 °C in the south, center and north of the basin, respectively, while the average minimum temperatures are 24 (south), 25 (center) and 26 °C (north). The second hot period occurs immediately after the rainy season. It is not as hot as the first, with an average maximum temperature of 34, 36 and 38 °C in the south, center and north, respectively (Barry et al. 2005).

The first cool period occurs in December-February, with average maximum temperatures varying between 33 and 35 °C in January and average minimum temperatures in the order of 14 (north), 17 (center) and 19 °C (south). This is the period of the harmattan, a dry dusty wind that is cold at night and hot during the day. The second cool period coincides with the rainy season. During this period, the moisture content of the air is at its highest. The average maximum and minimum temperatures during this cool period are subject to extreme variations due to the irregularity of the rains (Barry et al. 2005). The hottest month of the year is March or April and the coolest is August.

The southern section of the basin is more humid than the north. Mean daily humidity varies between 6 and 83% depending on the season and the location. In the coastal area of Ghana the relative humidity is 95 – 100% in the morning and about 75% in the afternoon. In the North, values can be as low as 20 – 30% during the harmattan period and 70 – 80% during the rainfall period. There are sometimes heavy falls of dew, especially in the south where levels of between 0.8 and 1 mm have been recorded (Barry et al. 2005).

3.3.3 Evaporation

Mean annual potential evapotranspiration is estimated to be lowest in the South (1,500 $mmyr^{-1}$) while it exceeds 2,500 $mmyr^{-1}$ in the northern part of the basin. Nearly 80% of rainfall is estimated to be lost to evapotranspiration during the rainy season (Oguntunde 2004). Total evaporation in August is generally lower than 100 mm whereas maximum pan evaporation of >400 mm is observed during March-April (Barry et al. 2005). Actual evapotranspiration in most parts of the basin depends partly on soil properties, and generally lies between 10 mmd^{-1} in the rainy season and 2 mmd^{-1} in the dry season (Martin 2006). In the Volta Basin of Ghana, the potential evapotranspiration varies from a minimum of 1,450 $mmyr^{-1}$ in the Black Volta Subbasin to a maximum of 1,968 $mmyr^{-1}$ in the White Volta Subbasin. In the Volta Basin of Burkina Faso, average annual pan evaporation varies from a minimum of 1,932 $mmyr^{-1}$ in the South to 2,334 $mmyr^{-1}$ in the North.

Table 3.1 shows the range of potential evapotranspiration as well as other hydrometeorological parameters in each subbasin of the Volta Basin in Ghana.

TABLE 3.1. Summary of hydrometeorological characteristics of the four major subbasins.

Subbasin	Rainfall ($mmyr^{-1}$)	Coeff. of Var.	Pan Evaporation ($mmyr^{-1}$)	Potential Evapotranspiration ($mmyr^{-1}$)
Black	1,023 – 1,348	0.17 – 0.23	2,540	1,450 – 1,800
White	930 – 1,054	0.16 – 0.20	2,540	1,650 – 1,968
Oti	1,050 – 1,500	0.18 – 0.20	2,540	1,550 – 1,850
Lower	876 – 1,565	0.17 – 0.35	1,778	1,450 – 1,800

Source: Barry et al. 2005.

3.3.4 Climate Change

Climate change is projected to intensify the challenges already faced by sub-Saharan Africa. The climate of the Volta Basin is predominately semiarid and subhumid. Potential evaporation in the semiarid climate exceeds precipitation. According to Gyau-Boakye and Tumbulto (2000), and Opoku-Ankomah (2000) there have been reductions of rainfall and runoff in the Volta Basin since the 1970s and this may be attributable to climate change. A study by Owusu et al. (2008) also concluded that total rainfall input to the Volta Basin has declined since the early 1970s, and this low frequency reduction in annual input has been more intense in the drier Sahelian, unimodal northern basin than in the more humid, bimodal, forest and Guinea savannah South. Kasei et al. (2010), who investigated temporal characteristics of meteorological droughts in the Volta Basin,

also found that the frequency of droughts has increased from the 1970s onward. The results of a study conducted by McCartney et al. (2012) also showed that reductions in rainfall, and increases in temperature and potential evapotranspiration, anticipated in certain climate change scenarios, would affect both river flow and groundwater recharge in the Volta Basin.

Climate change projections in the West African Region are inconsistent in projecting rainfall, with an almost equal number projecting an increase and a decrease in rainfall. All climate projections in the basin point to higher temperatures with increased evapotranspiration. Resultant impacts of climate change on river flows are inconsistent and dependent on the climate change scenarios and development trajectory used (Roudier et al. 2014). Increasing temperature and evapotranspiration will increase total water demand and use; coupled with the climate change projections this will potentially affect water availability for energy production and agriculture now and in the foreseeable future, especially in the northern parts. Climate change will not only affect rainfall, evapotranspiration and, river flows directly, but also lead to an increase of water demand for irrigation, and make rain-fed agriculture increasingly unreliable. Some climate change research predictions in the basin are reviewed below.

Awotwi et al. (2015) used an ensemble of the Regional Climate Model (REMO) to simulate and project the climate at local scale in order to investigate the hydrological impact of possible future climate change in the White Volta Catchment. They concluded that the catchment is sensitive to climate change, and with a small increase of 8 and 1.7% of the mean annual precipitation and temperature, respectively, annual surface runoff, annual baseflow and evapotranspiration recorded incremental increases of 26, 24, and 6%, respectively.

Amisigo et al. (2014) assessed the impacts of projected climate change on water availability and crop production in the Volta Basin and the southwestern and coastal basin systems of Ghana using four climate change scenarios in addition to a reference (no change) scenario. The results show that all water demands (municipal, hydropower, and agriculture) cannot be simultaneously met under any of the scenarios used, including the wet scenarios. In addition, the model forecasts negative impacts for the crop yields studied, with some crops and regions seeing larger impacts than others.

A study conducted by Amikuzuno and Hathie (2013) to assess climate impacts at the farm household level in the White Volta Basin revealed that net farm incomes and poverty rates are sensitive to climate change though irrigated and rain-fed farms respond differently to climate change. Since water for irrigation is not available everywhere in the study area, it means future climate change that results in reduced precipitation and high temperatures will negatively affect agriculture.

McCartney et al. (2012) used several models to assess a “middle impact” climate change scenario on existing water uses within the basin, and made projections based on four scenarios for water development within the basin. The outcomes of the modeling exercises project that by 2050 annual average rainfall, runoff and mean groundwater recharge will decrease, resulting in a 30% decrease in hydropower and inability to meet water demand for irrigation, under one scenario.

Kasei (2010) used calibrated regional climate models to assess the impact of plausible global climate change to regional climate as well as land surface and subsurface hydrology in the Volta Basin, using water balance for the period 1961-2000 as the baseline for comparison, and 2001-2050 as the simulated future. The results show an annual mean temperature increase of 1 °C over the basin. Mean annual precipitation is expected to reduce between 3 and 6% in the period 2001-2050 compared to 1961-2000. An average decrease of 5% is projected for total discharge with corresponding decreases in surface, lateral and baseflows.

Obuobie and Diekkrüger (2008) applied the Soil and Water Assessment Tool (SWAT) model to simulate the water resources of the White Volta River Basin and evaluate the impact of future

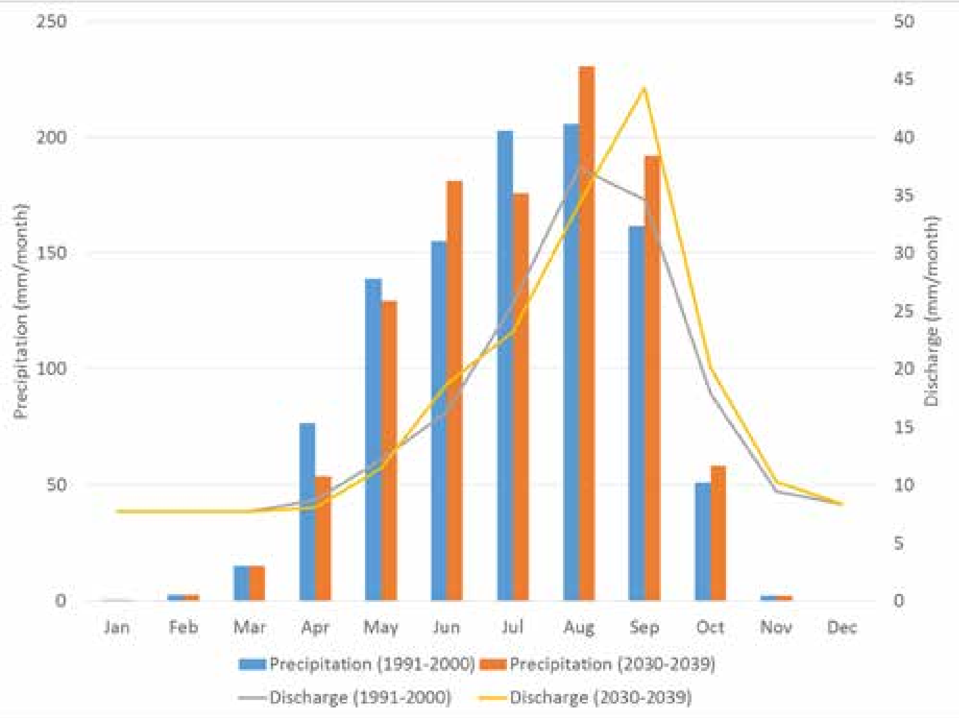
climate change. The results of the simulated future mean annual discharge, surface runoff and baseflow show increases of 33, 37, and 29%, respectively. Such high increases in flows, in response to a relatively small increase (6%) in rainfall, were attributed to the nonlinear response of discharge, surface runoff and baseflow to rainfall in the White Volta River Basin and the fact that actual evapotranspiration is already high in the rainy season and only part of the additional rain is evaporated.

Kunstmann and Jung (2005) and Jung (2006) compared the simulated rainfall and streamflow for a historical time series (1991-2000) and a global climate change scenario (2030-2039) using high-resolution regional climate and hydrologic simulations, and made the following predictions:

- A 30% decrease in mean April rainfall
- An increase in mean monthly rainfall in June, August and September
- An overall increase in annual rainfall of 5%
- Increasing duration of the dry season
- Increasing unpredictability of the onset of the rainy season
- Increase and intensification of rainfall at the end of the rainy season
- Mean annual runoff increase of about 18%
- Increase in flood events
- An annual mean temperature increase of 1.2 - 1.3 °C in West Africa and the Volta Basin.

In general, the study predicted a shortening of the dry season, with rainfall and runoff decreasing in the dry season but increasing in the wet season (Figure 3.4).

FIGURE 3.4. Monthly amounts of rainfall and river flow (1991-2000 and 2030-2039).



Source: Kunstmann and Jung 2005; Jung 2006.

3.4 Land Cover and Use

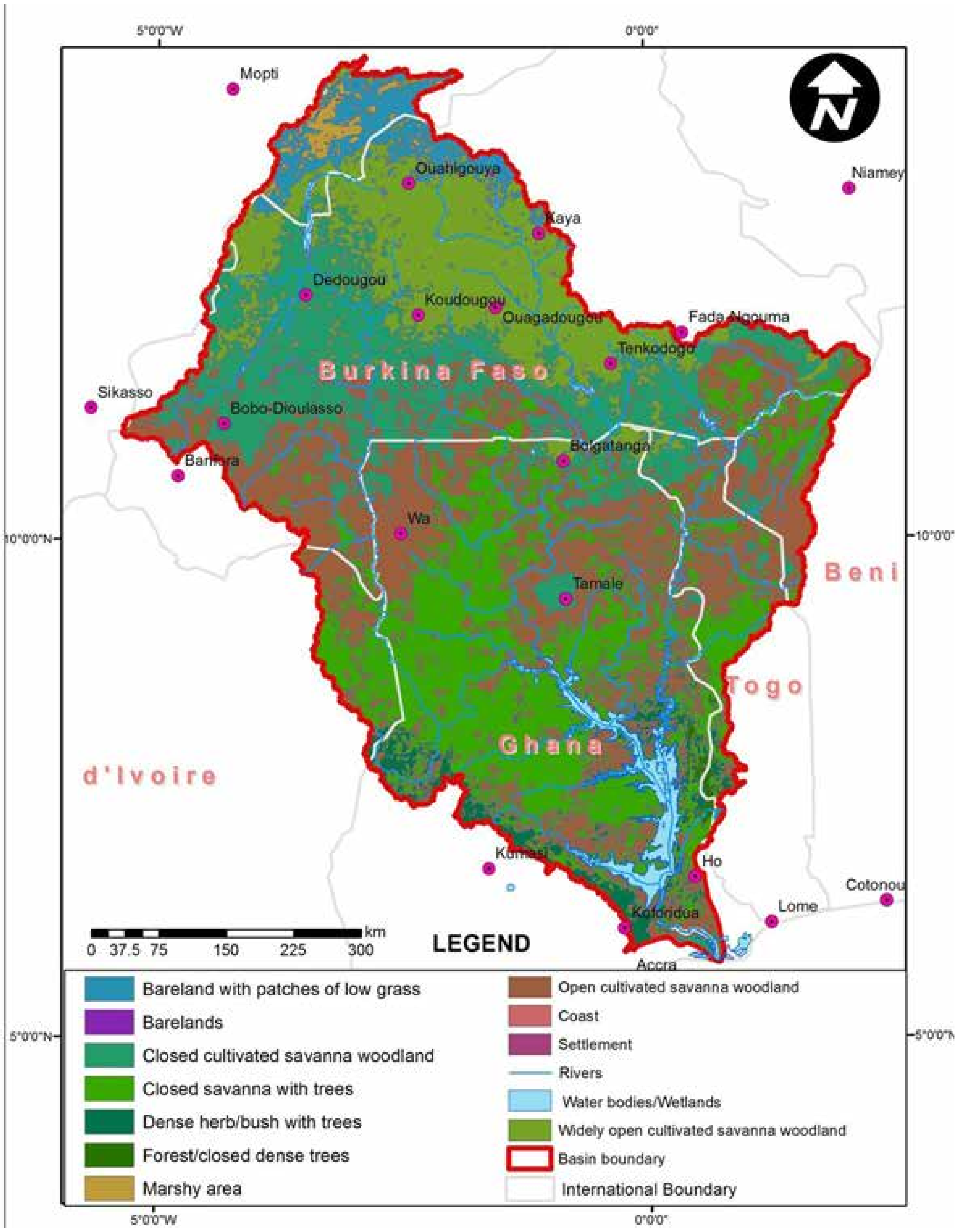
The dominant land cover in the Volta Basin is savannah (Figure 3.5), which consists of grassland interspersed with shrubs and trees. Together with grassland and shrubs, the savannah covers about 89.9% of the entire basin. Other land cover types include wetland and water bodies (3.0%), forest cover (3.4%) and bare land/settlements (3.7%). In general, tree cover in the basin is low as a result of extensive farming, wood extraction and overgrazing (Abubakari et al. 2012). The density of trees and the vigorousness of grassland associated with the savannah, decreases in a south-north direction (i.e., the same pattern as rainfall).

Two distinct types of savannah can be found in the basin: woodland savannah and grassy savannah. Woodland savannah, mostly found in the southern parts of the basin, is densely wooded with tall to medium tall grasses such as *Andropogon* and *Pennisetum spp*. Main tree species associated with woodland savannah include *Adansonia digitata, Vitera paradoxa, Daniella oliveri, Mitragyna inermis, Butryrospermum parkii, Khaya senegalensis, Parkia biglobosa, Tamarindus indica, Terminalia macroptera* and *Faidherbia albida* (MLNR 2012; Siaw 2001). Grass savannah, mostly found in the northern areas of the basin, is mainly grassland interspersed with trees and shrub in some areas. Tree species found in this type of savannah include *Acacia spp, Balanites aegytiaca, Leptadenia pyrotecnia, Aristida spp, Schoenfeldia gracillis, Cenchurus biflorus* and *Anogeissus leicarpus*.

The basin has a number of national parks, wildlife reserves, and other protected areas. The vegetation in these areas is green throughout the year, although some species do shed their leaves in the dry season (MLNR 2012). Common trees associated with the forest are *Cynometra ananta, lophira alata, Tarrietia utilis, Antiaris africana* and *Chlorophora excelsa*. These tree species appear to have a higher rate of regeneration and are more resistant to *the annual bush fires* (MOFA 2011). Some trees are protected. These include *Vitellaria paradoxa, Parkia biglobosa, Acacia albida, Anogeissus leiocarpus, Adansonia digitata* (Baobab), *Tamarindus indica, Mangifera indica* and *Ceiba pentandra*. Forest areas are thinning in favor of croplands. Fallow periods have also reduced significantly. This is mainly due to increasing population growth.

Landmann et al. (2007) analyzed land cover change within the Volta Basin between 1990 and 2000/2001, using 26 Landsat tiles each for 1990 and 2000/2001 and augmented with daily and well-corrected 250-meter MODIS time-series observations for the year 2000 onwards. The resulting land cover map indicates that 37% of the total land cover was transformed (changed from one class to another) from woodland with additional shrubs to managed herbaceous vegetation; 6% was modified (change in tree cover density) from closed woodland (40-95% tree cover density [TC]) to open woody vegetation (15-40% TC); and 3% was transformed from closed woodland (40-95% TC) to herbaceous vegetation. Pressure from increasing population was one of the important factors explaining the expansion of cropland areas and thinning of the tree cover.

FIGURE 3.5. Land cover distribution in the Volta River Basin.



4. WATER RESOURCES AND USE

4.1 Hydrology

The Volta River and its tributaries are an important source of water for the people of the six riparian states. Water plays a vital role in the livelihoods of people in the basin and in the promotion of economic growth. Apart from agriculture, water is also used to generate hydropower, which supports major industries (i.e., mining, aluminum, etc.). Other uses include livestock watering, fisheries, transportation, recreation and tourism.

The water resources of the Volta Basin are under severe stress due to poor climatic conditions and competing demands on the resources by the riparian countries. Climatic conditions in the region are such that there is high variability in both temporal and spatial distribution of rainfall over the basin causing a corresponding high variability in streamflow. Population growth in the two countries that cover the largest proportion of the basin (i.e., Ghana and Burkina Faso) has resulted in larger abstractions of water to meet the increasing demand (van de Giesen et al. 2001). Improper exploitation of these resources in the past has caused serious environmental problems in the basin, key among which is diminishing resources (UNEP-GEF Volta Project 2002). Climate change is also projected to exacerbate the problem of diminishing basin water resources (de Condappa et al. 2009; McCartney et al. 2012).

4.1.1 The Volta River System

The main tributaries of the Volta River system are the Black Volta (Mouhoun), the White Volta (Nakambe) and its main tributary - the Red Volta (Nazinon), and the Oti (Pendjari) River (Figure 4.1).

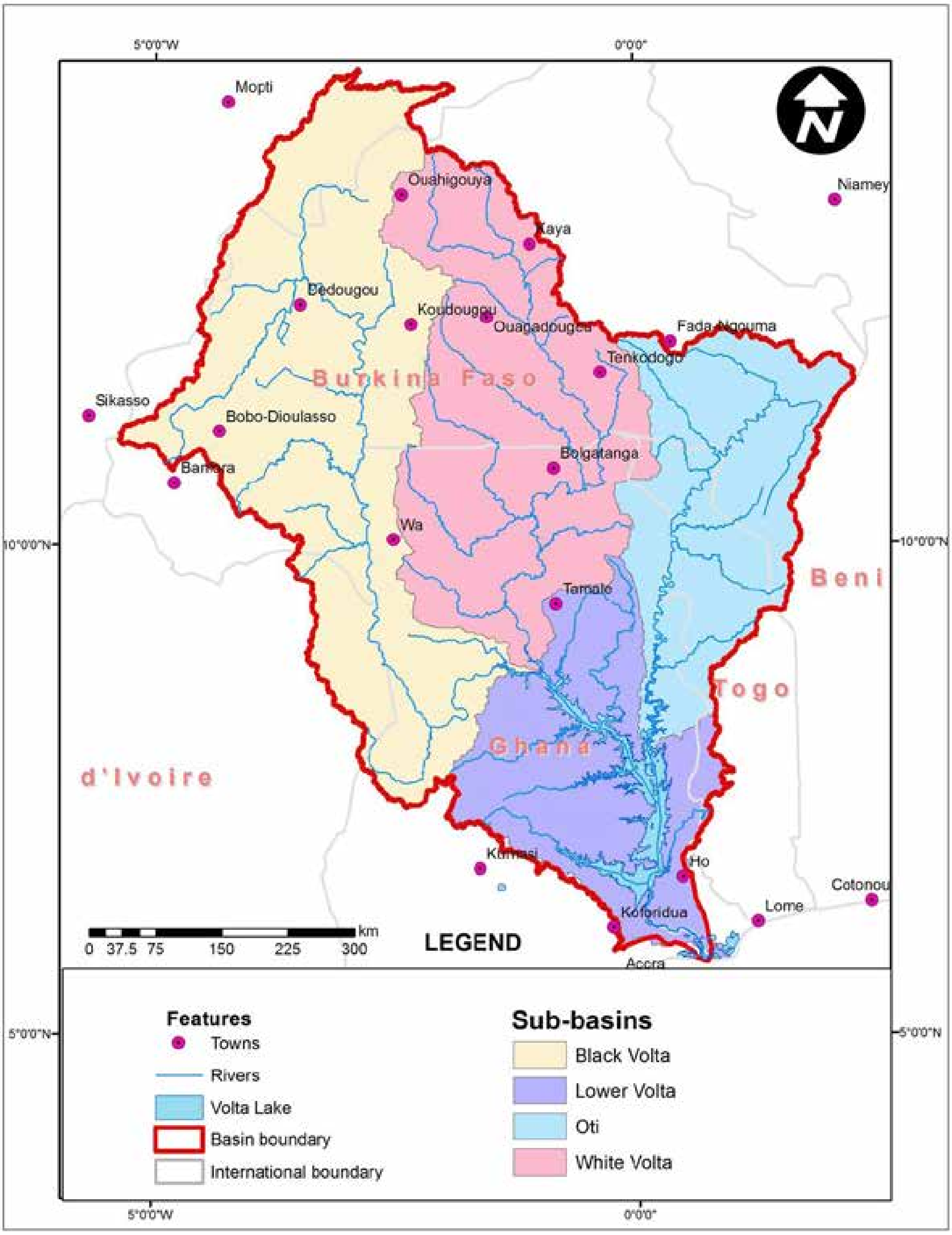
White Volta Basin

The White Volta originates in the north of Burkina Faso and flows southeastward to the border with Ghana. This basin has a total area of about 106,742 km² with 49,225.5 km² lying in Ghana, 1,088 km² in Togo and 56,428 km² in Burkina Faso. The main tributaries are Mole, Kulpawn, Sisili, Red Volta, Asibilika, Agrumatue, Nasia, Morago, Tamne and Nabogo rivers. They join the Black Volta near Nkamandei in the Northern Region of Ghana.

The river is 1,136.7 km long with a drainage density of about 0.011 $kmkm^{-2}$. The mean annual flow is 9.565x $10^6 m^3 yr^{-1}$ (MWH 1998a). At Yarigu, the total mean annual discharge is 80 $m^3 s^{-1}$. The total annual discharge at Nawuni is 230 $m^3 s^{-1}$.

The Red Volta Basin, a tributary of the White Volta Basin, is 393 km long and has a total catchment area of 11,370 km². The catchment area in Ghana is 588 km² with the rest of the area in Burkina Faso. It originates in the central part of Burkina Faso, near Ouagadougou, and flows southeastward to the border with Ghana. After crossing the border, it joins the White Volta near Gambaga in Ghana. At Nangodi, the computed annual discharge of inflow to the basin is 30.7 $m^3 s^{-1}$.

FIGURE 4.1. The Volta Basin.



Environmental Problems

The annual incidence of flooding in the White Volta Basin often results in loss of lives and property. Flooding occurs at the peak of the rainfall season when there is spillage from the Bagré Dam. Health problems like schistosomiasis and onchocerciasis have been recorded in some riparian communities. Groundwater sources with high fluoride concentrations are mostly found in this basin. The basin is contaminated along the banks due to indiscriminate disposal of untreated sewage. In this basin, communities depend directly on raw water for drinking and for other domestic purposes. Hence, the potential for waterborne and water-related diseases is high. There are frequent water shortages due to the drying up of some streams and wells in communities, especially in the dry season.

Black Volta Basin

The Black Volta (Mouhoun), shared by Ghana, Burkina Faso, Mali and Côte d'Ivoire, originates from the Kong Mountains in the Dinderesso Forest Reserve in the southwest of Burkina Faso. In the south, it becomes the border, first between Ghana and Burkina Faso and then between Ghana and Côte d'Ivoire. In Ghana, it covers a narrow strip of area stretching along the western boundary with the Ivory Coast. The river has an estimated length of 1,363 km and drains a total area of 142,056 km^2 (UNEP-GEF Volta Project 2013). About 33,302 km^2 of this total area lies in Ghana, 12,836 km^2 in the Ivory Coast, 8,710 km^2 in Mali and 87,208 km^2 in Burkina Faso. The main tributaries of the Black Volta are Sourou, Benchi, Chuko, Laboni, Gbalon, Pale, Kamba and Tain rivers.

The Sourou, coming from Mali, joins the Mouhoun where its flow turns from a northward to a southward direction. The Sourou flows through a north-south trough, called the Sourou depression. The Sourou depression naturally regulates the runoff of the Mouhoun. During the rainy season, when discharge of the Mouhoun exceeds a certain level, water from the Mouhoun flows to the Sourou depression and is stored there. At times of low-flow, it flows back and feeds the Mouhoun.

The flow of the Black Volta is partly controlled by the Lery Dam. The flow is fairly high in the upper parts of the river and drops in the valley where the gradient is less steep and water infiltrates into the soil (e.g., at Boromo hydropower station). The flow increases again downstream towards Bamboi as precipitation increases. Before the Lery Dam was constructed, there was a natural reversal of water flow in the rainy season and the water direction changed and flowed towards Mali. Further abstraction of water occurs at Tenado, upstream of Boromo, which could be another possible reason for the reduction in flow downstream near Boromo. The mean annual flow is 7.673×10^6 m^3yr^{-1} (MWH 1998a). The mean inflow into Ghana, estimated from discharges measured at Lawra, is 34.75 m^3s^{-1} in the dry season and 373.79 m^3s^{-1} in the wet season.

Environmental Problems

Flooding is a serious problem in the Black Volta Basin, leading to the displacement of people and destruction of crops for communities close to the river. Health problems like onchocerciasis also increase due to floods. The basin is affected mainly by agricultural activities. A slight pollution occurs along certain stretches of the banks as a result of indiscriminate disposal of human waste and garbage due to inadequate sanitary and waste disposal facilities.

Oti Basin

The Oti River rises in the heart of Benin's rainy Atakora Mountains, which are an extension of the Akwapim-Togo Ranges, where it is known as the Pendjari River. It flows through Togo and Ghana, where it is known as the Oti River. From the Atakora Mountains in the northwest of Benin, the Oti River flows northeast and then turns west to become the border, first between Burkina Faso and Benin, then between Togo and Benin for a short distance and then south across the north of Togo and then down its Ghana border where it joins the Volta River near Kete Krachi in Ghana. It is 936.7 km long and occupies an area of about 72,778 km^2. The catchment area within Ghana is 16,801 km^2 with the rest in Togo (21,572 km^2), Burkina Faso (21,352 km^2) and Benin (15,385 km^2).

The main tributaries of the Oti River are the Koumongou, Kéran, Kara, Mô, Kpanlé, Wawa, Ménou, Danyi, Afram, Obosom, Sene, Pru, Kulurakun, Daka, and Asukawkaw rivers.

The drainage density of the Oti River is about 0.012 kmkm-^{2}. Due to flow regulation by the Kompienga Dam in Burkina Faso, the Oti River has a permanent flow with an annual average of 100 to 300 m^3s-1, and can reach more than 500 m^3s-1. Virtually all the tributaries stop flowing during the dry season. The mean annual flow is 11.215 x 106 m^3yr^{-1} (MWH 1998a).

Environmental Problems

Several communities and even whole districts get isolated during periods of flooding in this basin. The flooding situation has been aggravated by the removal of forest cover. The presence of water weeds in this basin has hampered the development of trade and commerce. The weeds restrict the use of a variety of fishing gear and may also destroy them. In addition, these weeds serve as breeding grounds for various poisonous snakes and other reptiles. They also help in the spread of diseases like bilharzia. The Oti Basin is affected mainly by domestic and agricultural activities. Pollution is generally slight and localized along the banks as a result of indiscriminate disposal of untreated fecal matter and garbage due to lack of adequate sanitary and waste disposal facilities.

Lower Volta Basin

The main feature of the Lower Volta Basin is Lake Volta which is fed by the three major tributaries: Black Volta, White Volta and Oti. It also includes a series of small rivers flowing directly into Lake Volta, and the portion of the river downstream from the Kpong Dam. It is shared between Ghana and Togo, and the estimated drainage area is 71,608 km^2. The Lower Volta discharges into the Gulf of Guinea in Ghana, near the town of Ada Foah.

4.1.2 Surface Water Quality

The mean pH of the Volta River System varies from 6.9 in the Oti River at Saboba to 7.5 on the Black Volta at Bamboi. The range is not very wide and the water is predominantly neutral (pH 7.0). The maximum level of dissolved salts, in terms of conductivity, is 280.0 μScm^{-1} in the Oti River at Saboba (WARM 1998). The mean suspended solid concentration is generally low, less than 200 mgl^{-1}. The dissolved oxygen concentrations generally indicate low levels of pollution. The mean annual suspended yields in the river basin systems in Ghana are estimated as follows:

Black Volta : 19.97 $tonskm^{-2}yr^{-1}$

White Volta : 21.09 $tons km^{-2} yr^{-1}$
Oti : 53.58 $tons km^{-2} yr^{-1}$

4.1.3 Flooding

The Volta River Basin is characterized by high seasonal rainfall variability, with a distinct dry season, when rivers in most of the northern part of the basin dry up. During the wet season, large areas are flooded, in particular the valleys and low-lying areas along the Black and White Volta rivers and their tributaries (UNDP 2009). In general, heavy floods occur once every 10 years, with notable recent occurrences in 1989, 1999 and 2007 for Ghana (UNDP 2009) and 1988, 1992, 1994 and 1999 in Burkina Faso (UNEP-GEF 2002). Natural floods are linked to high rainfall intensities, exceeding 100 mm in 5 days (C&S COP 2013).

In more recent years, floods have also been attributed to the operation and management of dams, which have caused transboundary problems. These include operations of the Bagré and Kompienga dams in Burkina Faso causing flooding in downstream Ghana and Togo, respectively. Filling of the Lery Dam in Burkina Faso, is causing a backwater effect affecting rice farmers in upstream Mali.

Flooding is a very important phenomenon in the Lower Volta, where seasonal flooding inundates about 51,830 ha of land annually (Barry et al. 2005). It has both negative and positive impacts on the inhabitants of the basin. The annual cycle of flooding in the floodplains has created a productive environment that is being utilized by local farmers for flood-recession farming activities. These are activities practiced throughout the basin. In several countries, these practices are being discouraged because they are considered unsustainable. This is because they have been linked with erosion of the river banks, sedimentation of downstream dams, and other water quality issues. In Ghana and Burkina Faso, policies are in place for protection of the riparian zone, which is in conflict with the local practices of flood-recession agriculture. In addition, flooding creates an environment favorable for different fish types, and seasonal inundated creek fishing is very lucrative. Prior to the construction of the Akosombo Dam, high seasonality of the flows and dynamic saltwater intrusion downstream of the location of the dam created an environment where clams thrived and were easily harvested (salt-fresh water balance and seasonally low flows where, especially women could harvest the clams). With the construction of the Akosombo and Kpong dams, seasonal floods in the Lower Volta have ceased and, as a result, livelihoods have been affected. Coastal flooding is an issue, especially with the Volta River no longer carrying sediments that support the coast line.

Past flooding has caused significant damage to infrastructure, loss of life and loss of livelihoods. Infrastructure that has been affected by floods includes bridges, access roads, buildings and dams. Livelihoods are mostly affected through the destruction of farms, and displacement of people. On several occasions loss of life has occurred, for example, the 2007 flood in Ghana resulted in the loss of 61 lives. Estimates of affected people for some of the flood events that have occurred over the last three decades have been made for Burkina Faso and Ghana.

For Burkina Faso, severe flooding has occurred repeatedly over the past 30 years (in 1988, 1992, 1994, 1999, 2007, and 2009), especially in the north and center of the country, following successive periods of drought. Major crises were recorded in 1972/73 and 1983/84, and minor crises in 1990/91, 1995/96, and 1997/98 (World Bank 2011). In 2007, the National Agricultural Statistics and Forecasting Services reported at least 33,000 ha of farmland being completely inundated by floods between August and September. Two years later in 2009, heavy rainfall once

again flooded crops and washed away 22,220 ha of farmland, breaking 15 dams, and destroying 42,000 homes (Burkina Faso Post-Disaster Needs Assessment 2010).

In Ghana, more than 300,000 people were affected by the flooding of 2007, which was also exacerbated by unexpected water releases from the Bagré Dam (Reuters 2007).

4.1.4 Water Demand

The irrigation water consumptive demand of Ghana is projected by MWH (1998a) to expand by a factor of six between 2000 and 2025 from 565 to 3,605 Mm^3yr^{-1}; and in Burkina Faso, by a factor of two over the same period from 203 to 554 Mm^3yr^{-1} (Andah and Gichuki 2003). Overall, domestic water supply (provided largely by wells in rural regions with water of suitable quality) is projected to increase from 360 to 1,058 Mm^3yr^{-1}; livestock use from 166 to 511 Mm^3yr^{-1}, and irrigation consumption from 1,169 to 6,730 Mm^3yr^{-1}. Overall abstractive use will increase from roughly 1.7 km^3yr^{-1} in 2000 to 8.3 km^3yr^{-1} in 2025, nearly, all of which will be withdrawn at points upstream of the Akosombo hydropower generating facilities. The current and projected water demands in the basin are presented in Table 4.1. Generally, the demand for water in the northern section of the Volta Basin outstrips abstraction. This calls for the judicious use of the available water resources.

TABLE 4.1. Current and projected water demands.

		Mm^3yr^{-1}				% change relative to 2000		
Country	Sector	2000	2010	2020	2025	2010	2020	2025
Benin	Domestic	56	196	336	448	250	500	700
	Irrigation	152	548	1,225	1,600	261	706	953
	Livestock	40	94	133	175	135	233	338
	Total	248	838	1,694	2,223	646	1,439	1,991
Burkina Faso	Domestic	85	106	132	149	25	55	75
	Irrigation	203	384	554	639	89	173	215
	Livestock	46	61	78	88	33	70	91
	Total	334	551	764	876	65	129	162
Côte d'Ivoire	Domestic	4	5	12	14	25	200	250
	Irrigation	19	57	166	276	200	774	1,353
	Livestock	1	2	3	3	100	200	200
	Total	24	64	181	293	167	654	1,121
Ghana	Domestic	138	192	272	284	39	97	106
	Irrigation	565	1,871	3,605	3,733	231	538	561
	Livestock	26	41	63	67	58	142	158
	Total	729	2,104	3,940	4,084	189	440	460
Mali	Domestic	9	13	16	18	44	78	100
	Irrigation	180	219	291	311	22	62	73
	Livestock	34	74	123	142	118	262	318
	Total	223	306	430	471	37	93	111
Togo	Domestic	68	92	123	145	35	81	113
	Irrigation	50	91	133	171	82	166	242
	Livestock	19	22	30	36	16	58	89
	Total	137	205	286	352	133	109	157

(Continued)

TABLE 4.1. Current and projected water demands. (Continued)

Country	Sector	Mm^3yr^{-1}				% change relative to 2000		
		2000	2010	2020	2025	2010	2020	2025
Riparian States	Domestic	360	604	891	1,058	68	148	194
	Irrigation	1,169	3,170	5,974	6,730	171	411	476
	Livestock	166	294	430	511	77	159	208
	Total	1,695	4,068	7,295	8,299	140	330	390

Sources: MWH 1998a; Andah and Gichuki 2003; Laube and van de Giesen 2005; Rodgers et al. 2007.

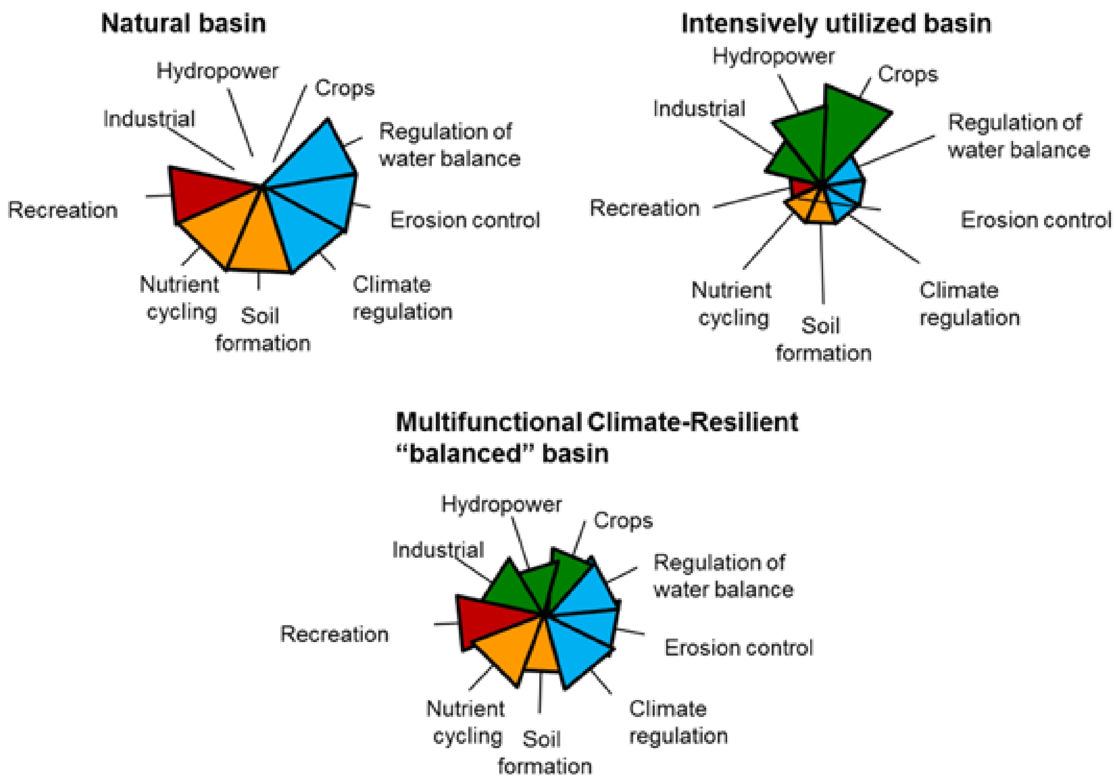
4.2 Natural and Built Infrastructure

Natural and built infrastructure are key features in river basins that affect spatiotemporal water availability. They provide services and functions that are important for economic development and poverty reduction. Although some of the services and functions overlap, such as water regulation and recreation, they also provide distinctive services (Figure 4.2). While concrete-and-steel built infrastructure plays a critical role in water storage and treatment, natural infrastructure can reduce or avoid costs and enhance water services and security, serving alongside necessarily built infrastructural components as part of an integrated system to cost-effectively deliver safe drinking water and other services. Furthermore, built infrastructure development can impact the performance of natural infrastructure by, for example, degrading/flooding wetlands, reducing flood flows from reservoirs, and drying up floodplains. On the other hand, natural infrastructure can support built infrastructure, by regulating water flows and sustaining the operation of the built infrastructure. Development of natural and built infrastructure must therefore be balanced to optimize the set of benefits – energy, food, provisioning and regulating ecosystem functions. This section describes key natural infrastructure (e.g., wetlands) as well as built infrastructure in the form of dams, irrigation schemes, etc. The Ramsar Convention has listed some natural and built infrastructure in the Volta Basin as sites of international importance for birds and other forms of wildlife (Table 4.2).

4.2.1 Wetlands and Lakes

There are several types of wetlands across the Volta Basin, including lakes and wetlands formed in natural local depressions that contain water throughout the year; seasonally flooded valley bottoms; and reservoirs formed by the construction of dams. The Volta Estuary also has key wetland systems in the form of coastal lagoons. These wetlands are of critical importance for the livelihood of local communities. Common activities found in these ecosystems are farming, livestock-rearing and fishing (Johnston and McCartney 2010). In addition, wetland vegetation is used for fuelwood and building materials. Clay and sand are mined in wetlands for construction purposes. These activities can be a threat to the ecosystems as overexploitation of resources (e.g., overfishing or water use) can influence and degrade the ecosystem.

FIGURE 4.2. Multifunctional climate-resilient “balanced” basin.



Source: WLE 2011.

These ecosystems are key sources of water, especially during the dry season. They provide habitat for different types of animals (water-based animals such as crocodiles and hippos), migrating birds and different plants and tree species. Several of these have been identified as Ramsar wetland sites (Ramsar 1971). Natural lakes in the basin include Lac de Dem in Burkina Faso. Natural wetlands along main rivers include La Valley de Sourou in Mali and Burkina Faso and La Mare aux Hippopotames along the floodplains of the Black Volta in Burkina Faso. Various dams have created wetland habitats and are recognized by Ramsar, such as Bagre Dam, and Lac de Bam and Kompienga Dam sites in Burkina Faso. National parks and other important areas with significant water bodies include Zone Humide de la Rivière Pendjari in Benin; Parc National de la Kéran; and Bassin Versant Oti-Mandouri in Togo. In the Volta Estuary in Ghana, the Songor Lagoon and the Keta Lagoon Complex have been included in the list of Ramsar sites. Apart from these nationally and internationally important sites, there are smaller wetlands and lakes that are important for local communities. For example, along the main streams of the Black and White Volta and Oti rivers, seasonally flooded floodplains are of critical importance to local communities; they provide replenishment of groundwater and deposits of fertile soils. In Ghana, these systems are increasingly being used for rice production.

TABLE 4.2. Ramsar sites within the Volta Basin.

Name	Country	Site type	Area (ha)
Zone Humide de la Rivière Pendjari	Benin	Wetland (river basin)	144,774
Lac de Dem	Burkina Faso	Wetland (natural lake)	1,354
Barrage de Bagre	Burkina Faso	Artificial and permanent lake	36,793
Lac de Bam	Burkina Faso	Artificial and permanent reservoir	2,693
La Vallée du Sourou	Burkina Faso	Valley (river basin)	615,000
Barrage de la Kompienga	Burkina Faso	Artificial lake	16,916
Keta Lagoon Complex	Ghana	Open lagoon	38,111
Songor Lagoon	Ghana	Closed lagoon	287,404
Parc National de la Kéran	Togo	National park	163,400
Bassin Versant Oti-Mandouri	Togo	River basin	425,000

Source: UNEP-GEF Volta Project 2013.

4.2.2 Irrigation Infrastructure

There are several small, medium and large reservoirs constructed in the basin primarily for irrigation. The most notable are the Lerinord Seourou (360 Mm^3) and Subinja (135 Mm^3) dams in Burkina Faso, and the Tono (93 Mm^3), Tanoso (125 Mm^3) and Amate (120 Mm^3) dams in Ghana (McCartney et al. 2012). The total storage volume of the irrigation reservoirs in the basin, including the Bagre used for both hydropower and irrigation is about 2,900 Mm^3 and formal irrigation is estimated to cover approximately 30,500 ha. There are also large numbers of small reservoirs with an estimated total storage capacity of approximately 232 Mm^3 located in the basin (Liebe et al. 2005; de Condappa et al. 2009). Table 4.3 presents the irrigation potentials of the riparian countries and Annex 2 illustrates irrigation schemes in the basin.

TABLE 4.3. Irrigation potential in the Volta Basin.

Country	Irrigation potential (ha)	Water requirement ($m^3ha^{-1}yr^{-1}$)	Potential total water requirement (km^3yr^{-1})
Benin	30,000	20,000	0.6
Burkina Faso	142,000	10,000	1.42
Côte d'Ivoire	25,000	20,000	0.5
Ghana	1,200,000	20,000	24
Mali	0	8,500	0
Togo	90,000	23,000	2.07
Total	1,487,000	91,500	28.59

Source: UNEP-GEF Volta Project 2013.

4.2.3 Hydropower

Hydroelectricity is considered a nonpolluting and environmentally friendly option for renewable energy, and is more economically attractive than other options. The World Energy Assessment (UNDP 2000) estimated that only a third of the sites classified as economically feasible for hydropower infrastructure are tapped worldwide, with a large majority of untapped sites situated

in the developing world. Hydropower generation is a major nonconsumptive water use in the Volta Basin. Hydropower is a relatively cheap way of generating power and supports major industries (e.g., mining, aluminum, etc.) in Ghana and is also exported to neighboring countries (Owusu et al. 2008). It is worthy of note that the basin has been experiencing an exponential increase in the demand for energy over the years, but an expected increase in generation capacity to match the demand has not occurred (MoP 2015). This has resulted in power shortages in Ghana and other riparian countries.

4.2.4 Inventory of Existing and Planned Hydropower Schemes in the Basin

Hydropower has the potential to contribute to solving the energy needs of the riparian countries. In the last 50 years, several dams have been constructed in the basin with the primary purpose of generating electricity and sometimes for irrigation (Table 4.4 and Figure 4.3). By the close of 2014, six hydropower plants within the basin were operational with the latest being Bui, commissioned in May 2013 on the Black Volta River. Bui, with a capacity of 400 MW is the second largest hydropower plant within the Volta Basin after the Akosombo Dam. The reservoir created by the dam, flooded about 20% of the Bui National Park and impacts the habitats of the rare black hippopotamus as well as a large number of wildlife species. It required the resettlement of 1,216 people, and affected many more (IIED 2014). In addition to the major dams at Akosombo, Kpong, Kompienga, Bagré and Bui, there is a new dam currently under construction in Burkina Faso mainly for hydropower generation at Samandeni on the Black Volta. Several other small hydropower schemes are planned for construction in the basin in the near future.

TABLE 4.4. Existing and planned hydropower dams in the Volta Basin.

Name of dam	Subbasin	Country	State	Year	Capacity (MW)
Akosombo	Lower Volta	Ghana	Existing	1964	1,020
Kpong	Lower Volta	Ghana	Existing	1981	160
Bui	Black Volta	Ghana	Existing	2013	400
Kompienga	Oti	Burkina Faso	Existing	1984	14
Bagre	White Volta	Burkina Faso	Existing	1992	16
Batchanga	Oti	Benin	Incomplete		15
Samendeni	Black Volta	Burkina Faso	Planned		2.4
Noumbiel	Black Volta	Burkina Faso	Planned		48
Juale	Oti	Ghana	Planned		87
Arli	Oti	Burkina Faso	Planned		0.92
Pwalugu	White Volta	Ghana	Planned		50
Kulpawn	White Volta	Ghana	Planned		40
Daboya	White Volta	Ghana	Planned		43
Bandongo	White Volta	Burkina Faso	Planned		3
Bagre Aval	White Volta	Burkina Faso	Planned		14
Koulbi	Black Volta	Ghana	Planned		68
Ntereso	Black Volta	Ghana	Planned		64
Jambito	Black Volta	Ghana	Planned		55
Lanka	Black Volta	Ghana	Planned		95

(Continued)

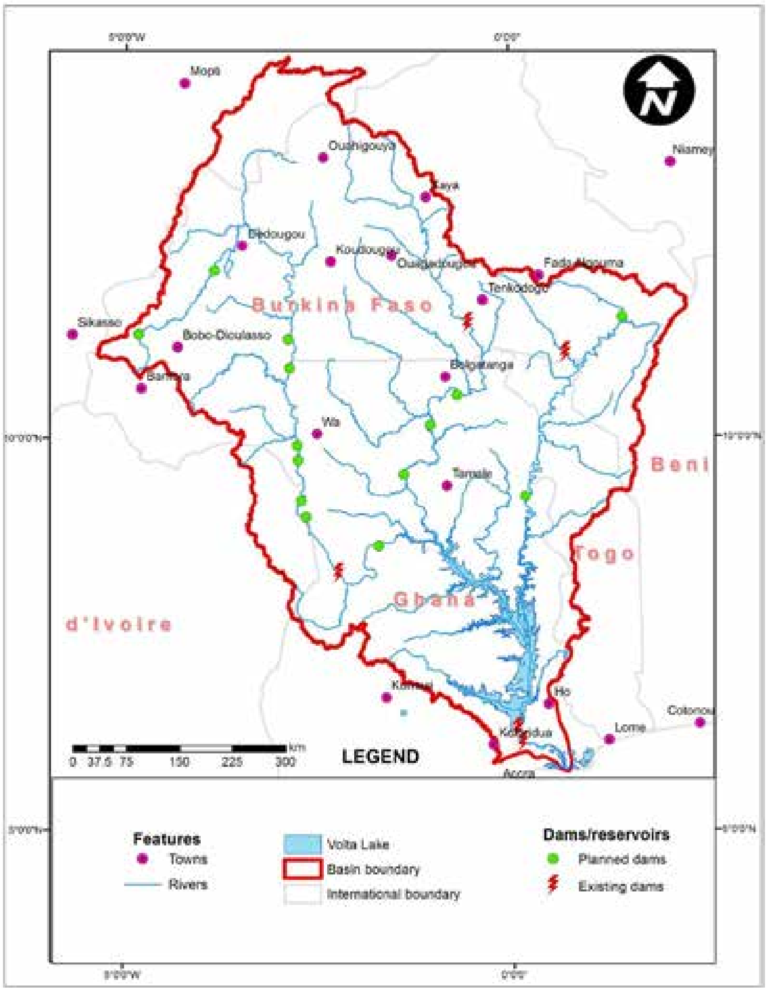
TABLE 4.4. Existing and planned hydropower dams in the Volta Basin. (Continued)

Name of dam	Subbasin	Country	State	Year	Capacity (MW)
Bon	Black Volta	Burkina Faso	Planned		7.8
Bontioli	Black Volta	Burkina Faso	Planned		5.1
Bonvale	Black Volta	Burkina Faso	Planned		0.3
Gongourou	Black Volta	Burkina Faso	Planned		5
Landa Pozada	Oti River	Togo	Planned		-
Tihalea	Oti River	Togo	Planned		-

Source: McCartney et al. 2012.

There are no hydropower dams in the Volta Basin in Mali, Côte d'Ivoire or Togo (UNEP-GEF Volta Project 2013). However, two are planned on the tributaries to the Oti River in Togo. According to Lemoalle and de Condappa (2009) the construction of the Bui Dam may compromise a proposed dam in Noumbiel (Burkina Faso/Ghana), some distance upstream on the Black Volta, as it floods the proposed site. In Burkina Faso, the Bagré Reservoir is used for both hydropower and irrigation, whilst Kompienga is used only for hydropower. Both reservoirs are very sensitive to rainfall variability because of their location in the upper drier part of the basin (Lemoalle and de Condappa 2009).

FIGURE 4.3. Location of existing and proposed dams in the Volta Basin.



4.2.5 Environmental Impacts of Hydropower

The environmental impact of hydropower plants in the Volta Basin can best be illustrated using the Akosombo Dam, the first to be constructed in the basin.

The Akosombo Dam flooded large areas of land and displaced over 80,000 people (Tsikata 2006). The loss of land and relocation brought about loss of primary economic activities from fishing and agriculture, and this ultimately affected community stability. Insufficient planning resulted in the relocation of communities into areas that were not capable of providing for their former livelihoods and traditions. The growth of intensive agriculture as a result of massive loss of farm lands to the construction of the dam has led to a rise in fertilizer runoff into the river. This process, along with runoff from nearby cattle stocks and sewage pollution, has caused nutrient enrichment of the river waters. The nutrient enrichment, in combination with the slow water movement, has allowed for the invasion of aquatic weeds, such as water hyacinth, which block navigation and transportation. These weeds can crowd out other river animal and plant life. The weeds also provide habitat for the black fly, mosquitoes and snails, which are the vectors of waterborne illnesses such as bilharzia and malaria. Additionally, the degradation of aquatic habitat has resulted in the decline of downstream shrimp and clam populations, impacting negatively on the rural and industrial economies.

Following the construction of the Akosombo Dam, there has been a steady decline in agricultural productivity along the lake and its tributaries. This is as a result of the cessation of the periodic flooding that brought nutrients to the soil before the natural river flow was halted by the construction of the dam. Akosombo Dam has also cut off the supply of sediment to the Volta Estuary, affecting also neighboring Togo and Benin.

5. ECOSYSTEM SERVICES

Ecosystems occurring in the Volta Basin are highly dependent on the climatic zone in which they occur. The main ecosystems occurring in the Volta Basin are dense forests, semi-deciduous forests, dry deciduous forests and woodlands, and savannas and steppes (UNEP-GEF Volta Project 2013). Apart from the terrestrial ecosystems which are influenced much by the climate, the dense river networks (with perennial lakes and ponds) create conditions for aquatic and riparian ecosystems, which are of key importance, especially in the drier parts of the river basin. Marine and coastal ecosystems are also found in the most southern part of the basin.

These different ecosystems provide a variety of different ecosystem services, and sustain different livelihoods (Lemoalle and de Condappa 2009).

The Millennium Ecosystem Assessment (MA 2005) identifies four different categories of ecosystem services: provisioning services; regulating services; cultural services; and supporting services. Provisioning services consider products that are directly obtained from the ecosystems such as food, freshwater, fuel, wood, fiber and medicines. Regulating services constitute benefits that are obtained by regulating ecosystem processes. This includes climate regulation, flood regulation, disease regulation, and water purification. Cultural services are defined as material and nonmaterial ecosystem benefits such as aesthetic, spiritual, educational, and recreational benefits. Supporting services are services that are necessary for the production of all other ecosystem services such as soil formation, nutrient cycling, and primary production. The section below describes some of these ecosystem services that are found in the Volta River Basin, followed by a section that describes the challenges facing the sustenance of these services. The information is

mainly derived from the GEF-Volta Study on ecosystems in the Volta Basin (UNEP-GEF Volta Project 2011).

5.1 Provisioning Services

5.1.1 Food

Ecosystems across the Volta Basin provide different food products, of which some are traded regionally and even internationally. Tree species such as Shea, Dawadawa and Baobab provide various products which include oil, butter, seeds, fruits, etc. These products are consumed fresh, dried or prepared in various ways. Several refined ecosystem services products such as almond butter, vegetable oil, honey, and palm wine are also available.

Ecosystems provide habitats for different types of species that are collected and consumed. This includes both organisms inhabiting in the terrestrial ecosystems and the aquatic ecosystems. Forest ecosystems provide habitats for edible mushrooms, snails and game. Other animals that are consumed in the basin include, insects such as locusts, grasshoppers, crickets, termites, and larvae and eggs of certain species. A few nonpoisonous species of amphibious reptiles and snakes are also consumed. Different bird and mammal species are hunted and consumed in the basin. A variety of these species are sold on the market for consumption and also for the use of their parts such as the skin.

Fishing is the primary livelihood of many residents around the main surface water bodies, both natural and artificial (such as the Volta Lake). The majority of the fish species found in the basin are edible. Along the shoreline of the Volta Lake are about 1,232 fishing villages inhabited largely by impoverished rural populations whose main source of livelihoods relates primarily to fishing activities in the Lake. In addition, the coastal zone is a great contributor to the provisioning services of fish, mussel and crab species. It is estimated that over 80,000 fishers, 20,000 fish processors and traders are involved in Lake Volta fishing. There are 17,500 canoes actively fishing in the Lake Volta (Braimah 1995). Although the fish production is large, it is insufficient for the local market, and large amounts of fish are imported annually.

5.1.2 Wood and Other Materials

Tree stems and leaves of specific trees are used as building materials, either as poles or roofing materials. Tree stems are also used to make tools such as mortars and pestles. Specific leaf types are used for mats, hats and fans. Other products that have used forest materials include brooms, toothpicks, sponges, chairs and baskets. Trunks of some timber species and coconut trees are used for the construction of canoes. Most of these products are sold at local markets.

5.1.3 Energy Products

Wood and other biomass are the common energy sources in the basin especially for cooking. The population in the basin is dependent on wood from forests for about 70-90% of their energy supply. Energy products consist of firewood and charcoal. These serve as subsistence income for many households since they are sold as a source of energy for towns and cities. The women are usually involved in collection of fuelwood. Unsustainable harvesting of these products contributes to the degradation of forest and savanna ecosystems.

5.1.4 Timber

Timber products can be found across the different forest ecosystems, from the dense forests, semi-deciduous forests to the dry deciduous forests.

5.1.5 Medical and Pharmaceutical Products

Medicinal and pharmaceutical products are derived from various forest and wetland products in the basin. The leaves, barks, seeds and roots of a range of plant species are used to treat different ailments. A variety of pharmaceutical and medicinal products are also derived from the fauna that inhabit the ecosystems in the basin.

5.2 Regulating Services

There are different types of regulation services taking place in the Volta Basin. The focus of this project is on the regulation of water flows, water quality and erosion control. Land use and land use change influence the regulating capacity of different ecosystems. Changes in land use affect rainfall partitioning, increasing or decreasing evaporation and infiltration and, in turn, affecting water availability downstream (increasing or decreasing water yield of an area), as well as influencing flood flows (peak flow, duration, etc.). Erosion has been noted as a major concern in the basin, affecting fertility of the soil and, therefore, agricultural productivity and the life span of small and large dams through sedimentation. Sedimentation along the main rivers also causes problems to the riparian communities, which are more prone to flooding as a result.

5.3 Cultural Services

Forest ecosystems provide products used to produce attributes that are used in cultural displays, such as masks, flutes and drums. In addition, several species of reptiles, amphibians, fish and mammals are traded at local markets for cultural ceremonies. Various species also appear in local legends and rituals, and are used for traditional therapies. Traditional symbols also depict various animals and plants. In addition, many sacred forests and places of cultural interest are found in the basin, especially, in mountainous and rocky areas, e.g., Tongo Hills and Tengzug Shrines in the Upper East Region of Ghana.

The Volta Basin has a number of national parks, wildlife reserves, and other protected areas which tourists visit to watch animals in their natural habitat (Table 5.1; Figure 5.1). Bird-watching is an important touristic activity, both for water birds (in particular in Mali and Burkina Faso) and for parrots in forest reserves. Several of the national parks in the basin provide opportunities to view large mammals. Crocodiles and pythons and, for a minor part, tortoises and reptiles also attract tourists (e.g., Paga crocodile pond in the Upper East Region of Ghana). Freshwater sports-fishing also occurs in various areas in the basin.

TABLE 5.1. Protected areas in the Volta Basin.

Country	Name	Area (ha)	Country	Name	Area (ha)
National parks			*Other types of reserves*		
Benin	Pendjari National Park	1,250,000	Benin	Pendjari Biosphere Reserve	144,774
Burkina Faso	Arly National Park	93,000	Burkina Faso	Koulbi Forest	40,000
	Pô National Park	155,500		Boulon Koflandé Forest	42,000
	Park des Deux Balé	80,600		Pâ Forest	11,000
Côte d'Ivoire	Comoé National Park	1,149,450		Sissili Forest	35,330
Ghana	Bui National Park	182,100		Tapoa Djerma hunting concession	35,000
	Kyabobo National Park	20,000		Koakrana hunting concession	25,000
	Mole National Park	457,700		Pagou Tandougou hunting concession	39,335
Togo	Fazoa-Malfakassa	192,000		Ougarou hunting concession	64,469
	Oti Keran	69,000		Konkonbouri hunting concession	64,608
Wildlife reserves				Sissili hunting concession	32,700
Burkina Faso	Bontioli	42,200		Sa Sourou hunting concession	19,400
	Singou	192,800		Mare aux hippopotamus Biosphere Reserve	19,200
	Kourtiagou	51,000	Côte d'Ivoire	Comoé Biosphere Reserve	1,150,000
	Pama	223,700	Ghana	Kogyae Integrated Reserve	38,600
Togo	Oti-Mandouri	110,000		Agumatsa Biodiversity Sanctuary	300
	Galangachi	12,490		Gbele Production Reserve	56,500
				Kalakpa Production Reserve	32,500
			Mali	Douentza (Gourma) Elephant Reserve	1,200,000
				Segue Natural Forest	83,200
				Samory Forest	245,000
			Togo	Assoukoko Forest	10,000

Source: UNEP-GEF Volta Project 2013.

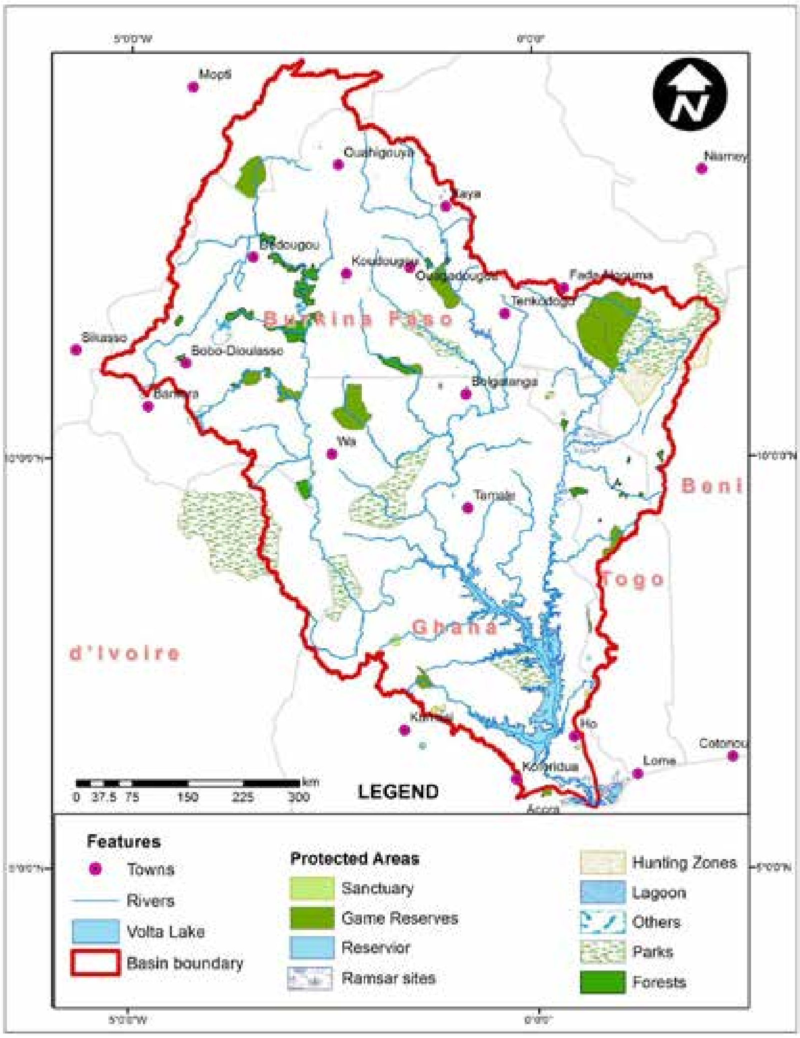
5.4 Supporting Services

Forest ecosystems contain different types of bacteria and mushrooms which create an environment that contributes to enriching the soils, by binding nutrients and therefore contributing to nutrient regulation. Fauna in these ecosystems also contribute to the supporting services, improving the soil quality and structure and help with pollination.

5.5 Drivers Affecting Ecosystem Services

Over the years the extent and quality of the ecosystems in the Volta Basin have been affected and they are continuously being degraded. There are several anthropogenic drivers that are affecting ecosystems and their services. Fragmentation and destruction of ecosystems are due to agricultural expansion, exploitation of forests, increasing production of bioenergy, mining activities, built infrastructural development (including that for water resources development) and urbanization. Overexploitation of ecosystems due to poaching (wildlife and fish) as well as illegal logging is common. Sources of aquatic pollution are agricultural (herbicides and pesticides), erosion

FIGURE 5.1. Map of the Volta Basin showing important reserves.



Source of data: Google Earth, 2015

(affecting turbidity and eutrophication), industrial pollution, and domestic pollution. Unsustainable management practices in agriculture, forestry and livestock-rearing are also causing destruction of ecosystems. Invasion of exotic species is due to the lack of control in the introduction of new species, and absence of natural enemies. Global increases in anthropogenic gas emissions are affecting the climate. These causes lead to the reduction in quantity and quality of biodiversity in the ecosystems in the Volta Basin.

5.6 Macro-Level Ecosystem Services Assessment

The first step in the ecosystem services mapping of the WISE-UP project was a technical session organized during the first stakeholders' meeting. The meeting in the Volta Basin was attended by participants from the Volta Basin Authority, Volta River Authority, Environmental Protection Agency, and other governmental and nongovernmental organizations. The information gathered was then corroborated with a literature review and other relevant documents. The aim of the exercise was to have a rapid assessment of important ecosystem services in the Volta Basin.

5.6.1 Approach

A mapping exercise was introduced following a general presentation on what ecosystem services are and what the project intends to do on ecosystem services mapping. The four categories of ecosystem services considered were: provisioning services, regulating services, cultural services, and supporting services. The stakeholders were split into groups of 3-5 persons and asked to indicate on Volta Basin maps, where important ecosystem services are, and to indicate to which categories they belong. The participants were encouraged to write additional information where available. This exercise resulted in eight different maps of the Ecosystems in the Volta Basin. The following describes the main ES that were identified and provides a short description of each, based on information obtained from literature.

5.6.2 Findings

From the eight maps received, two focused only on Burkina Faso, one mapped ES in both Burkina Faso and Ghana and the other five mapped ES in Ghana only. The ES mapped in Burkina Faso seems to be much more concentrated around key features in the basin, whereas the ES mapped in Ghana included some more general ES mapped across Ghana. Figure 5.2 shows the combined maps, showing the four different ecosystem services. Altogether 321 stickers, representing four different types of ecosystem services were placed. Not surprisingly, the major group of services identified was provisioning services, though other services were also well represented. It was also noticed that the groups indicated different types of ecosystem services provided by one site; this was especially the case for the Burkina Faso maps. The sites can be grouped into:

1. Natural ecosystems, such as forests, natural lakes and wetlands, which are, sometimes also, classified as national parks and/or protected areas.
2. Built infrastructure, such as dams, providing different types of services (in some instances even all four services groups).
3. Important cultural services, such as historical and tourist places.

Most services that were mapped had a link to the surface water resources, as requested. For some maps, additional information was provided by text added to the maps and tables indicating for example, the name of the site and type of ecosystem service.

From the text added to the maps and comparing the identified locations to Google maps and other supporting documents, the following list of ecosystems that provide key ecosystem services was derived for the Volta Basin. The ecosystems are categorized into the three main groups identified earlier (natural systems; built infrastructure; and ecosystems harboring important cultural services, see also Figure 5.3 for locations).

Figure 5.2. Map showing combined ES mapped by high-level stakeholders (Annex 3 shows the eight individual maps and the participants in each group).

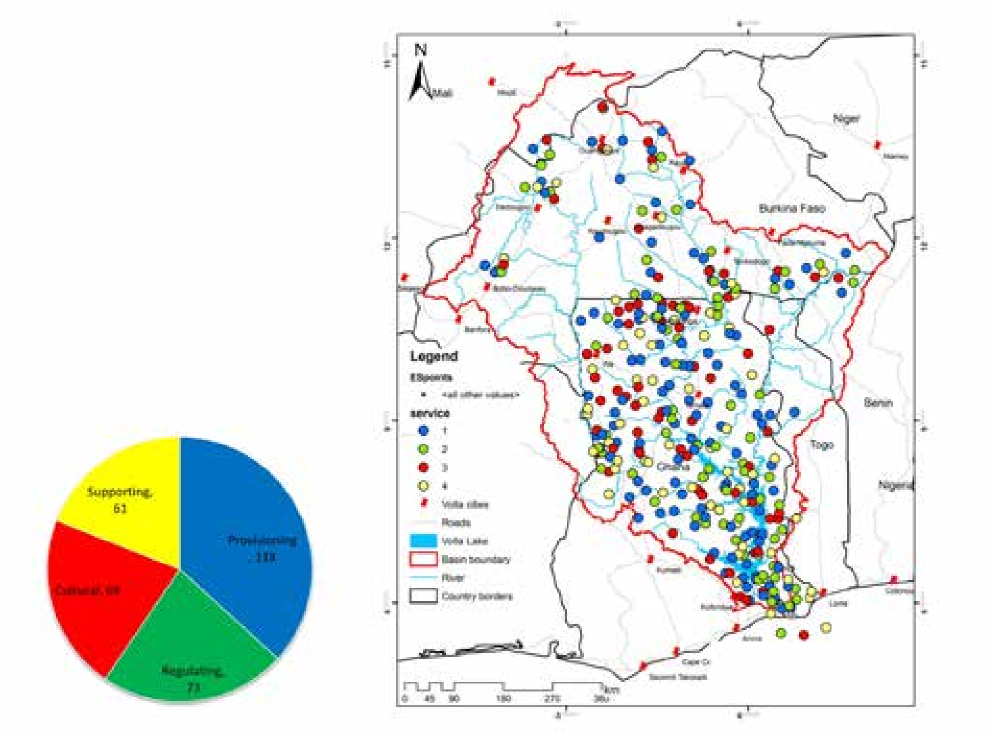
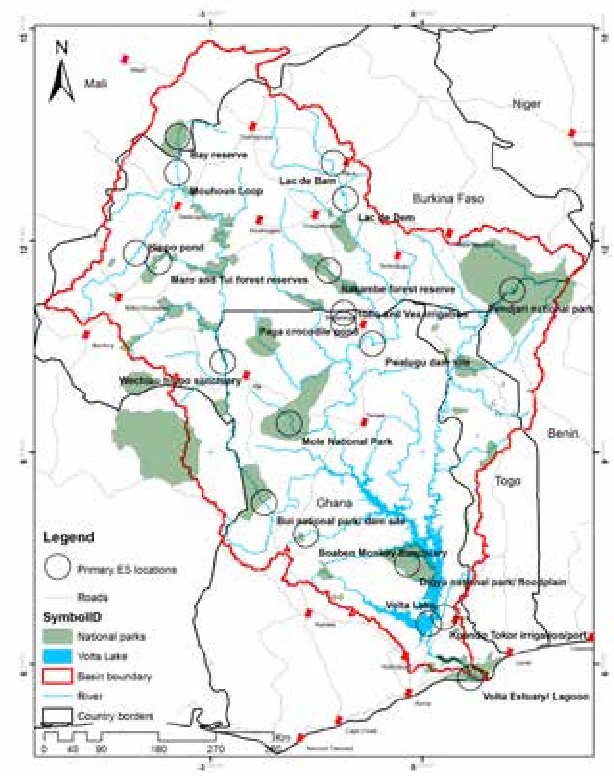


Figure 5.3. Identified ES in the Volta Basin derived from the high-level stakeholder mapping exercise.



Burkina Faso

Maro and Tui forest reserves
These two forest reserves are located in the headwaters of the Bougouriba River, a tributary of the Black Volta.

Hippo Pond (Mare aux Hippopotame)
The hippo pond in the Black Volta River is a Ramsar Site, with over 100 hippos. It consists of pools and marshes which are flooded during the flood season.

Mouhoun Loop/Bay Reserve
The Souhou River originates in Mali, where a large floodplain is located along the river. It joins the Black Volta near the Mouhoun loop, where the Black Volta makes a sharp turn before heading southwards.

Lac de Bam and Lac de Dem
These two lakes are natural lakes located in the White Volta Basin. Although the streams entering and leaving these two lakes are intermittent, the lakes have a permanent supply of water. Both lakes are utilized, Lac de Bam for some small-scale irrigation, and Lac de Dem for domestic water use.

Nakambe Forest Reserve
The Nakambe Forest Reserve is situated along the Red Volta River in Burkina Faso. The Red Volta River joins the White Volta in Ghana after the proposed Pwalugu dam site.

Various large- to medium-scale dams in the White Volta Basin (e.g., Ziga/Bagré/Kompienga)
There have been some developments in terms of constructing medium to large dams in Burkina Faso. Two of these dams are classified as important ecological reserves by the Ramsar convention (Kompienga and Bagre in Burkina Faso) and provide habitats for aquatic species and migrating birds.

National parks in the headwaters of the Oti River Basin
In the headwaters of the Oti River Basin are four national parks which together form the transboundary Niger 'W' national park. The parks are Penjari in Benin, and Arli, Singou and Pama in Burkina Faso. The parks consist of some perennial rivers and floodplain areas.

Ghana

Lower Volta Basin/Keta Lagoon System
Downstream of the Akosombo and Kpong dams is the Volta Estuary. The production of the area is dependent on the flows released from the two dams. Fisheries and other aquatic resources thrived under the historical dynamic flow conditions. In particular, the dynamic saltwater gradient supported the clam and oyster production. The current steady flow regime is supporting a limited number of fish species, predominantly freshwater fish. Clams and oysters are still harvested but only in the most downstream part of the Lower Volta. The area of mangroves has declined, affecting the spawning grounds for the fish.

Volta Lake
The Volta Lake was created when the Akosombo Dam construction was completed in 1966. With a total surface area of more than 8,000 km^2, the lake provides a large part of the fish demand of Ghana. In addition, the lake facilitates north-south transport. Several groups indicated the islands formed inside the Lake after construction and filling of the dam, to be potential sources for cultural services.

Vea and Tono reservoirs
These two reservoirs located in the Upper East Region are constructed for irrigation, and provide various ecosystem services, year-round water supply, fishing opportunities and habitats for migratory birds.

Paga Crocodile Pond
The Paga Crocodile Pond is located along the road from Bolgatanga to Ouagadougou, near the Ghana-Burkina Border. The site is frequented by travelers along this road. It is not clear if this site is linked to the main river system.

Mole National Park
This is the largest national park in Ghana, with two ephemeral rivers (Mole and Lovi) running through it. The park houses large communities of elephants, hippos, buffalos and a variety of antelopes.

Bui National Park/Dam
The Bui National Park was established in 1971 and hosts a large community of hippos. Part of the park is inundated by the construction of the Bui Dam.

Wechiau Hippo Sanctuary
The Wechiau Hippo Sanctuary is a community-based project, stretching along 40 km of the Black Volta, bordering Ivory Coast, and harboring a large community of hippos.

Digya National Park
Digya National Park is located along the shores of Lake Volta, and is the oldest reserve in the country. It houses some primate species and elephants.

Boaben Monkey Sanctuary
This monkey sanctuary is another example of a community-based project. The area is considered a sacred site, with local customs prevailing.

Gbele Resource Reserve
This is a nature reserve with open savannah landscape, housing a variety of species.

Pwalugu Multipurpose Dam/ Gambaga Forest Reserve
The proposed site for the Pwalugu Dam is located in the White Volta Basin. The reservoir is expected to partially flood the Gambaga Forest Reserve, which houses a variety of bird species. Approximately 25% of the reserve is expected to be lost with the construction of the dam.

Kpando Tokor irrigation/port
One key feature along the Volta Lake is the port located at Kpando Tokor. In addition, this area uses water from the Volta Lake directly for irrigation (356 ha).

5.7 Selection of Nodes and Subbasins

This baseline report for the Volta Basin shows the large heterogeneity that occurs in the basin and the large number of natural and built infrastructural features it contains. This last section of the report presents an overview of the key elements of natural and built infrastructure identified that play a significant role in the Volta River Basin. The built infrastructural features consist of both existing and planned structures (mainly dams and irrigation schemes). The contributing catchments are also grouped into subbasins which are relatively homogeneous. This selection of nodes and subbasins will be used for the further analyses to be done in the WISE-UP to Climate project and are consistent with the water resources system model schematization. The selected subbasins will be the focal point for the ES mapping exercise, and ecosystem services will be aggregated in these subbasins and included in the water system (model) at downstream "nodes".

The selection of nodes and subbasins for the basin-wide analyses was done following a number of criteria.

- The nodes should be consistent with the SWAT nodes, which have been located at strategic points.
- Key natural and built infrastructure should be represented at these nodes.
- Nodes can be located at the confluences of major subbasins.

Altogether, 19 subbasins and 20 nodes were identified (Figure 5.4 and Table 5.2).

FIGURE 5.4. Map of subbasins and nodes for the Volta Basin..

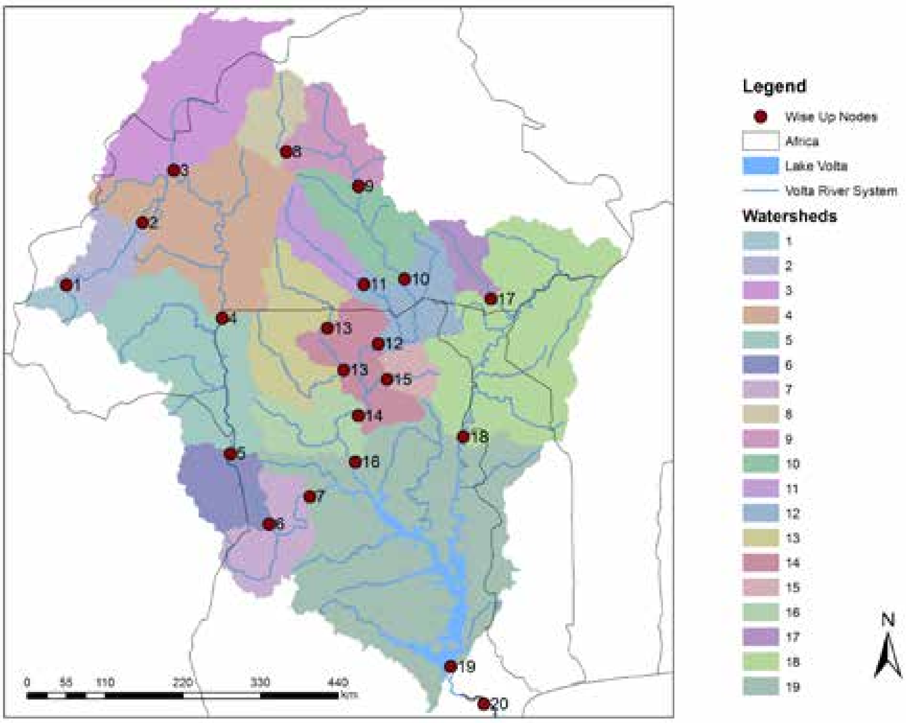


TABLE 5.2. Overview of nodes and key features of the subbasins.

ID	Local name of river	Subbasin	Country	Natural infrastructure	Built infrastructure
1	Mouhoun	Black Volta	Burkina Faso		Samendeni Dam (proposed, 610 Mm^3, 5,000 ha, 2.4 MW)
2	Mouhoun	Black Volta	Burkina Faso	Downstream of Hippo pond	Bonvale Dam (proposed, 130 Mm^3, 0.3 MW); Nwokuy River irrigation (3,291 ha)
3	Souhou / Sourou	Black Volta	Burkina Faso/ Mali	Floodplain 'Bay reserve'/ Mouhoun Loop and associated ES (flood recession agriculture, irrigation, bird migration)	Lery Dam located on Sourou River flooding upstream floodplain. (existing, 9,646 ha, 360 Mm^3)
4	Mouhoun	Black Volta	Burkina Faso	Maro and Tui forest reserves on tributary	Bon Dam (proposed, 2,000 Mm^3, 7.8 MW); Dapola River irrigation (1,362 ha);Bontioli Dam (proposed, 320 Mm3, 5.1 MW)
5	Black Volta	Black Volta	Burkina Faso/ Ghana	Downstream of Wechiau hippo sanctuary	Koulbi Dam (proposed, 2,950 Mm^3, 68 MW); Noumbiel Dam (proposed, 11,300 Mm^3, 7,800 ha, 48 MW); Ntereso Dam (proposed, 1,370 Mm^3, 64 MW)
6	Black Volta	Black Volta	Ghana	Bui National park	Bui Dam (existing, 12,570 Mm^3, 30,000ha (proposed), 400MW)
7	Black Volta	Black Volta	Ghana		Jambito Dam (proposed, 760 Mm^3, 55 MW)
8	Nakambe	White Volta	Burkina Faso		Kanonzoe Dam and Wayen Irrigation
9	Nakambe	White Volta	Burkina Faso		Ziga Dam (domestic water use Ouagadougou)
10	Nakambe	White Volta	Burkina Faso	Ramsar site	Bagre Dam (1,700 Mm^3, 4,695 ha (30,000ha proposed), 10 MW)
11	Red Volta	White Volta	Ghana		Nangodi River irrigation (184 ha)
12	White Volta	White Volta	Ghana		Pwalugu Dam (proposed, 3,260 Mm^3, 20,000 ha, 50 MW)
13	Kulpawn, Sissilli	White Volta	Ghana	Gbele game production reserve Sissili forest	Kulpawn-Sissilli irrigation scheme
14	White Volta	White Volta	Ghana	Nanzinga forest reserve	Daboya Dam (proposed, 3430 Mm^3, 43 MW)
15	Nasia	White Volta	Ghana		Small-scale valley irrigation
16	White Volta	White Volta	Ghana	Mole National park	
17	Kompienga	Oti	Burkina Faso	Ramsar site	Kompienga Dam (existing, 2,025 Mm^3, 14 MW)
18	Oti	Oti	Ghana	Several forest reserves including Pendjari in Benin	Juale Dam (proposed, 87 MW)

(Continued)

TABLE 5.2. Overview of nodes and key features of the subbasins. (Continued)

ID	Local name of river	Subbasin	Country	Natural infrastructure	Built infrastructure
19	Akosombo	Lower Volta	Ghana	Volta Lake & associated ES, floodplains around Volta Lake (including Digya National Park)	Akosombo Dam (existing, 144,000 Mm^3, 1,020 MW)
20	Kpong	Lower Volta	Ghana	Estuary, clam production and fisheries	Kpong (existing, 150,000 ha (proposed), 160 MW)

6. CONCLUSIONS

The Volta River Basin provides a range of benefits to the people in the riparian countries. These benefits are derived from natural freshwater ecosystems, and are enhanced by built infrastructure. Benefits derived from the natural freshwater ecosystems used by riparian communities consist of food (fishing, flood-recession agriculture); water (domestic and livestock); fuel (firewood); construction materials (poles, timber), amongst others. At a larger scale, freshwater ecosystems supply water of sufficient quantity and quality, reduce floods and support baseflow. Built infrastructure can provide similar services such as water supply and flood protection and, in addition, it also generates benefits in conjunction with natural infrastructure - such as hydropower and provides water for irrigation.

Due to these positive benefits, the development of additional built infrastructure is high on the agenda in the Volta Basin. Currently, there are six hydropower dams in the basin with a total installed capacity of 1,610 MW. Nineteen additional dam locations have been identified, adding an estimated 550 MW installed capacity to the hydropower pool. Irrigation in the basin is largely private smallholder irrigation, using small-scale individual pumps with water derived from small reservoirs. Only an estimated 30,000 ha are currently part of public irrigation schemes. Irrigation potential (based on land suitability) in the basin is very high, with an estimated 1.5 Mha undeveloped. However, the required water for all this irrigation is unlikely to be available. Irrigation development is however expected to increase.

The transboundary diagnostic analysis commissioned by the VBA identified five major concerns for the Volta Basin: changes in water quantity and seasonal flows; degradation of ecosystems; water-quality concerns; governance and climate change. Built infrastructure development has contributed to these concerns, by reducing flows due to abstraction, and altering the natural flow regimes through dam operation in favor of hydropower production.

Built and natural infrastructure are co-dependent, and degradation of natural infrastructure, through land use degradation can affect the performance of the built infrastructure. For example, erosion of the degraded landscape can fill up downstream reservoirs and reduce the live storage capacity. On the other hand, natural infrastructure can be affected by the construction and management of built infrastructure, through upstream impoundment, changing flow regimes and reducing flows. The future development and management of built infrastructure will not only bring benefits but has also the potential to further degrade natural infrastructure. Basin development should therefore take a holistic approach and include natural infrastructure in the basin development plans.

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ANNEXES

Annex 1. Existing Irrigation Schemes in the Volta Basin.

Name	Subbasin	Command area (ha)			Storage capacity (Mm³)
		Potential	Developed	Irrigated	
Ghana					
Golinga	White Volta	100	40	20	1.23
Libga	White Volta	40	16	16	0.76
Botanga	White Volta	570	570	570	25
Tono	White Volta	3,840	2490	2490	92.6
Vea	White Volta	1,197	852	468	17
Subinja	Black Volta	121	60	18	River Subin
Afife	Lower Volta	950	880	880	31.4
Aveyime	Lower Volta	150	63	59	Lower Volta River
Kpando-Torkor	Lower Volta	356	40	10	Lower Volta River
Amate	Lower Volta	202	101	101	Volta Lake
Dedeso	Lower Volta	400	20	20	Volta Lake
Kpong	Lower Volta	3,028	2786	616	Lower Volta River
Tanoso	Lower Volta	116	64	47	0.04
Akumadan	Lower Volta	1 000	65	40	5.2
Sata	Lower Volta	56	34	34	Sata Stream
Burkina Faso					
Bagre	White Volta	30 000	2,140		Bagre Dam
Sourou	White Volta	30, 000	2,000		
Loumbila	White Volta	1,000	60		42
Savili	White Volta	700	42		
Tensobenenga	White Volta	200	100		
Yako Kanozoe	White Volta			5,319	75
Nangodi	White Volta			184	Nangodi River
Nwokuy	Black Volta			3,291	Nwokuy River
Noumbiel	Black Volta			230	Noumbiel River
Dapola	Black Volta			1,362	Dapola River
Lerinord-Seourou	Black Volta			9,646	360

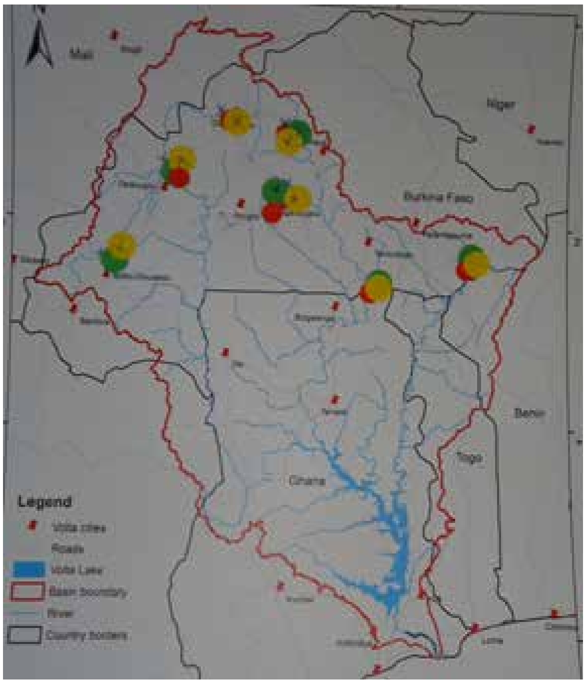
Source: McCartney et al. 2012; Namara et al. 2011; Ofosu 2011.

Annex 2. Planned Irrigation Schemes in the Volta Basin.

Name	Subbasin	Potential command area (ha)	Storage capacity (Mm^3)
Ghana			
Bagri	Black Volta	100	
Duuli	Black Volta	150	
Gbari	Black Volta	100	
Bui	Black Volta	30,000	12,570
Asantekwaa	Lower Volta	200	
New Longoro	Lower Volta	200	
Buipe	White Volta	200	White Volta River
Yapei	Black Volta	200	Black Volta River
Pwalugu	White Volta	-	White Volta River
Dipala	White Volta	100	
Sogo	White Volta	100	
Tiego Yarigu	White Volta	200	
Sambolekuliga	White Volta	200	
Daboya	White Volta	50	
Accra Plains (includes existing Kpong)	Lower Volta	11,000	Lower Volta River
Burkina Faso			
Noumbiel	Black Volta	7,800	11,300
Samendeni	Black Volta	5,000	610
Togo			
Namiele	Oti	1,250	
Wakuti	Oti	1,350	

Source: McCartney et al. 2012.

Annex 3. ES Maps Produced by the Eight Groups.



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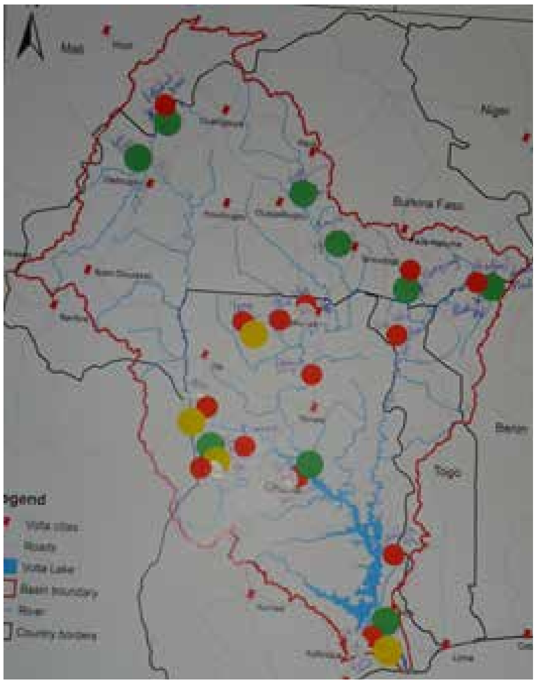
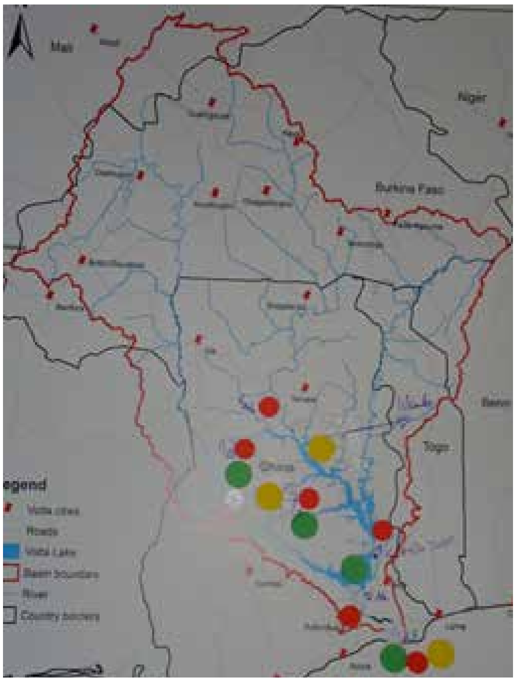
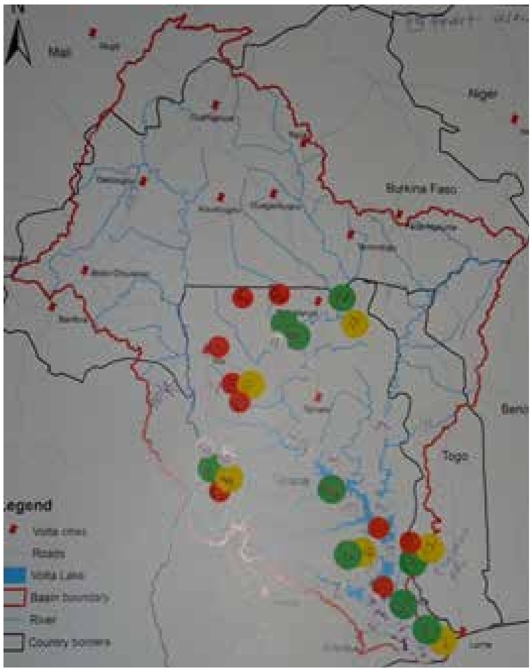
Sawadogo Hawa - GCBF
Compaore Emmanuel - INERA
Konditamde P. Yolande – APIPAC



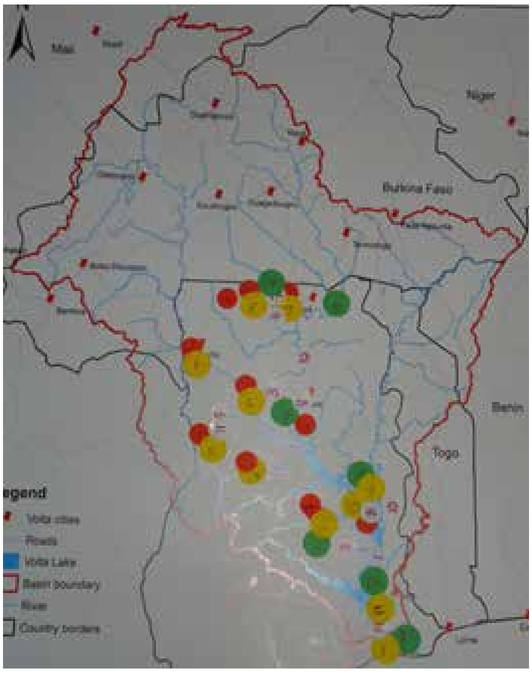
Tumbulto Jacob - VBA
Richard Twum Barimah – Ghana Dams Dialogue
Michael Appiah-Arthur – Minerals Commission



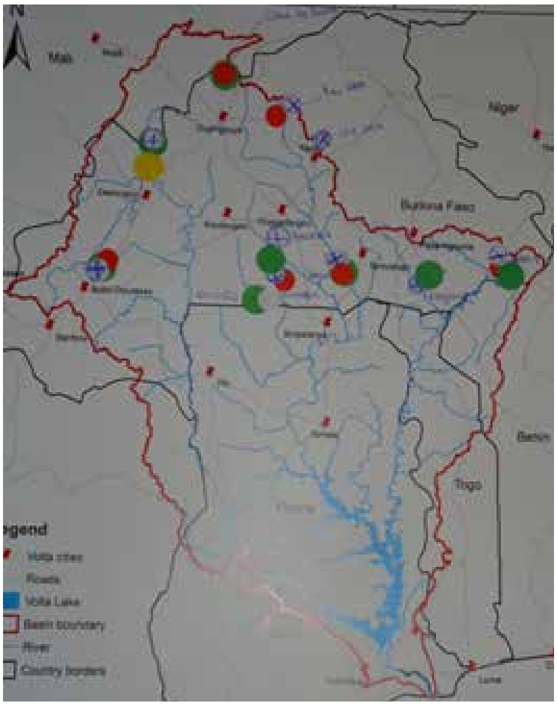
Kwame Awuah- NDPC
Nancy Akwen – RIPS-UG
Samuel Adoboe – GIZ



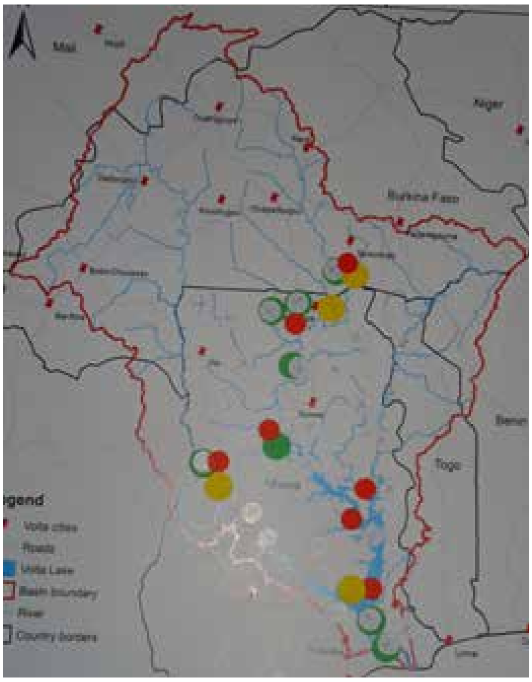
Eliane T. Lawson – IESS - UG
Ayilari-NaaJuati - GMet
Emmanuel Tabie Obeng - EPA
Jewel Kudjawu – EPA



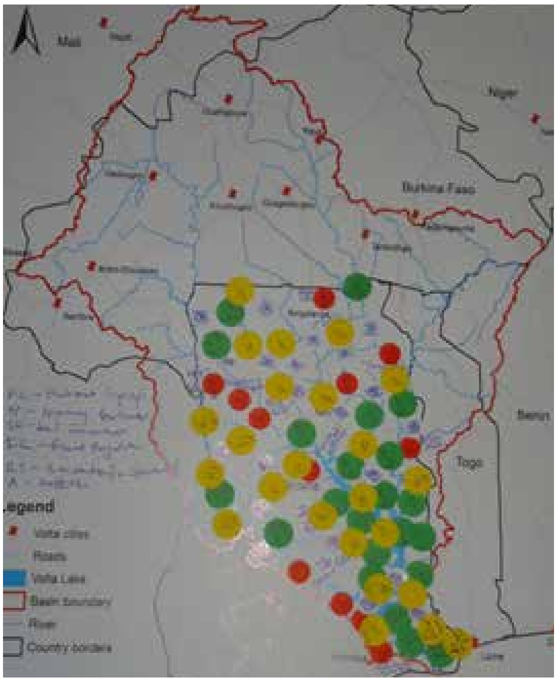
Felix Addo - Yobo - NDPC
Jonos Quartey – CAW UG
Samuel Kofi Nyame – IUCN – Ghana



Millogo Founeme – Sonabel - BF
Kabore Colette – DGRH- BF
KY-Zerbo Alain – PANA - BF



Evans Y. Balaara - GWCL
Gyimah Mohammed - MESTI
Francis D. Ohemeng - GIDA
Zachary A. Gbireh - GIDA
Ahunu Eric - HSD
Benjamin Arthur - CONIWAS



Seth Mahu MoEN
Diana Gakpetor - ABANTU
Ama Kudom -Agyemang - KlamateAware
Emmanuel Bekoe - WRI

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