PREFACE

The Water Resources Commission (WRC) was established by Act 522 of 1996 with the mandate to regulate and manage Ghana's water resources and coordinate any policy in relation to them. In the execution of its mandate the Commission has since its establishment adopted the principles of Integrated Water Resources Management (IWRM) using the river basin as a unit for planning. The first IWRM Plan elaborated was for the Densu River Basin which was finalised towards the middle of 2007. This was followed by the development of IWRM plans for Ankobra and the White Volta basins in 2008.

The present Dayi River Basin IWRM Plan is the fourth of its kind. The basin was chosen due to the impact of climate change on its water resources and ultimately livelihoods. Water related hazards such as floods have become more frequent in the basin and the unpredictable rainfall pattern has adversely affected rain fed agriculture. In instituting proper water resources management mechanisms with regards to adaptation to climate change, the ADAPTS Concept of building resilience of vulnerable communities and ensuring a transition from traditional agriculture to irrigated and sustainable agriculture was adopted. The ADAPTS approach to climate change adaptation builds on the needs, priorities and actions of local people and their communities and ensures that adaptation considerations are effectively incorporated into water policies, plans and investment strategies.

A number of activities have been invested since 2009 in creating a basin-based IWRM structure for the Dayi River Basin. The decentralised IWRM structure, which has evolved through a targeted participatory and consultative process with grass root stakeholder involvement, combines the following partners: a broadly anchored stakeholder-oriented coordinating body, i.e. the Dayi River Basin Board, planning and executive units of the District Assemblies and WRC's representation which serves as the coordinating unit.

In parallel to the organisational arrangements, activities of a more technical and hydrological nature have been undertaken by WRC with support from the Development Institute (a local NGO) and our partners in the Netherlands (Institute for Environmental studies of Vries University (IVM), Acacia water and Both Ends), which eventually resulted in the present Dayi River Basin IWRM Plan. This plan should also be viewed as an integral part of the stipulations in the WRC Act 522 of 1996 to "propose plans for utilisation, conservation, development and improvement of water resources" in adherence with the overall National Water Policy.

It is the Commission's sincere hope that this plan can be a useful catalyst towards accelerating concrete water management activities incorporating climate change adaptation measures in the Dayi River Basin, and more importantly, may also serve as a source of inspiration to advance the ADAPTS blueprint in other basins in Ghana.

Paul Derigubaa

Chairman, Water Resources Commission

Accra, December 2011

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ABBREVIATIONS

CC	Climate Change
CBO	Community-Based Organisation
CWSA	Community Water and Sanitation Agency
DA	District Assembly
EPA	Environmental Protection Agency
GIS	Geographic Information System
GWCL	Ghana Water Company Limited
ha	hectare
HSD	Hydrological Services Department
GIDA	Ghana Irrigation Development Authority
IWRM	Integrated Water Resources Management
km^2	square kilometre
mg	milligram
mm	millimetre
m^3	cubic metre
MDAs	ministries/departments/agencies
MOFA	Ministry of Food and Agriculture
MWRWH	Ministry of Water Resources, Works and Housing
NADMO	National Disaster Management Organisation
NGO	Non-Governmental Organisation
VR	Volta Region
pop	population
SEA	Strategic Environmental Assessment
sec	second
UN	United Nations
VRA	Volta River Authority
WEAP	Water Evaluation and Planning Model

WHO	World Health Organisation
DBB	Dayi Basin Board
WRC	Water Resources Commission
WRI	CSIR-Water Research Institute
WSSD	World Summit on Sustainable Development (August 2002)
WQI	Water Quality Index

1. INTRODUCTION

1.1 IWRM in an international context

At the World Summit on Sustainable Development (WSSD) held in Johannesburg in 2002, the international community took an important step towards more sustainable patterns of water management by including, in the WSSD Plan of Implementation, a call for all countries to develop "*integrated water resources management and water efficiency plans*". Activities aimed at enhancing "water efficiency" are considered important components of IWRM, and hence should be included as an integral part of an IWRM plan.

The term integrated water resources management (IWRM) has been subject to various interpretations, but the following definition by the Global Water Partnership[1] has been adopted in the Ghanaian context:

> *"... a process which promotes the coordinated development and management of water, land and related resources in order to maximise economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems ..."*

Due to competing demands for the water resource (in the worst case resulting in limiting economic development, decreasing food production, or basic environment and human health and hygiene services), the process is intended to facilitate broad stakeholder input in order to build compromise and equitable access. This is particularly the case for developing countries like Ghana, which allocates much effort in addressing poverty reduction and in implementing the UN Millennium Development Goals.

IWRM is a broad based approach to the development of water, addressing its management both as a resource and within the framework of providing water services.

The Global Water Partnership models the IWRM process as a cycle of the following activities:

- establishing the status and overall goals;
- building commitment to the reform process;
- analysing gaps;
- preparing a strategy and action plan;
- improving the legal and institutional management framework; and
- monitoring and evaluating progress.

[1] *Global Water Partnership (GWP): Integrated Water Resources Management, Technical Advisory Committee, TAC Background Paper No. 4 (2000)*

The goal of preparing IWRM plans as called for at the WSSD has set the tone for a worldwide initiative, which Ghana has adopted with the purpose "to promote an efficient and effective management system and environmentally sound development of all its water resources"[2] based on IWRM principles.

1.2 IWRM planning in the Ghanaian context

In Ghana, IWRM plans are thought initially to be prepared at the river basin level starting with the most "water stressed" basins of the country. At a later stage, this exercise can provide input to preparation of an IWRM strategy/plan at national level incorporating trans-boundary water resource and climate change related issues. The IWRM plans and strategies shall be prepared with the overall purpose of addressing major problems at a river basin level related to:

- Water resources availability;
- Water quality;
- Climate change; and
- Environmental/ecosystem sustainability.

Due account shall be taken to water use, and the social and economic implications of implementing an IWRM plan. Actions to be taken as a consequence of planning shall be prepared based on scenarios describing different approaches for solving major management problems within a defined time period.

As such the prime outcome to be provided are prioritised and ranked sets of programmes/actions, which from a political, legal, technical, sociological and economic point of view are considered as the most sustainable and efficient solutions. Political (democratic) aspects of IWRM planning in this regard require, that plans shall be elaborated with a participatory approach guided by principles which are imbedded in the concept of Strategic Environmental Assessment (SEA).

Generally, SEA is applied with two purposes:

- to evaluate environmental impacts and to rank the environmental effects of plans and programmes; and
- to evaluate conformity and/or conflicting stipulations between various related plans and programmes.

SEA tools have in Ghana been applied in assessing the first Ghana Poverty Reduction Strategy and during formulation of the National Water Policy. As a continuation of these approaches, a SEA Practical Guide[3] has been prepared, which presents a number

[2] *National Water Policy - Government of Ghana, Ministry of Water Resources, Works and Housing (June 2007).*

[3] *SEA of Water and Environmental Sanitation – a Practical Guide. Ministry of Water Resources, Works and Housing; Ministry of Local Government, Rural Development and Environment; and Environmental Protection Agency (April 2007).*

of SEA tools applicable to the water and sanitation sector, including water resource planning, development and management.

Key aspects, therefore, in the IWRM-SEA process is a participatory approach involving users, planners and policy makers to build commitment; a holistic view that calls for cross-cutting interaction within basins; an integration in terms of upstream-downstream catchment implications; and recognition to the fact that water is an economic good.

As part of a process, the basin-based IWRM plan shall form a widely accepted and easily understood document describing the current state of the water resources and outlining strategies that enable basin-based water management, which adheres to stipulations in the National Water Policy. Thus, the IWRM plan can be considered a “blueprint”, that describes steps to be taken towards realising the visions.

1.3 Purpose and institutional setting of the IWRM plan

The target group of the basin-based IWRM plans is planners and decision-makers operating in the water sector, including the river basin boards, who are provided with a tool for “what to do” and for detailing activities and programmes concerning specific interventions. More specifically, the purpose of the IWRM plan is to:

- to help build resilience of communities to adapt to the impact of climate change such as floods and droughts
- contribute to the provision of sufficient supply of good quality surface water and groundwater as needed for sustainable, balanced and equitable water use;
- prevent further deterioration and protect the status of aquatic ecosystems with regard to their water needs;
- protect terrestrial ecosystems directly depending on the aquatic ecosystems; and
- provide appropriate water management with efficient and transparent governance in the sector at local, district or basin-based level.

IWRM is a cyclic and long-term process. Hence, the IWRM plan can be seen as a milestone in this process, where the status of the process is documented, and the plan inevitably will need to be kept up-to-date when new knowledge surfaces, e.g. related to changes in the hydrological regime and projections of future water requirements.

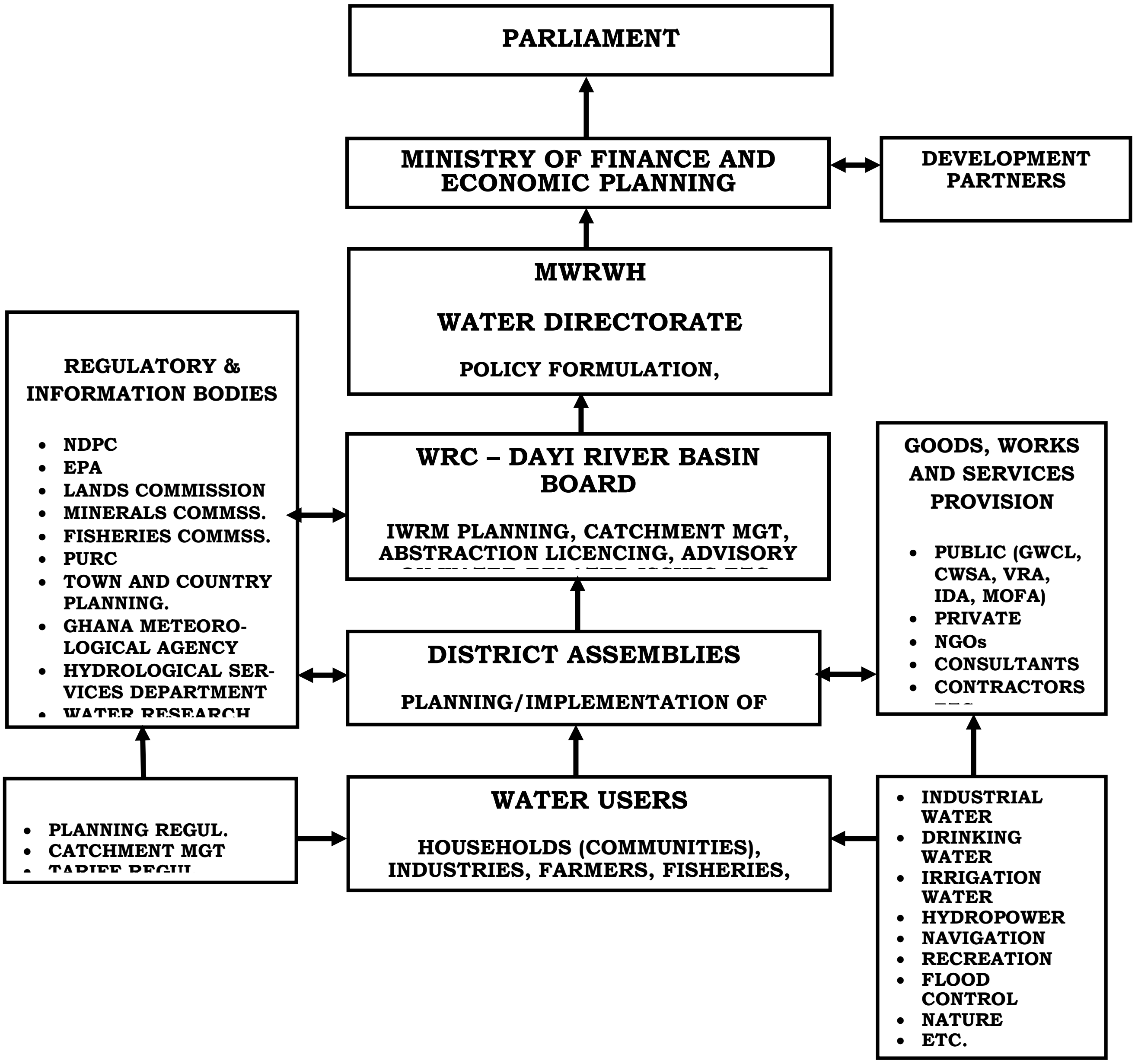
For the IWRM plan to be successfully implemented, it is imparative that the WRC collaborates with institutions and major water abstractors affected by the plan. This is because the plan impacts on a variety of societal aspects, viz. utilisation and protection of natural resources, social and cultural situations, economics and production, and the legal, administrative and institutional frameworks. It is evident that there must be effective collaboration with planning efforts in these areas.

For instance, Water Resources Commission (WRC) has to collaborate with –

- MDAs, CWSA and GWCL in water demand projections;
- MDAs, Lands Commission, Minerals Commission, EPA, MOFA and traditional authorities in catchment management;
- MDAs and EPA in controlling various wastes into water bodies; and
- EPA, Forestry Commission, Fisheries Department, Water Research Institute and HSD in assessing environmental flow requirements.

The overall institutional setting as it relates to the further planning and implementation of activities and measures outlined in the IWRM plan is depicted in Figure 1.1.

Figure 1.1: Overall institutional setting indicating initiation of the planning process from the grass root (Bottom–up approach)



1.4 Status of IWRM activities in the Dayi River Basin

For quite many years Ghana has been planning for and engaged in the introduction of IWRM at various levels of society, and as such has advanced in the IWRM process resulting in a new national water policy and legislation facilitating water resources management and development based on IWRM principles. Furthermore, an enabling institutional framework has been introduced at national level, i.e. establishment of the Water Resources Commission and the Water Directorate under the Ministry of Water Resources, Works and Housing, and at local river basin level in the form of creation of River Basin Boards.

The Dayi Basin Board (DBB) was the fourth river basin management set-up to be established and was officially inaugurated in July 2010. DBB has a consultative and advisory role as it relates to the management of the the Dayi River Basin’s water resources and represents a wide sphere of interest groups within the Basin, including the traditional authorities. The DBB membership includess the following:

(a) A chairperson appointed by the WRC,

(b) A representative of the WRC,

(c) One person representing each of the following within the basin.

- Woadze Sustainable Agric Farmers Co-operative, Hohoe
- Forestry Commission, Volta Region
- Gbi Traditional Council, Hohoe
- Kpandu Traditional Council, Kpandu
- Ministry of Health, Hohoe
- Environmental Protection Agency, Volta Region
- Department of Women and Children affairs, Volta Region
- Jasikan District assembly
- Ministry of Food and Agriculture, Hohoe
- Development Institute, Accra (NGO)
- Ghana Water Company Limited, Hohoe
- Ghana Fire Service, Volta Region
- God Deliver Farm association, New Baika, Jasikan
- Hohoe Municipal, Hohoe
- Kpandu District assembly

(d) The Basin Officer as ex-officio member to be appointed by the WRC in charge of the Board’s Secretariat.

Over the past few years quite many specifically targeted studies and related activities have been completed aimed at providing data and new information of relevance for the IWRM planning. In the following chapter “Baseline Description” these various sources of information and reports are acknowledged as and when used.

Furthermore, in the Dayi River Basin, a number of IWRM activities have also been initiated by the WRC as well as NGOs and other development partners such as the Development Institute (DI), Both Ends, Acacia Water, Insitutes of Environmental Studies of the Vries Universtiy, Amsterdam, all with the purpose of addressing the growing water variability and floods as a result of climate change as well as address water quality degradation facing the Basin.

Other IWRM activities undertaken by WRC prior to the development of this plan ionclude:

- promotion and support for target groups' awareness creation and education within the basin (in communities and schools), and development of educational materials;
- identification of raw water users (to assist in the process of registering and granting water rights/issuance of permits);
- establishment of links with the Basin's District Assemblies, traditional authorities/landowners to tackle specific issues relating to pollution and degradation of the catchment area, e.g. relocation of waste dump sites away from the river banks;

1.5 Preparation and structure of the IWRM plan

The WRC has elaborated the present IWRM plan for the Dayi River Basin as part of WRC's mandate to "*propose comprehensive plans for utilisation, conservation, development and improvement of water resources"* [4] with due consideration to stipulations in the National Water Policy.

The IWRM plan is based on a number of dedicated assessment studies and information reviews, all unveiling implications relevant for decisions made during the process of prioritising measures forming the IWRM plan. Guided by SEA procedures and application of "tools", consultative meetings and workshops have taken place during the course of preparation, specifically targeting the DBB members as well as District Assemblies and their planning officers.

Following the introductory chapter, Chapter 2 presents the baseline description, which provides the background against which the planning and identification of actions can be made. In Chapter 3 water demand projections are presented based on district development plans and other information notably the 2000 census results. Furthermore, in this chapter a number of scenario analyses are presented comprising different development options and strategies for the utilisation of the basin's water resources, including likely climate change impacts on the water resources.

Chapter 4 describes the consultative process followed towards identification and ranking of water resource management problems and issues as perceived by local stakeholders and planners of the basin. As a result of this process the chapter further presents an action plan comprising of a number of prioritised activities and measures for implementation required to meet the water resource management challenges of the basin. Chapter 5 outlined the steps to be initiated to move forward towards implementation of the action programme.

[4] *Water Resources Commission (WRC) Act No. 522 of 1996*

2. BASELINE DESCRIPTION

2.1 Physical, demographic and socio-economic features

The Dayi River Basin is one of the sub-basins of the Volta River system and spans Togo (source of the river), and Ghana. In the context of this IWRM Plan the interest is on the Ghana part of the basin.

The Dayi flows through Semi-deciduous Forest, Savannah, and Mountain Vegetation. Because of the increasing destruction of vegetative cover mostly due to poor farming practices and indiscriminate lumbering, the degradation of the environment has become an important concern in the basin.

The prevailing extensive rain-fed agriculture of an otherwise increasing population at the expense of the mountain forests resulting in erosion, increased peak flow and loss of biodiversity are distinct water resource issues characterizing the basin. Furthermore, a progression in land degradation and unchecked waste disposal in the river system are also experienced.

Although droughts rarely occur, the increasing degradation of the water resources within the basin is envisaged to cause shortages for production of potable water in the future and in support of sustainable agriculture. Frequent flooding during the rainy season and drying of rivers during the dry season as well irregular rainfall patterns are emerging as the number one water management issues in the basin.

2.1.1 Location, topography and river network

The Dayi River Basin in Ghana is located between latitude 7° 19' N - 6° 38' N, and longitude 0° 39' E -0° 17' E. The basin is bounded to the east by the Togo border, to the north by the Asukawkaw Basin and Volta Lake, to west by the Volta Lake, and to the south and south east by the Volta Lake, Alabo Basin and Todzie Basin.

The basin has a series of highlands and adjacent lowlands, scattered hills and ranges of varied lengths and heights. Mountains rising above 500 metres can be found at Akpafu, Likpe and Kpeve.

The highest mountainous peak in Ghana, Afadjato, which rises to a height of 890 metres above sea level, is located within the basin. The topography of the basin is depicted in Map.1 (inserted at the end of the chapter).

It has the Akwapim- Togo-Atakora ranges as one of its astounding physical features. There are also several spectacular waterfalls such as the Wli and Tsatsadu falls and swamps in the basin. The basin is as well marked with natural caves in Akpafu and Likpe Todome.

The Dayi River Basin belongs to the Volta River Basin System and covers an area of about 1,544 km^2. The main river in the basin is the Dayi River with Rivers Utuka, Koloe, Nabui, Tsatsadu and Seku, as its tributaries. The Dayi River takes its source from the Akpafu range (extends to Togo), draining through the low-lying portion of the Hohoe Municipality between the Akwapim-Togo ranges and around the Volta Lake and extending to the Detu highlands in the south of Hohoe Municipality. It then discharges into the Volta Lake in the Kpando District.

2.1.2 Administrative structure, population and settlement pattern

The Dayi Basin area is located in the Volta Region. The basin covers five (5) districts/municipals in the region;

- Jasikan District
- Kpandu District
- South Dayi District
- Hohoe Municipal
- Ho Municipal

The Hohoe Municipal covers an area of about 72% of the basin with Kpandu covering about 17%, Jasikan district 6%, Ho Municipal 4%, and South Dayi district 1%. These features are depicted in Map 2 (inserted at the end of chapter) with figures given in Table 2.1 below.

Based on the 2000 Population Census[5], Table 2.1 presents the population size and distribution within the basin. The settlement categories is based on the population threshold of 5,000 people for urban and less than 5,000 for rural settlements. The portion of a district's rural population living within the basin is estimated by matching the proportion of the area of the respective district, which is located in the basin, and using the percentages to calculate the rural population.

The population increases recorded in the latest intercensal period (i.e. between the censuses of 1984 and 2000) showed in the Volta Region an annual average growth rate of 1.9 % as compared to the national average of 2.7 %.

As an average for the entire Dayi Basin, the population density (year 2000) is 86 pop/km^2, as compared to the overall national average of 77 pop/km^2. The total population (year 2000) residing within the basin was 145,065 of which the urban population constituted 23.2%. The location of a number of the major settlements/towns within the basin is also indicated in Map 2.

[5] *Ghana Statistical Service (2002) : 2000 Population and Housing Census (official results on CD- ROM)*

Table 2.1: Population in the Dayi River Basin (Derived from 2000 Census)

Region	District	Settlement category	Population (2000)	Area in basin (km^2)	(%)	Density (pop/km^2)
Volta Region	Jasikan District	Rural	5,697	108	6.4	65
		Urban	1,424			
	Kpandu District	Rural	15,085	281	16.8	67
		Urban	3,890			
	South Dayi District	Rural	-	18	1.0	-
		Urban	-			
	Hohoe Municipal	Rural	85,084	1213	72.2	91
		Urban	25,414			
	Ho Municipal	Rural	5,574	61	3.6	138
		Urban	2,897			
Dayi Basin, total		Rural	111,440	1681	100	86
		Urban	33,625			

2.1.3 Socio-economic profile

The water resources of the Dayi Basin contribute significantly to the livelihood of the people living in the basin. Water is used for domestic and agricultural purposes, especially, in fishing and irrigation farming.

The main occupation within the basin is agriculture, which employs about 60% of the entire population. The majority of the people live in rural communities and indulge in slash and burn or shifting cultivation on a subsistence scale. They grow staples such as plantain, cassava, maize, groundnut, rice, cocoyam, bananas, cocoa, colanut and coffee. Some of the vegetables grown are okro, garden eggs, tomatoes, and pepper.

The fishing industry in the basin employs about 5% of the basin population. This is as a result of the Dayi River and its tributaries, and the basin closeness to some portion of the Volta Lake.

The basin is characterised by large clay deposits at Akpafu Odomi and in Ve area especially at Koloenu, Dafor and Golokwati. This resource is being used on a small scale for pottery and ceramics works.

The mining of iron ore and manufacture of simple farming implements such as the hoe, and cutlass in Akpafu area by the ancestors suggests the existence of large deposits of high grade iron ore especially at Akpafu Todzi. The extent of deposits untapped is yet to be investigated. The reserves of the iron ore deposits might call for a large-scale mining industry in the future.

Other major industries in the basin are Brick and Tile (Ve Koloenu, Ve Dator), Pottery and Ceramics(Ve Koloenu), Gold Smithery (Hohoe), Black Smithery (Alavanyo, Lolobi,Likpe), Distillery, Bagged Water, Key Cutting, Carving, Weaving(Tafi Abuife), Batik Tie and Dye (Hohoe), Oil Extraction (Logba, Gbledi, Golokwati), Soap Making(Lolobi), Bakery, and Milling . The above socio-economic pattern is highlighted in Table 2.2.

The figures in the table are derived from the 2000 Census data, and are given as percentages of the economically active population (above 15 years of age).

Table 2.2: Occupation (in %) of the economically active population (Derived from 2000 Census)

Economic Activity (industry)	Districts			
	Ho	Hohoe	Kpandu	Jasikan
Agric. Hunting & Forestry related Workers	50.5	46.4	54.4	64.7
Wholesale / Retail Trade & related Workers	13.5	14.6	11.4	8.8
Manufacturing	11.4	12.1	12	8
Fishing	0.8	5	1.9	5
Education	5.3	5.9	5.5	3.9
Construction	4.5	3.6	2.9	2.4
Transport, Storage & Communication	2.5	1.9	2.3	1.3

2.1.4 Land use pattern and ecological trends

The original ecology of the Dayi Basin was moist semi-deciduous and rainforest with thick undergrowth and closed canopy. The human activities through time, however, have greatly modified this forest ecology – and at an accelerating rate. Within the past 10-20 years, the ecological perspective of the Dayi Basin has changed significantly. The thinning of the forest has intensified as a result of the marked shift in land use for agriculture especially within the mountainous areas. Besides, other uses of the land have led to the creation of secondary forest and savannah woodland vegetation in the basin.

At present the Dayi Basin is characterized by two different types of vegetation zones. The north-western and eastern section of the basin is forested land, but with intensive de-vegetation activities ongoing to allow agricultural activities to take hold. The forest is characterised with closed canopy of branches and little undergrowth. It is found on the slopes of the Akwapim-Togo-Attakora ranges.

The northern section of the basin is savannah woodland and it is characterised with grass and scattered trees like acacia, bamboo and baobabs.

In the basin, the predominant land use is agriculture. Food crop farming and livestock rearing constitute the predominant agricultural activities in the basin. Farming is largely the traditional cutlass and hoe. Mechanised farming is very limited and the rate of adoption of other agricultural related technologies is equally low. The farmers produce mainly food crops such as rice, yam, cassava, maize and groundnuts.

Map 3 (inserted at the end of chapter) provides a simplified overview of the land use/cover situation as derived from satellite image maps produced in year 2000. From similar image maps representing year 1990, Table 2.3 summarises the development in area coverage of the forested land and other zones described above as it has occurred during this ten-year period.

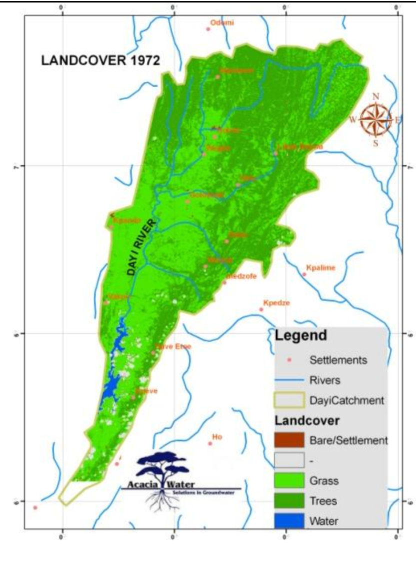
Table 2.3: Development in land use/cover of the Dayi Basin (1990-2000)

Year	Forest areas with tree cover	Savanna woodland/grass	Arable land	Settlements and unclassified areas
1990	29%	31%	34%	6%
2000	10%	29%	50%	11%

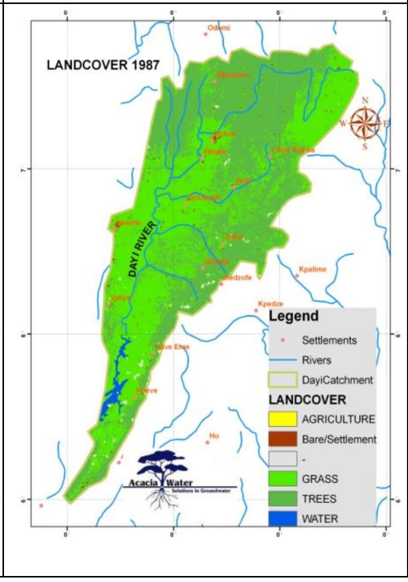
From table 2.3, it can be seen that deforestation in the basin has increased tremendously in the last decades resulting in the decrease of river and spring flow. A spatial and temporal analysis of land cover is carried out using satellite images. LANDSAT images show that deforestation intensified after 1987. However large-scale erosion is not visible and deforestation does not seem to be the only factor responsible for the observed decreased in river flows.

It is clear that agriculture land use has shown a remarkable growth between 1987 and 2001 especially in the areas close to the lake. Also the bare patches (which could be fallow land at the image capture time) or settlement areas have shown an increase. The forest/grass ratio seems to have decreased from 1972 to 2001 based on the LANDSAT images. However, there is no visible effect on the size of the lake itself over this entire period. Figure 2.1 presents the land use change between 1972 and 2001.

1972



1987



2001

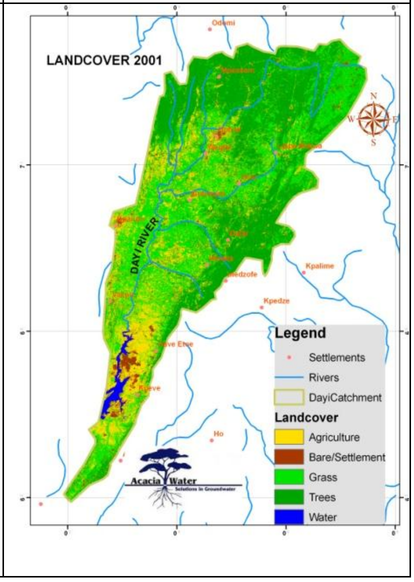


Fig. 2.1 Interpreted Land Use/cover based on LANDSAT Dataset

LANDSAT NDVI indexes which are an indication of vegetation presence and characteristics are more or less stable over the years. Apparently the deforestation has been compensated with secondary forests and dense cropping patterns.

Long term annual and monthly NDVI show a marginally higher vegetation density presence in October than in February for the same areas in different directions of the catchment (upper head water and lower downstream parts). This is expected because October is approximately the end of the rainy season and February approximately is the end of the dry season. Eighteen year average of the NDVI for January, March and September for the whole catchment show the expected highest vegetation index in September and lowest in March.

Steep slopes are present close to the ridge boundaries and on the headwater side of the catchment area. Agriculture spread over the entire catchment and in 2001 also takes place on steep slopes. Presence of settlements close to such areas can be seen as an explanation of agriculture spread due to economic pressure from farmer communities.

2.1.5 Protected Areas

Tafi Atome Monkey Sanctuary

It is a sacred grove in a traditional conservation area in the Dayi Basin. Tafi Atome is the home of Mona and Pata monkeys. These monkeys are found in a remnant patch of forests, which has survived fire and human disturbance around the village. These monkeys are regarded as gods and as such the natives do not kill them.

Wli Falls and Wli Natural Reserves

The Wli Falls is located at the edge of the Agumatsa Wildlife Sanctuary in the Wli Natural Reserves. The Wli Fall cascades throughout the year and water fall from a height of about 30m. The Agumatsa Wildlife Sanctuary has hundreds of fruit bats and a few monkeys and antelopes.

Other important protected areas in the basin include Odomi forest reserve, Kpandu Range Dayi Block forest reserve, Kpandu Range West forest reserve, Togo Plateau, etc

2.2 Water Resources

2.2.1 Meteorological characteristics

Data concerning the meteorological conditions are obtained from the Ghana Meteorological Agency, which operates a number of climatologic and rainfall stations in the Basin. The location of the meteorological stations is indicated in Map 5 (inserted at the end of chapter).

The climate of the basin is tropical, greatly influenced by the southwest monsoon wind from the South Atlantic Ocean and dry harmattan winds from the Sahara Desert. The basin is characterized by a bi-modal rainfall regime with considerable variation in the onset, duration and intensity of the monthly rainfall. The main rainy season extends from mid-April to July and attains a peak in July, whereas the second - less intense – rainy season occurs between September and November with October in some instances recording the highest of the two peak rainfall regimes. Table 2.4 and Fig. 2.2 present mean monthly rainfall in selected stations within the basin.

Table 2.4: Mean monthly rainfall (mm) of selected stations in the basin

STATION (duration)	Jan	Feb	Mar	Apr	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Hohoe (1950-2009)	16.40	49.92	120.53	146.01	167.24	201.78	172.17	138.84	239.15	192.88	88.21
Ho (1950-2009)	21.88	61.12	113.03	140.77	169.76	194.95	123.80	86.57	156.80	167.84	54.78
Kpandu (1958-2008)	9.68	30.58	79.10	120.98	133.86	180.98	192.57	134.46	171.58	137.36	50.63
Kpeve (1950-2009)	24.90	50.64	108.81	133.46	158.43	189.58	127.48	98.59	158.43	158.19	60.94
New Ayoma (1955-	21.52	42.80	108.83	127.24	136.75	176.01	205.54	150.16	230.91	140.93	64.71

1986)											
Akuse (1950-2009)	15.11	40.76	92.99	122.42	166.05	184.99	82.79	50.54	113.21	139.85	80.30
Baglo (1955-1980)	16.45	48.33	120.30	113.42	121.76	197.10	194.06	153.02	222.49	124.18	49.29
Akaa (1956-2006)	8.51	38.33	99.35	142.03	164.71	183.17	190.18	179.57	178.90	164.43	61.52
Likpe Mate (1955-1985)	18.46	41.60	117.62	109.35	146.23	183.03	186.59	169.20	243.18	168.31	55.45
Leklebi Dafo (1950-1980)	27.00	56.99	112.64	130.20	147.87	208.70	155.94	111.17	203.12	158.89	89.83
Helu (1961-1983)	19.50	45.30	91.95	74.45	114.42	156.03	106.09	93.39	170.45	105.01	50.20
Anfoega Akukome (1955-2002)	21.84	48.95	105.66	147.97	169.01	182.23	157.73	110.29	144.70	183.15	55.01
Amedzofe (1963-2009)	13.48	56.48	104.77	147.09	163.36	214.71	178.46	136.02	199.71	161.80	63.82
Teteman (1976-1983)	9.21	52.13	128.81	134.99	269.30	306.64	208.26	164.99	272.03	207.17	75.26

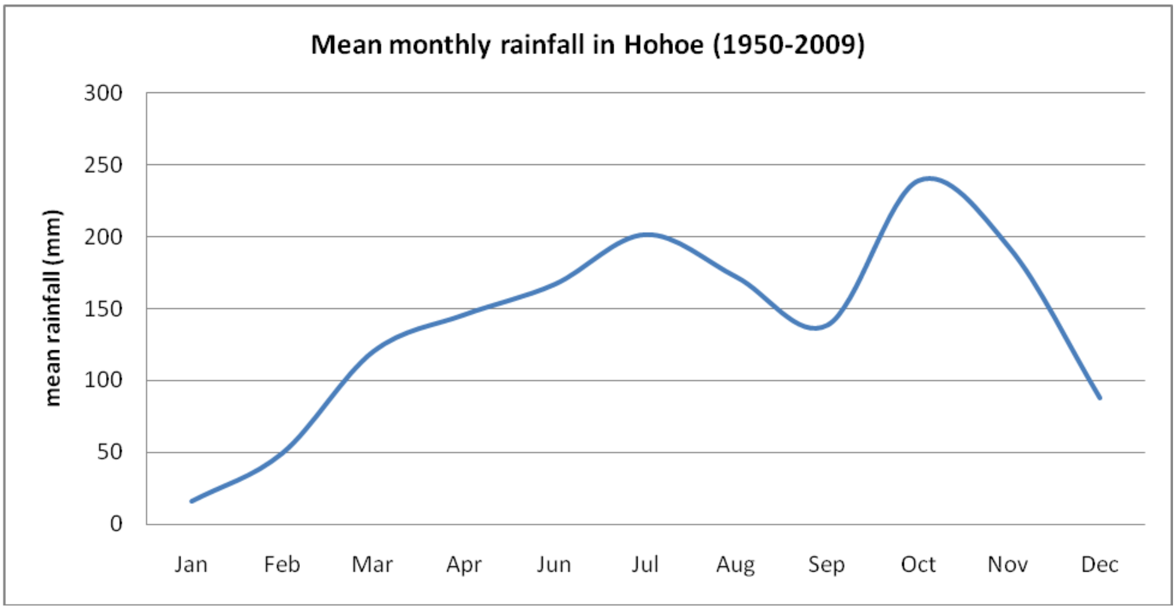


Fig. 2.2 Mean Monthly rainfall Hohoe (1950 – 2009)

The annual rainfall of the lower plains averages about 1100-1300 mm and approaches 1,400-1,600 mm in the higher ranges in the northern part of the Basin where the Dayi river system has its headwaters. Generally, the rainfall is not reliable even during the main season for crop production. Failures of the minor season rains have often been experienced in the basin.

The meteorological statistics show that the mean annual number of rainy days is between 90 and 120 days. July usually records the highest rainfall (peak) with a mean monthly rainfall of about 197mm and this is followed by October with a mean monthly rainfall of about 193mm.

The meteorological data also shows that the Dayi Basin is characterized by uniformly high temperatures throughout the year with a mean annual temperature of about 26°C. March is the hottest month in the basin with a mean monthly temperature of about 28°C. September is the coolest month with a mean temperature of about 25°C. Table 2.5 presents average monthly temperature in the Basin.

Table 2.5: Average monthly temperature (^{o}C) at Hohoe, Kpandu and Akaa

STATION (duration)	Jan	Feb	Mar	Apr	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Hohoe (1963-2008)	25.71	27.06	27.61	27.58	26.97	26.10	25.03	24.86	25.34	26.62	26.85
Kpandu (1963-2008)	26.40	28.00	28.34	28.06	27.50	26.30	25.31	25.09	25.58	26.65	27.59
Akaa (1956-1994)	24.71	26.70	27.73	27.84	27.50	26.13	25.01	24.90	25.44	26.19	26.24
Kpeve (1953-2000)	25.58	27.37	28.17	28.10	27.81	26.51	25.50	25.28	25.84	26.71	27.26

Amedzofe (1963-2006)	24.01	24.64	24.70	24.51	24.02	22.30	20.88	21.92	23.36	24.93	26.69

2.2.2 Surface water Resources

The Dayi River and its tributaries constitute a well watered and perennial surface water system. The main tributaries are Utuka, Koloe, Nabui, Tsatsadu and Seku Rivers.

2.2.2.1 Water (hydrological) balance

With the rainfall-runoff model HBV the discharge at Hohoe is simulated using precipitation, temperature and potential evapotranspiration as input. Calibration of the simulated discharge on the measured discharge is carried out to find parameters which characterize the region. Using these parameters, several scenarios with changes in precipitation are simulated (Figure 2.3).

After 1980 base flow seems to be decreasing significantly. For the runs 2000 – 2002 and 2005 – 2006 the model was not able to simulate the base flow (often zero). The ’86-’87 run gives the highest efficiency (Fig. 2.4)

The dataset shows some gaps and some unrealistic high values for discharge. Besides that, it is visible that base flows before 1972 are higher than the base flows after 1976.

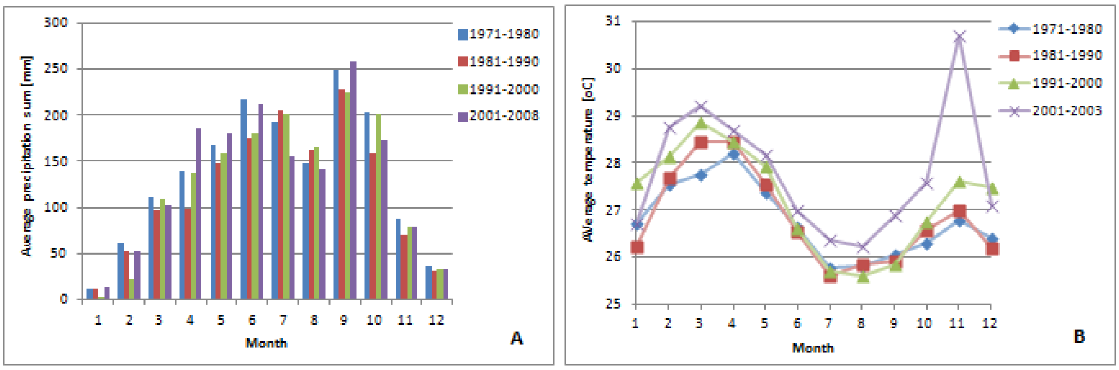


Figure 2.3 Observed precipitation average sum (A) and observed temperature average (B).

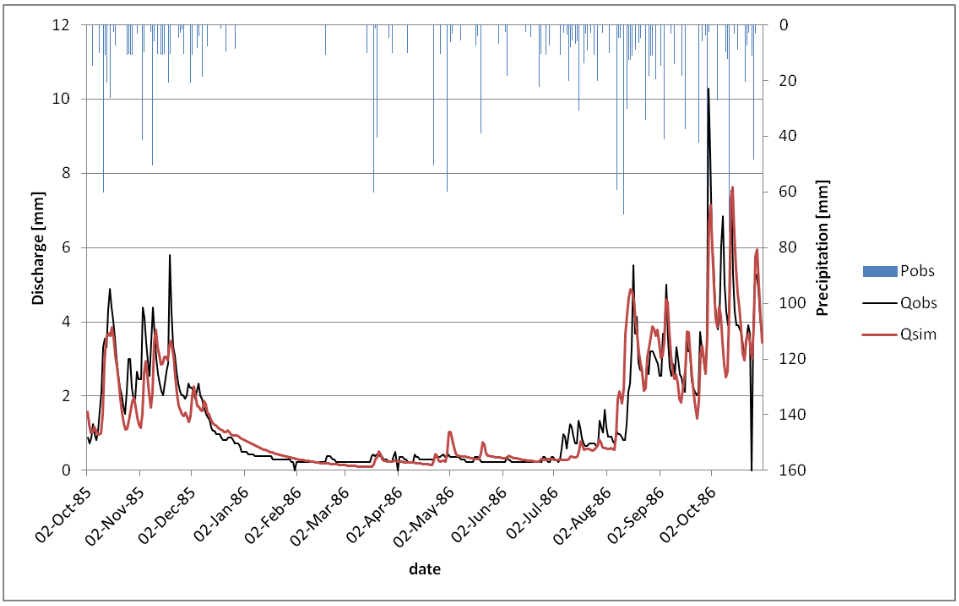


Figure 2.4 Observed precipitation [mm], observed and simulated discharge [mm] for 1986 and 1987

2.2.2.2 Runoff statistics

Recorded flow data was obtained from the Hydrological Services Department, which operates a number of river gauging stations in the Basin. However, the available data records comprise in general short time series with many gaps. Unbroken records of more than five years are not available from the Hohoe gauging station.

Nevertheless, analyses carried out on the available data series indicate in many instances clearly detectable correlation between the recorded flows and rainfall. For example, September records the highest mean monthly rainfall as well as the highest mean monthly flow. The two graphs clearly show that flow is dependent on rainfall; as when there is an increase in rainfall, the flow also increases.

Table 2.6: Mean monthly flow (1992-2007), Hohoe (m^3/sec)

	Jan	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
Mean	0.42	0.13	1.12	5.27	4.29	20.30	83.06	79.31	184.78	162.38	26.31	5.37
Max.	0.00	0.00	0.00	0.01	0.04	1.99	3.36	8.84	47.43	41.40	2.22	0.00
Min.	2.14	0.78	0.34	40.92	15.92	44.31	278.39	213.81	487.65	369.17	66.20	17.61

Table 2.7: Mean monthly flow (2002-2007), Gbefi (m^3/sec)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Mean	35.99	22.96	30.55	69.18	85.29	200.27	466.20	590.42	768.64	717.35	238.29	64.38
Min.	25.19	19.15	25.10	17.72	50.06	19.99	166.26	381.44	193.07	429.43	103.85	45.05
Max.	52.08	27.51	36.51	197.28	176.10	624.97	873.39	744.98	1246.11	890.59	307.44	74.25

2.2.3 Minimum/environmental flow considerations

Generally, it is the low flow characteristics of the river that determine its suitability as source for a year-round water supply, i.e. direct abstraction without a storage reservoir. Furthermore, the flow of the Dayi River and its tributaries particularly during the dry season has a significant impact on the flora and fauna associated with the prevailing aquatic system.

Undoubtedly, the aquatic ecosystems of the Dayi River are envisaged to be under significant pressure due to the drying out of rivers during the dry seasons as a result of low base flows and the poor surface water quality as a result of unchecked waste disposal in the river system. In defining the minimum amount of flow required to maintain the aquatic ecosystems of the basin, a certain acceptable water quality level for the sustenance of these ecosystems must be specified and maintained. This should be done under an overall IWRM framework for the basin. In this regard, the environmental flow consideration is not only a matter of maintaining a minimum flow regime, but as importantly also to safeguard that this flow maintains a certain acceptable water quality for the aquatic ecosystems to prevail.

2.2.4 Groundwater resources

2.2.4.1 Geology and aquifer systems

The Dayi Basin is underlain by three geological formations namely, Buem, Dahomeyan and the Togo Series. These features are depicted in Map 6 (inserted at the end of chapter). About 50% of the Basin's total area is underlain by the Buem formation. The Dahomeyan formation within the Basin is made up of basically Schist & Migmatites, many of which are rich in Garnet, Hornblende & Biotite. These also constitute percentage coverage of about 2% of the total basin area. The Togo Series are made up of Quartzite, Sandstone, Shale, Phyllite, Schist & Silicified Limestone; and they make up the remaining 48% coverage of the total basin area.

2.2.4.2 Borehole yields

Borehole data in the Basin has revealed high yielding aquifers in the basin. Hydrological modelling results have also indicated high recharge rate. It is therefore sufficient to assume that the groundwater potential in the basin is very high which can be tapped into and used for domestic, industrial and irrigation purposes.

2.3 Utilisation of water resources

The Dayi River and its tributaries constitute a major source of water supply to communities within the basin. However, most streams in the basin, including major tributaries such as rivers utaka, koloe, and seku either dry up or have very little flow in the prolonged dry season. During this period, the main Dayi River becomes the only source of surface water resources for use in the basin.

Groundwater resources also serve as an important source of supply for the basin's population, particularly in the rural areas. Table 2.8 gives an overview of the sources and coverage of water supply in the Basin.

Table 2.8: Source of water supply in the Basin

District	Piped borne inside	Piped borne outside	Well	Bore-hole	Spring/ rain water	River/ Stream	Dug out	Tanker supply	Other
Ho	12	28.3	12.6	10	5.3	22.3	8.3	0.7	0.5
Kpandu	8.4	33.5	5	17.2	6.9	19.9	8.2	0.7	0.2
Hohoe	5.5	25.5	11.9	8.6	8.8	36.9	2.3	0.4	0.1
Jasikan	2.2	21.1	3.9	17.8	7.1	40.9	5.8	0.7	0.5
Overall for Basin	**8**	**27.3**	**9.6**	**12.3**	**6.8**	**28.7**	**6.4**	**0.6**	**0.3**

Source: 2000 Population and Housing Census. Ghana Statistical Service

Households in the basin derive their drinking water from diverse sources but the six main sources are river/stream, well, standing pipes, spring/rainwater, dugout and borehole, which together, constitute the main source for 99.1 per cent of households. The figures in Table 2.8 shows that about 47.6% of households in the basin (2000 Census data) have access to potable water (combining borehole and piped supplies - either in the form of direct house connections or from public stand-pipes), though pipe-borne water reaches only 35.3% of households and is shared largely by households in Ho, (12%).

Table 2.8 shows that spring and rainwater are more common sources of drinking water for households in Hohoe than in any other district within the basin. On the other hand, dugouts are common in households in Ho and Kpandu. Boreholes are similarly common in households in Jasikan and Kpandu.

2.4 Water quality and pollution

2.4.1 Water quality monitoring

As part of a surface water quality monitoring in the South-western, Coastal and Volta River Basins, covering the Dayi Basin under the Catchment–Based Monitoring Project in Ghana (National IWRM Plan) a water sampling exercise, which includes 40 locations in the various river basins started in 2010. The sampling sites are visited quarterly and water samples collected for laboratory analyses thus, the exercise could only provide a “snapshot” picture of the water quality situation in the basin as it prevailed at that time.

The surface water monitoring in the Dayi Basin incorporates one sampling station along the river, i.e. at Hohoe (representing the section of the river). Before this programme no water quality monitoring has been carried out on the Dayi River.

2.4.2 Water Quality Index

The Water Quality Index (WQI), adopted by WRC in 2003, is used to facilitate comparison and to classify to which extent the natural water quality is affected by human activities. The index is used to describe the state of water quality as a whole instead of looking at individual parameters, and can provide indications as to the suitability of the water for various purposes. The methodology incorporates selected key physical, chemical and microbiological determinants, and aggregates them to calculate a WQI value at a specific water quality monitoring/sampling site.

Based on the WQI value, the index classifies water quality into four categories as presented in Table 2.9 with a descriptive note concerning the pollution level of the water body in question. The aim is to protect natural waters from pollution such that the water falls at least in the upper portion of Class II - and more desirable in Class I.

Table 2.9: Criteria for classification of surface water quality

Class	WQI - range	Description
I	> 80	Good - unpolluted water
II	50 – 80	Fairly good quality
III	25 – 50	Poor quality
IV	< 25	Grossly polluted water

The Water Quality Index calculated and presented in Table 2.10 on the River Dayi at Hohoe in March 2010, indicates that it is in Class I and therefore could be described as Good quality water.

Parameter	**Value**	**Score**	**Maximum Score**
Dissolve Oxygen (% saturation)	92.0	17	18
BOD (mg/l)	3.7	10	15
Ammonia-N (mg/l)	<0.001	12	12
Faecal Coliform (Counts/ 100ml)	9	12	12
pH	7.21	9	9
NO3-N (mg/l asN)	0.246	8	8
PO4-P (mg/l as P)	0.029	8	8
Suspended Solids (mg/l)	<1	7	7
Electrical Conductivity (Us/cm)	88.5	6	6
Temperature (^{o}C)	29.7	5	5
Percentage Total Score (%)		94	100
WQI	**88.4**		

Table 2.10: WQI calculation at Hohoe in the Dayi River

2.5 Impacts of Climate change

The results of Interviews conducted within the local population in the Dayi River Basin indicate that people are aware of climate change in their surroundings. Rainfall has decreased over the past decades and is less reliable. The first rainy season starts late and the late rainy season ends early. As a result two cropping periods are no longer possible. Farmers are dependent on the rains in April / May to grow their seedlings. Mostly, this rains come late therefore interrupting the cropping season. Rivers and springs disappear or are no longer perennial. Almost all the communities in the Basin have encountered prolonged dry seasons and rainfall variability every 2-3 years. For all three ecological zones, crop failure is the most mentioned effect of a prolonged dry season.

Rainfall data show that annual rainfall at Hohoe changed from approximately 1700 mm/year in 1975 to 1400 mm/year in 2010. Early and late rains decreased. Lower rainfall amounts have been recorded over the years due to longer dry seasons and as a result have led to more and more tributaries and main rivers drying up quickly, leading to a lower surface and groundwater availability for the increasing population.

Mean annual daily temperature has increased by almost 2°C in the period 1969-2000 (Fig. 2.5) and is projected to increase by 2.5-3.0 °C by 2050.

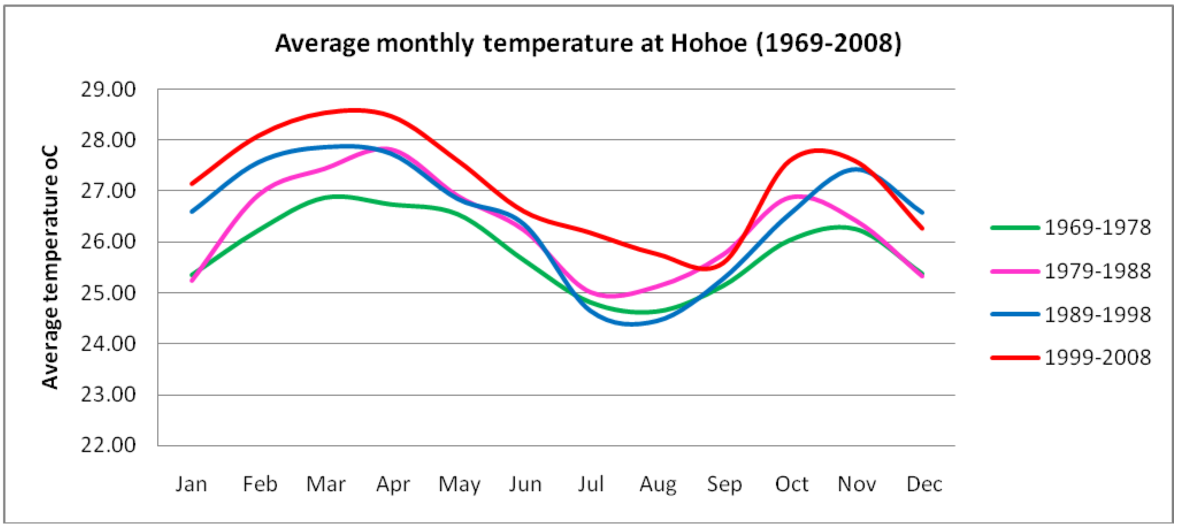


Fig. 2.5 Average monthly temperature at Hohoe (1969 – 2008)

In a study by the Environmental Protection Agency[6] the impacts of likely climatic changes on river discharges (runoffs) were analysed for the country. One of the basins included in the study was the Volta basin. It is imperative that the impacts and consequences cited in that study report are duly recognised in future water resource planning activities for the Dayi River Basin. The main findings of relevance for the Dayi IWRM plan are:

- There was an observed increase in temperatures of about 2°C over a 30-year period, and reductions in rainfall and runoff in the historical data sets.
- Simulations using realistic climate change scenarios (10-20% change in rainfall and a 1-2°C rise in temperature) indicated reduction in runoffs of 15-20% over the coming 20-year period.
- The climate change scenarios also cause reduction in groundwater recharge at a rate of 10-15% during the same period.
- Irrigation water demand would be affected considerably by the simulated climate change adding some 50% to the base period water demand.

A recent projection from the Netherlands Climate Assistance Programme (NCAP) indicates a further decline of rainfall and a shortening rainy season, combined with increasing temperatures throughout the year.

The Vrije University of Amsterdam (VUA) has developed a rainfall generator for the tropics. The rainfall generator uses historical rainfall data from several locations and a temperature rise based on a certain scenario to create the new dataset with nearest neighbor resampling .For the case of the Dayi River basin, a scenario with a temperature rise of 3 ^{0}C in one century is used. The result is a time series of 25 years with data of temperature and precipitation representing the present situation, the 2040 climate and the 2080 climate.

[6] *Environmental Protection Agency (EPA): Climate Change Vulnerability and Adaptation Assessment on Water Resources in Ghana (February 2000)*

The rainfall generator gives an average of increasing yearly rainfall sum when comparing the present situation with the 2040 and 2080 climate (table 2.11; Fig.6). This increase mainly occurs in the months of March, April and August till November. For September and October the precipitation for the 2040 scenario is lower than for the 2080 scenario (Fig. 2.7).

Table 1.11 Average sum of precipitation and temperature for a period of 25 years

	Avg. sum of Precipitation [mm]	Avg. of Temperature [°C]
Present	1520	26.9
2040	1548	27.3
2080	1666	27.8

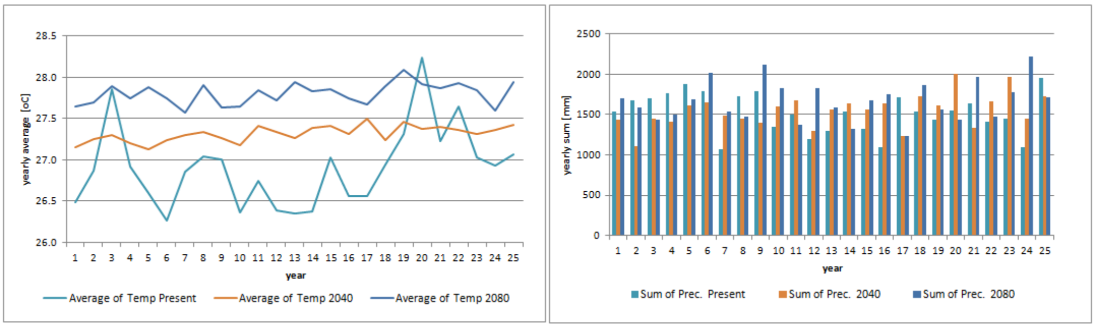


Fig.2.6 Yearly average temperature and yearly sum of precipitation in VU rainfall generator

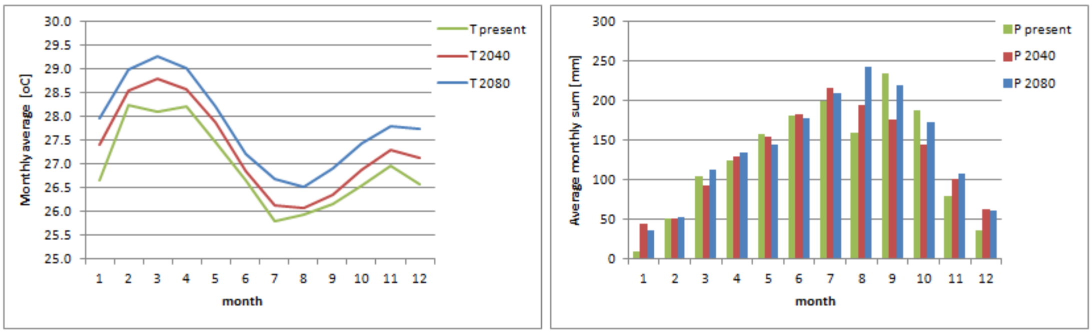
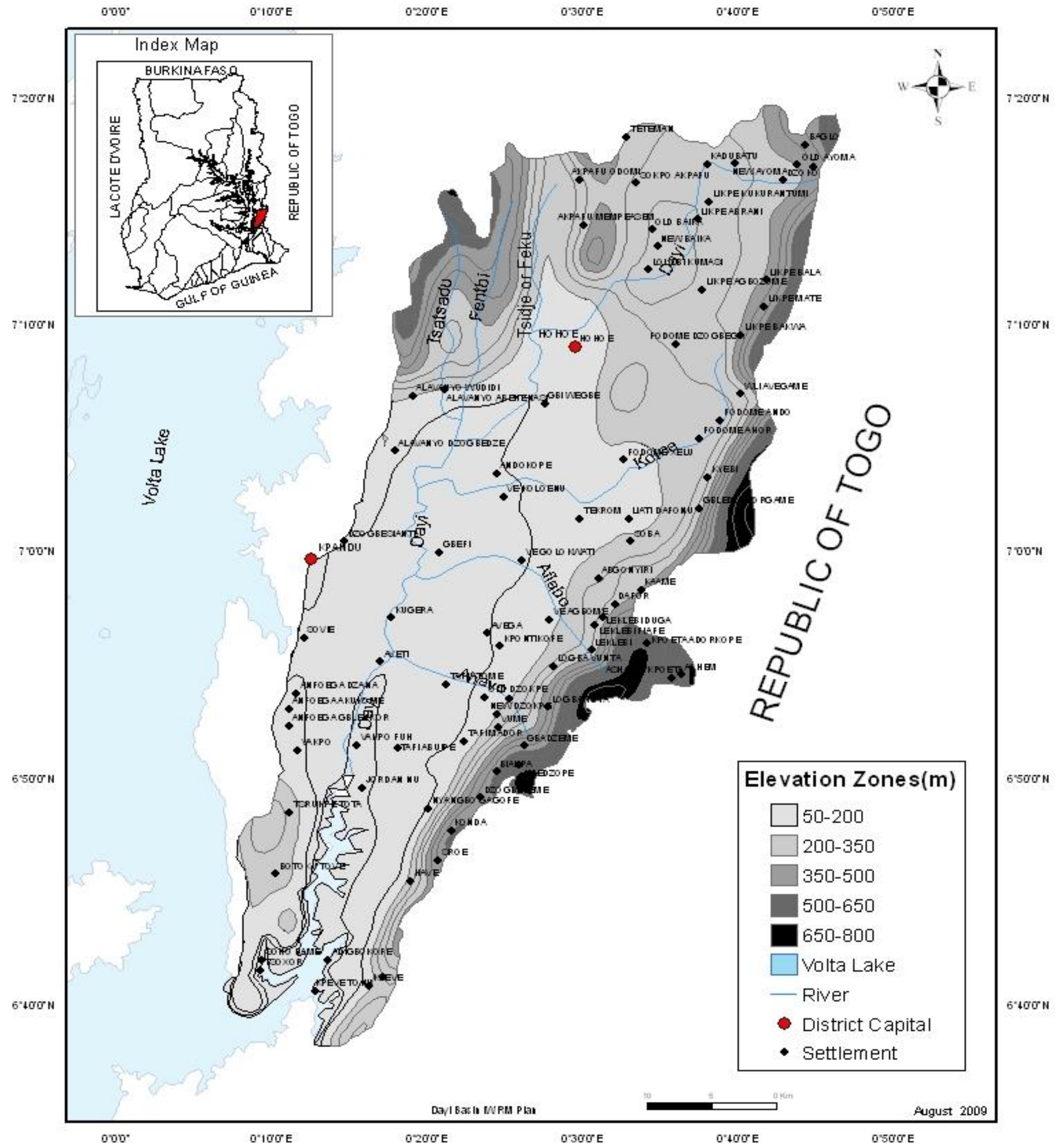


Fig. 2.7: Monthly average temperature and average monthly sum of precipitation in VU rainfall generator for present situation, 2040 climate and 2080 climate.

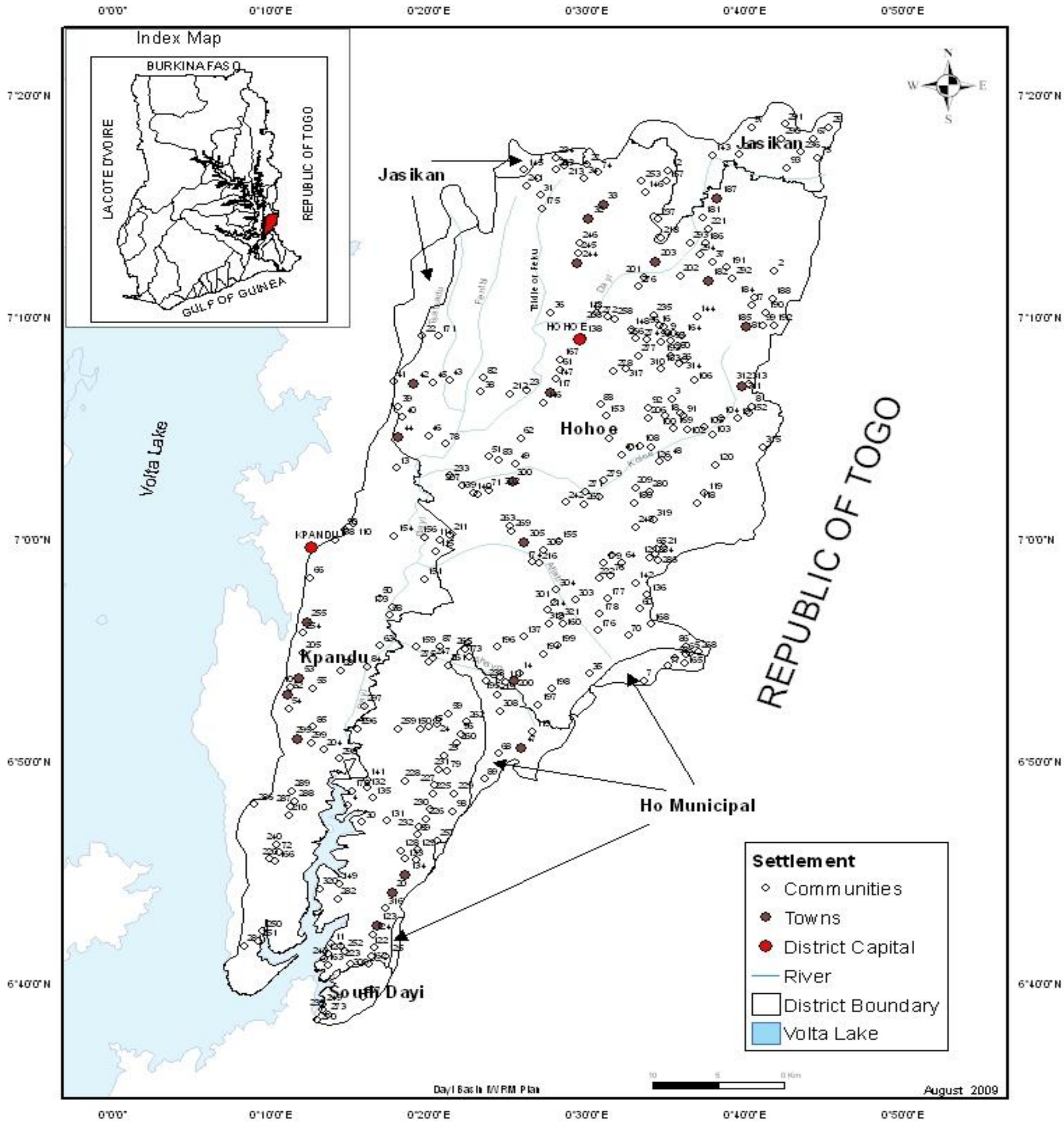
Almost 60% of the economically active population within the basin depends on the agricultural sector, it is important to look at the vulnerability of the agricultural sector towards climate change.

Currently only 29% of the total arable land within the basin is under cultivation. Since irrigation is often not a common practice, farmers have become completely dependent on the precipitation and have to adjust their farming patterns according to the changing pattern of rainfall.

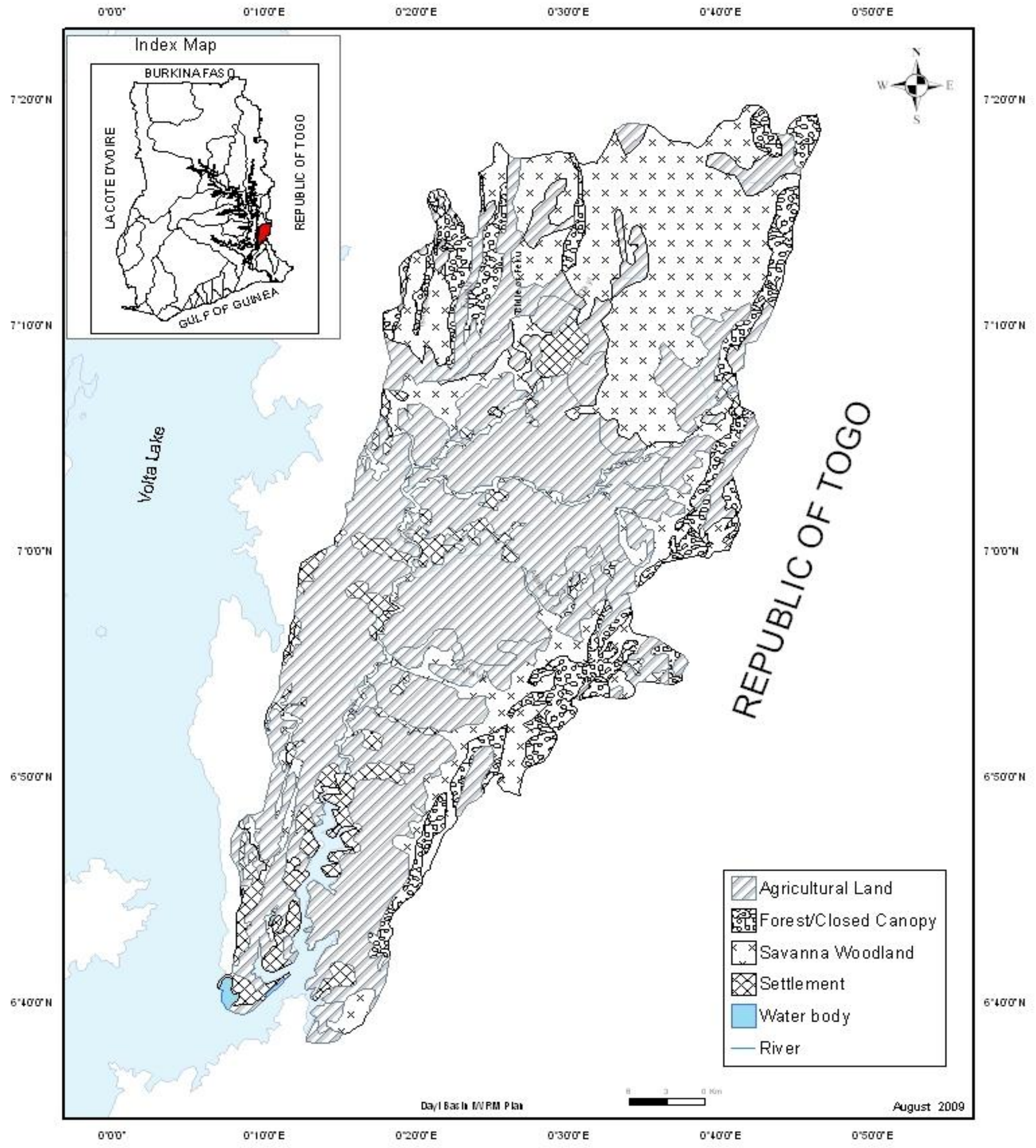
The decrease in the amount and reliability of rains has a severe impact on rain-fed agricultural. This amplifies the negative effects of shifting agricultural practices and population growth that already led to over-harvesting of wood, bush fires and ultimately land degradation.



Map1: Topography of Dayi Basin

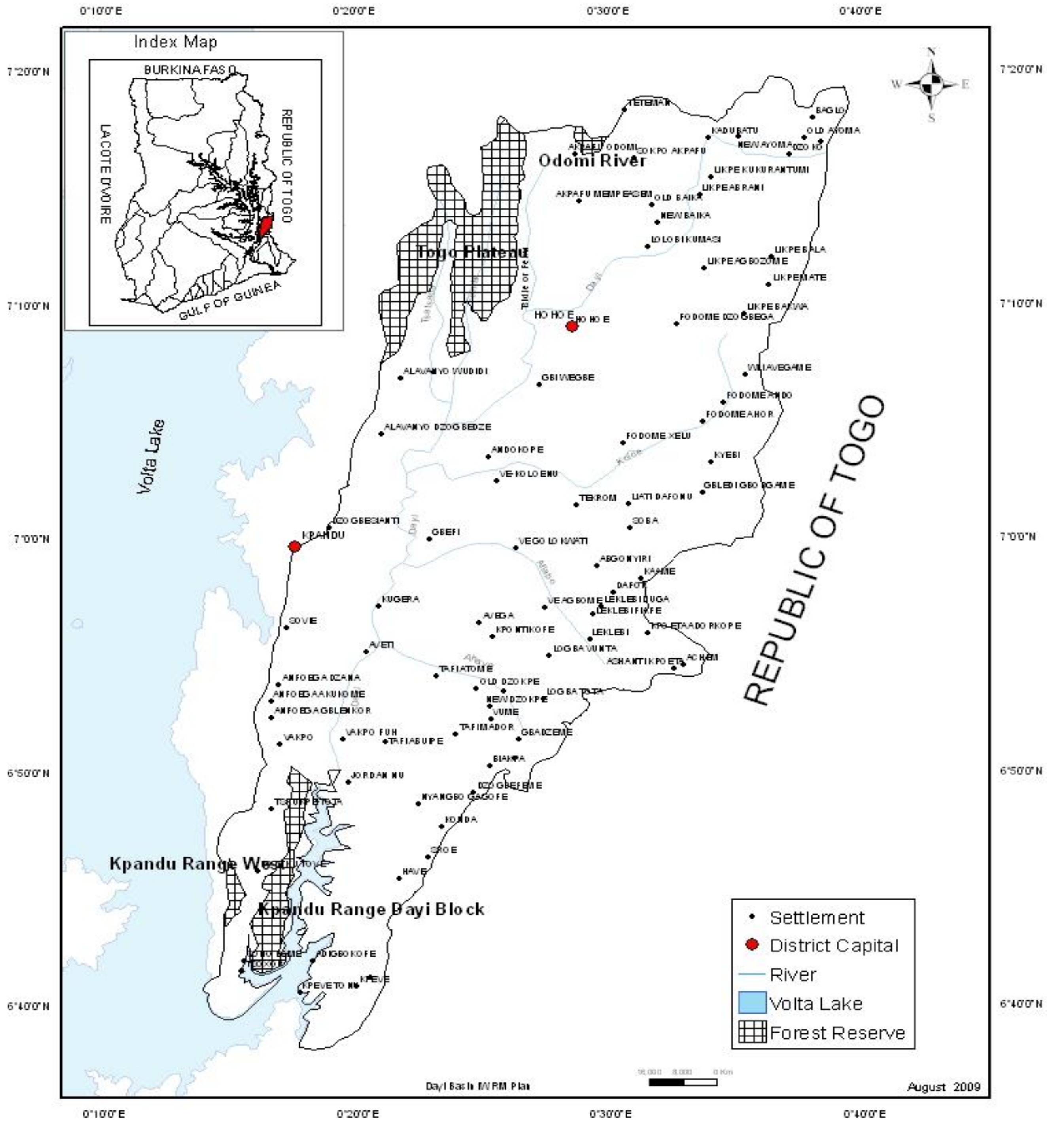


Map 2: Districts and Towns/Settlement in Dayi Basin

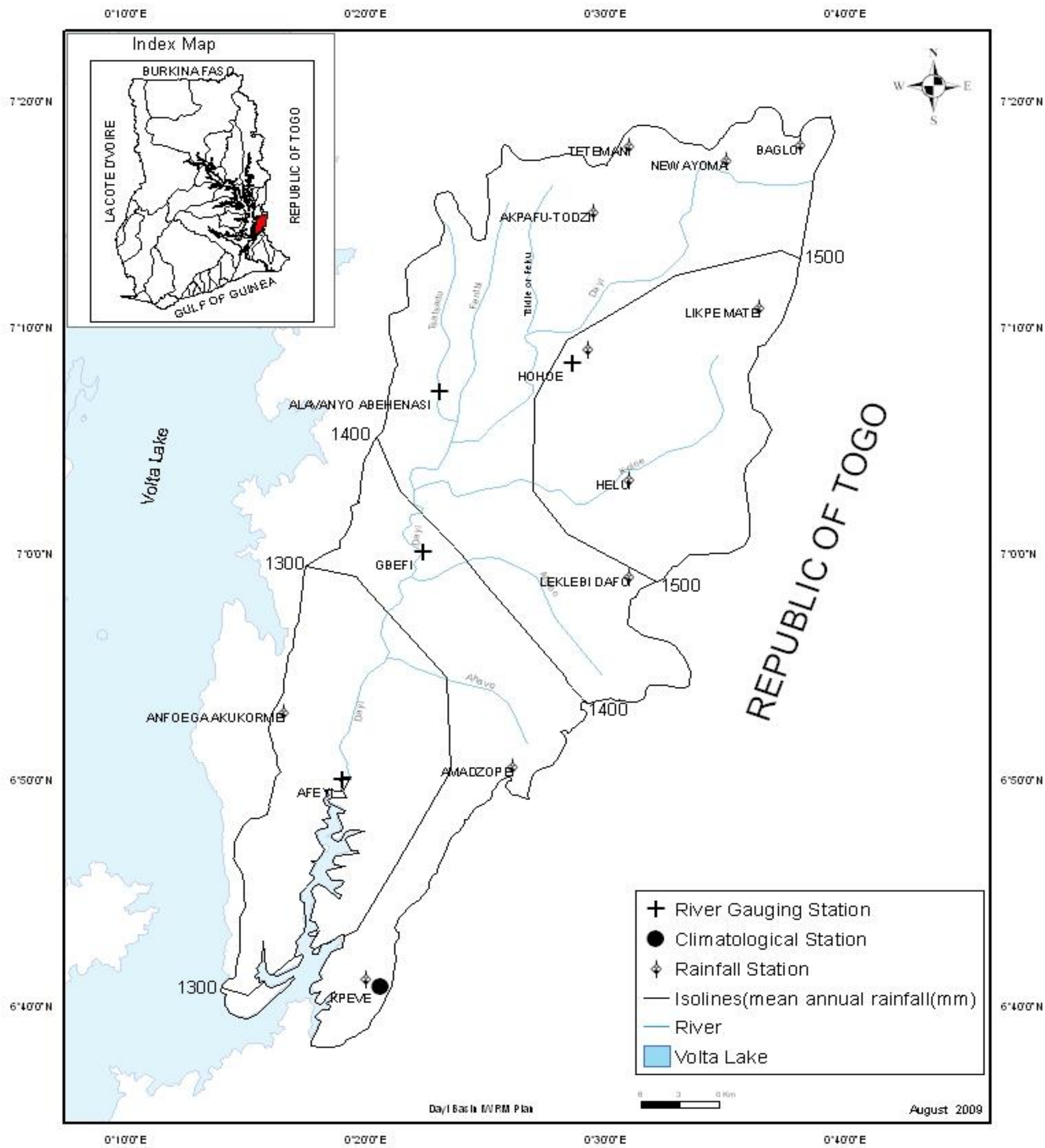


Land Use	Ha
Agricultural Land	86896.431
Forest/Closed Canopy	17055.937
Savanna Woodland	50282.259
Settlement	12122.977
Water body	6692.925

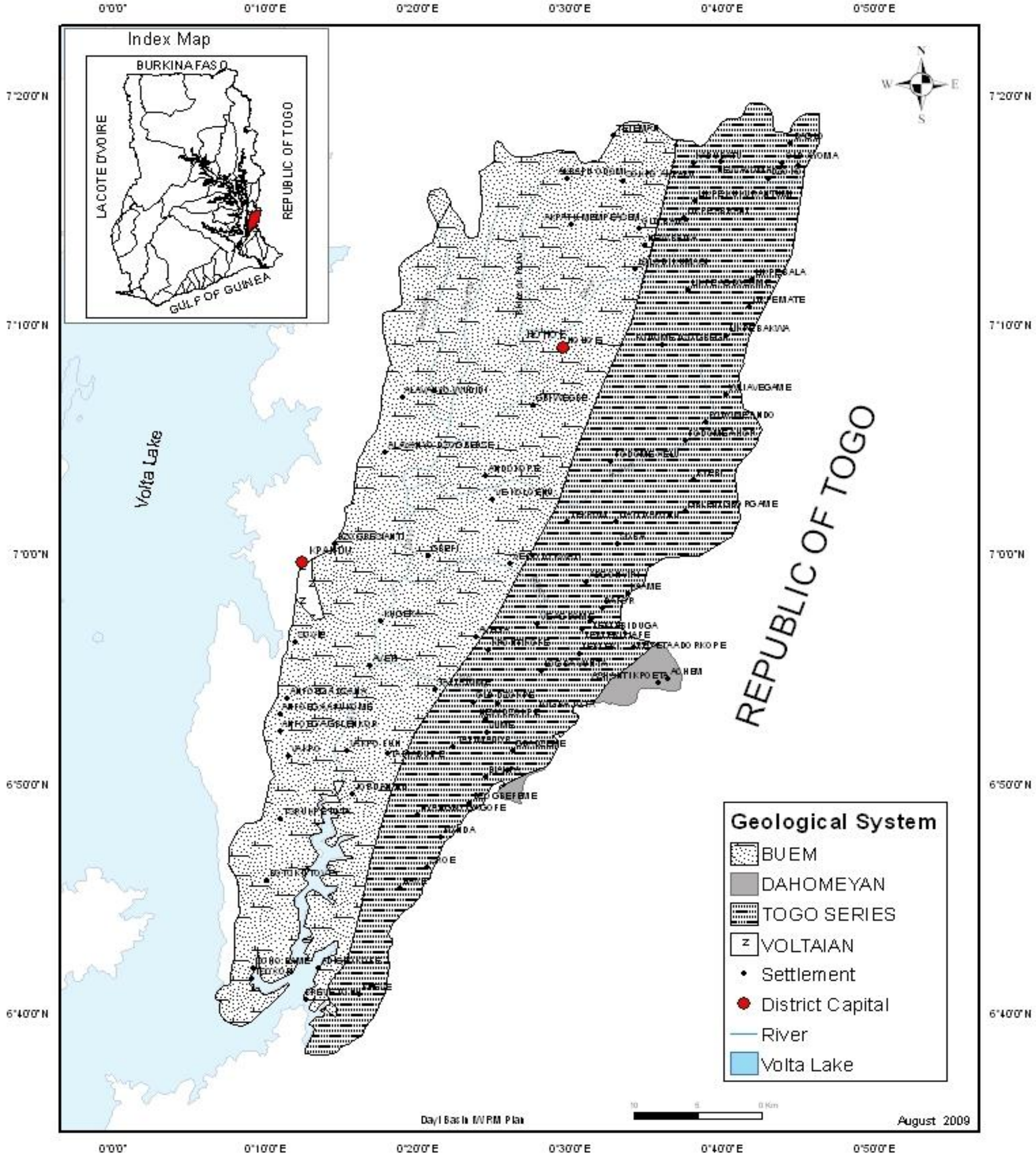
Map 3: Land Use/Cover (2000) of Dayi Basin



Map 4: Forest Reserve in Dayi Basin



Map 5: River Network, Meteorological & Hydrological Monitoring Stations of Dayi Basin



Map 6: Geological Map of Dayi Basin

3. WATER DEMAND PROJECTIONS AND WATER AVAILABILITY

Based on the demographic and socio-economic conditions, findings related to the overall water balance of the basin and the river flow regime (floods/droughts) given in the baseline description in the previous chapter, projected water demand and assessments of the balance between future requirements and water resources availability has been carried out.

The demand projections versus future availability of water resources is addressed by presenting a number of scenario analyses, which highlight various options related to utilisation and management of the water resources. The water demand projections are made covering a plan period ending by year 2025.

The scenario analyses capture some of the key “quantitative” water resource planning issues associated with the Dayi River Basin in meeting future demands, namely impacts of diminishing water availability particularly during the low-flow season due to climate change and variability, and possible changes in the cross-border flow from upstream Togo.

The result of meeting environmental flow requirements to protect the ecosystems of the riverine environment is also accounted for in the demand projections.

3.1 Demographic and socio-economic development trends

The assumptions used in calculating water demand for the supply of potable (municipal/domestic) water and to meet water requirements for the main socio-economic activities, notably agriculture (irrigation), are outlined below.

3.1.1 Assumptions for projection of potable water demand

The requirement for potable water for domestic, institutional and industrial purposes is determined based on estimates of per capita water demand figures. The unit water demand (daily per capita demand) figures applied are adapted from the design values generally used by Ghana Water Company Limited, which are differentiated according to settlement size and time horizon as depicted in Table 3.1.

The unit consumption rate of 35 litres/capita/day indicated for the rural communities is set relatively high to reflect the fact that some water from the point sources (boreholes/wells) also is used for subsistence farming and cattle watering purposes.

Table 3.1: Unit water demand (litres/capita/day)

Settlement size	Category	2008	2015	2020	2025
< 5,000	rural	35	35	35	35
5,000-15,000	urban	55	65	75	85
15,000-50,000	urban	85	85	90	95
> 50,000	urban	105	110	115	120

Based on the 2000 Census report, the population of various districts within the Dayi basin was computed, annual Regional population growth rate was used to compute the projected population sizes for each district within the Dayi River Basin. The district population growth rates were not readily available therefore the regional growth rate was adopted.

The population growth rates used for the districts population projection do not make a distinction between municipalities/urban areas and rural settlements/villages, which means (it must be assumed) that the indicated growth rates represent "average" values combining both the rural and the urban settlements of the respective districts. In the context of the IWRM planning these compounded figures provide sufficient detailing for overall water demand estimation, water balance analysis etc. Further details in this regard are only required, e.g. in connection with actual design of specific water supply schemes.

With these basic assumptions in mind, Table 3.2 presents the population forecasts per district and accumulated for the entire Dayi River Basin.

Table 3.2: Population projections for the Dayi River Basin (2000-2025)

Region	District	Settlement category	Annual growth rate (in %)	Population				
				2000 Census	2011	2015	2020	2025
Volta	Jasikan	rural	1.9	5,697	7,000	7,600	8,300	9,100
		urban		1,424	1,750	1,900	2100	2,300
	Kpandu	rural	1.9	15,085	18,600	20,000	22,000	24,200
		urban		3,890	4,800	5,200	5,700	6,200
	South Dayi	rural	1.9	-				
		urban		-				
	Hohoe	rural	1.9	85,084	104,700	112,800	124,000	136,200
		urban		25,414	31,300	33,700	37,000	40,700

Region	District	Settlement category	Annual growth rate (in %)	Population				
				2000 Census	2011	2015	2020	2025
	Ho	rural	1.9	5,574	6,900	7,400	8,100	8,900
		urban		2,897	3,600	3,800	4,200	4,600
Dayi River Basin total		rural	1.9	111,440	137,100	147,800	162,400	178,400
		urban		33,625	41,400	44,600	49,000	53,800

The total population of the Dayi River is expected to increase from the 2000 Census figure of about 145,000 to about 231,000 in 2025. It has to be added that the water resources of the Dayi river basin is also a source of water supply for most communities outside the boundaries of the basin.

3.1.2 Assumptions for projection of agriculture water demand (*Irrigation)*

Irrigation water requirements are in various documents, for instance the WARM study[7], reported to vary from an annual amount of about 10,000 m^3/ha for vegetable produce to around 25,000 m^3/ha for rice fields. This amount matches well with a similar figure which can be derived from the State of Environment Report[8], indicating an amount of 14, 300 m^3/ha/year in average for the entire country.

In the context of this IWRM plan, it is further assumed that the irrigation efficiency factor is embedded in the above given average water requirement per unit area under irrigation.

More importantly, the analyses also need to incorporate the effect of climate change, which besides having an effect on the river flow regime also has a pronounced bearing on the water requirement per unit area under irrigation. In these analyses, the present estimate of irrigation water demand is about the same with rural water demand. Taking into consideration the effect of climate change on irrigation water requirement, (which has been estimated to be 75% more than the present irrigation water requirement), an estimate of irrigation water demand has been included in the water demand projection.

Livestock watering is insignificant in the basin and therefore was not added to the water demand projection.

[7] *Ministry of Works and Housing: Water Resources Management (WARM) Study, Information "Building Block" Study, Part II, Vol. 2: Information on the Volta Basin System (May 1998)*

[8] *Environmental Protection Agency: State of Environment Report 2004. EPA (April 2005)*

3.2 Water demand projection on a basin basis

By applying the various assumptions and figures given in the preceding section, the future water demand for the Dayi River Basin as a unit has been calculated with results given in Table 3.3. To account for the fact that some of the communities presently classified as "rural" eventually will move into the "urban" category, i.e. when they grow to exceed 5,000 people, it is assumed that 15% of the 2025 calculated rural water demand will be part of the urban water demand – this aspect is also imbedded in the water demand figures given in Table 3.3. Furthermore, it should also be emphasised that the figures in the table represent the "ultimate" water demand as required by the whole population of the basin, i.e. assuming 100% service coverage both in the rural and urban settings.

Table 3.3: Water demand projections in the entire Dayi Basin (2011-2025)

User category	2011		2015		2020		2025	
	m^3/day	10^6m^3/yr	m^3/day	10^6m^3/yr	m^3/day	10^6m^3/yr	m^3/day	10^6m^3/yr
Urban population	5,000	1.8	5,400	2.0	5,900	2.2	6,500	2.4
Rural population	4,800	1.7	5,200	1.9	5,700	2.1	6,300	2.3
Irrigation	8400	3.0	9,100	3.3	10,000	3.7	11,000	4.0
Dayi River Basin, total	-	6.5	-	7.2	-	8.0	-	8.7

(i) Unit water demand/ capita/day of 120 liters was used for the entire urban population

The figures in table 3.3 indicate that the irrigation water requirement in the future (incorporating climate change impacts) will be by far the largest demand category followed by urban water requirement which is about the same with rural water supply.

3.3 Scenario analyses of water availability vs. requirements

3.3.1 Introduction to scenario analyses and model assumptions

The low-flow regime of the Dayi River system determines its viability to sustain a year-round supply for larger schemes designed for direct abstraction without storage (reservoir) capacity provided. Therefore, to examine the consequences and extent of future water shortages in step with increased demand, the low flow regime – as reflected in runoff records from a number of river gauging stations in the basin – is introduced as requisite input in the water accounts analyses.

3.3.2 The WEAP water accounts model tool

The computer-based Water Evaluation and Planning (WEAP) model as applied to the Dayi Basin is developed to support water resources planning and to inform decision making on water allocation in the basin. The WEAP is an integrated model combining demography and water requirements of various uses, water resources availability and allocation in a typical basin.

Based on the river network and associated contours, the Dayi basin was divided into five (5) hydrologic sub-catchments which are essentially the areas that contribute to the river flows as observed at the gauging stations located on the outlet of each catchment. For all intents and purposes, the Lower Dayi catchment was ignored in this exercise owing to the influence of the Lake Volta waters on the fringes of its delta.

3.3.3 Parameterization of WEAP

A number of data and information that characterize the Dayi basin require processing and organized into formats usable in WEAP. These include hydrological and meteorological data, land cover and land-use, demography and water requirements for various uses.

3.3.3.1 Hydro-meteorological data

The Dayi basin is located in the Volta basin and thus begins its water year in March. Historical hydrological and meteorological data of river-flows, rainfall and temperature on daily time series for Dayi basin were obtained from data gathering institutions. Further, data on relative humidity and cloud cover for the basin was extracted from the TS 2.1 dataset of the Climate Research Unit (CRU) of the University of East Anglia (http://www.cru.uea.ac.uk/cru/data/hrg/cru_ts_2.10). Arranged in a grid of 0.5° spacing, it was overlaid on the said basin for which only one pixel fell within the basin. The data associated with the pixel that fell in the basin was extracted, computed and processed into daily time series. The CRU dataset used covered the period 1951 – 2002. Data on wind speed was obtained from literature.

3.3.3.2 Land cover/land use projections

Land cover in the Dayi basin is characterized by grassland, savannah, forests, wooded wetland, the Volta Lake and human settlement as recorded through satellite imagery in the 1970s, 1990 and 2000. The grassland which constitutes mainly agricultural lands has increased over the years. This is attributed to population expansion and the need for food security especially when local councils were elevated to district assembly status coupled with the creation of new ones in the late 1970s and early 80s which might have enhanced migration to such areas. It is also expected that proper town planning of settlements would be instituted by the District and Municipal Assemblies to influence/control infrastructure and housing development towards managing environmental sanity. In the same vein, forest lands have been converted into savannah with the expectation that by 2030, the total forests lands would be halved over the forty year period.

3.3.4 Development of scenarios under climate change

This section focuses on scenarios to assess the effects of climate variability and change on water availability, exploitation and which portion(s) in the basin is/are likely to experience water stress in the future, including projected development(s). Scenarios have been developed over a 20-year period with the year 2010 as "base" or "current year" of simulations.

A report on the meeting of the *Intergovernmental Panel on Climate Change (IPCC in 2007)* indicated increasing temperature trends per decade in the West African sub-region[9]. At the same time, the meeting produced no consensus on the expected changes in the precipitation pattern and trends over space and time, whether a decrease or an increase relative to historical trends.

Thus four scenarios are developed as follows:

- Reference scenario- uses historical daily data as input towards 2050.
- B1 which is a low climate change scenario of the HadCM3 model (developed by the Hardly Centre in the UK), downscaled to the Dayi basin. Here, the precipitation on monthly time series is divided by the average number of days, repeating the average monthly temperature for each day.
- A2 represents a high climate change scenario of the HadCM3 model downscaled for the Dayi basin. The B1 process of translating monthly data into daily data applied.
- Weather Generator - this is a statistical tool developed by the Vrije Universiteit that correlates future temperatures with likely precipitation levels, based on historic relations. This model produces daily output.

3.3.5 Results of the Model

Having "inputted" daily hydro-meteorological data, land cover/land-use, demography and water consumption per capita, the model was run. The WEAP was then explored to ascertain the renewable water resources in a changing climate, and how the projections of water requirements of various uses were met.

3.3.5.1 Annual water resource

The WEAP churned out the volume of water available for exploitation from the "inputted" daily precipitation data. Following, the daily volume of water was aggregated to present the annual perspective of the resource in the basin. Clearly, the result is characterized by wet, normal and dry years in all the scenarios with the climate change under drier state being more pronounced. "All catchments" imply the entire Dayi basin whiles "all days" refer to the

[9] http://www.ipcc.ch/publications_and_data/publications_and_data_figures_and_tables_gr-climate-changes-2001-syr.htm

annual total volume of rainfall. Thus annual precipitation volumes range from nearly 2 billion m^3 in a dry year under reference scenario to 4.2 billion m^3 in a wet year under low climate change scenario as presented in Fig 3.1.

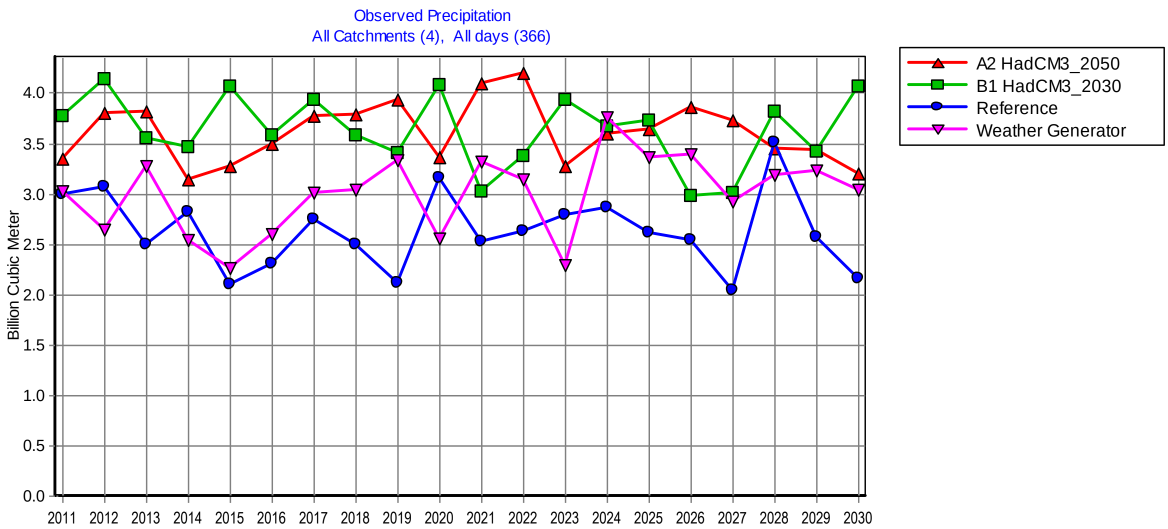


Figure 3.1: Total annual precipitation in the Dayi basin for typical climate change scenarios

This volume of precipitation is expected to satisfy the hydrologic cycle through runoff, evapo-transpiration, storage and groundwater recharge

3.3.5.2 Exploitable water resource

The volume of water available for exploitation is certainly the volume of precipitation that contributes to runoff and consequently river flows per river system in the basin. As shown in figures 7, about 16 % to 26 % of the total volume of precipitation contributes to runoff and thus available for exploitation (Fig. 3.2). This implies that a greater volume of water accounts for evapo-transpiration and groundwater recharge.

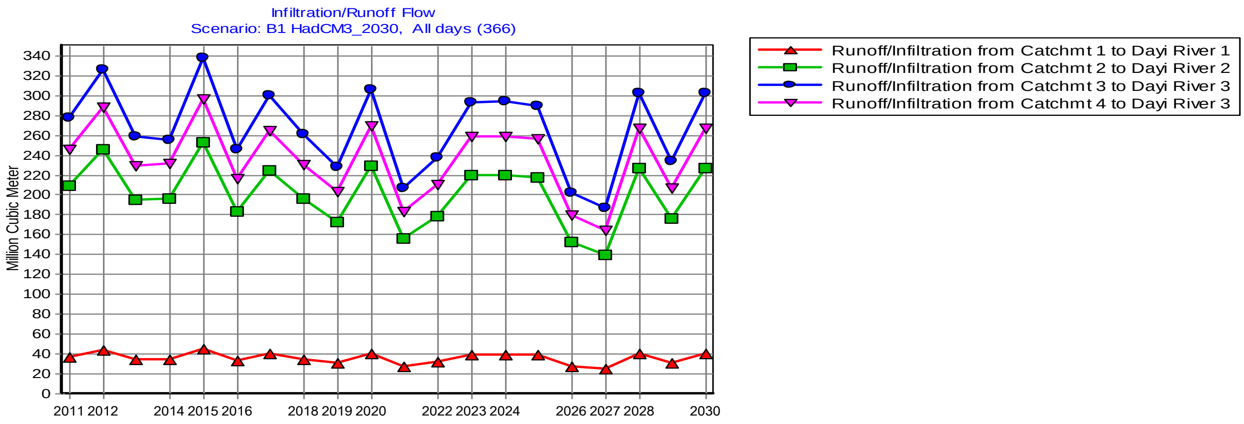


Figure 3.2: Total annual runoff as per the catchments under low climate change scenario

Although the annual view looks good in terms of available water resources, the daily perspective is somewhat low as shown in figures 3.3 and 3.4. Whereas figure 3.3 looks at the annual view, figure 3.4 looks at the runoff during the dry periods of the water year notably from November to February.

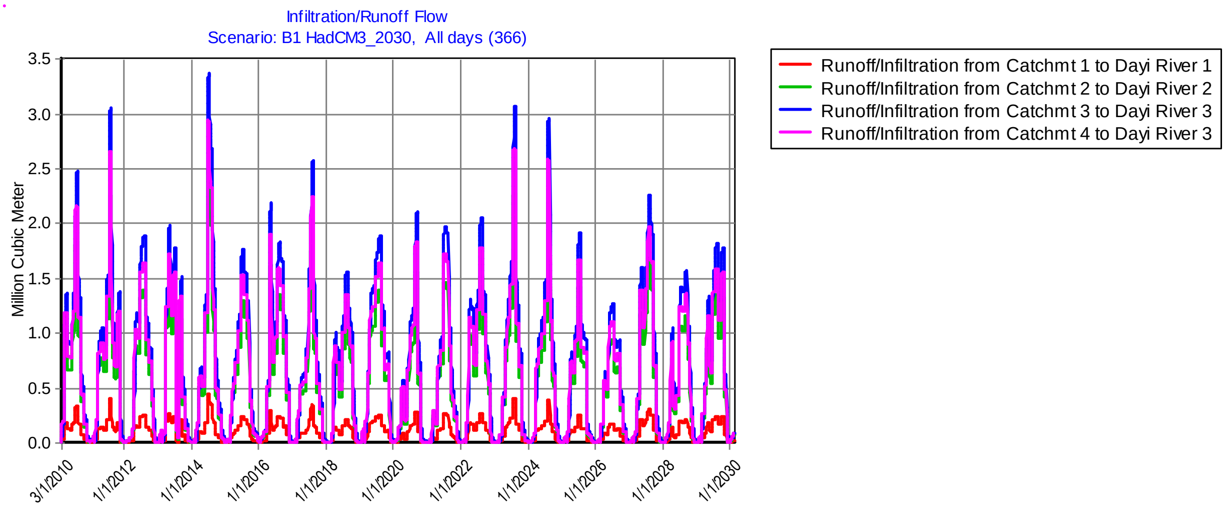


Figure 3.3 Daily runoff from the catchments to the main rivers under low climate change scenario

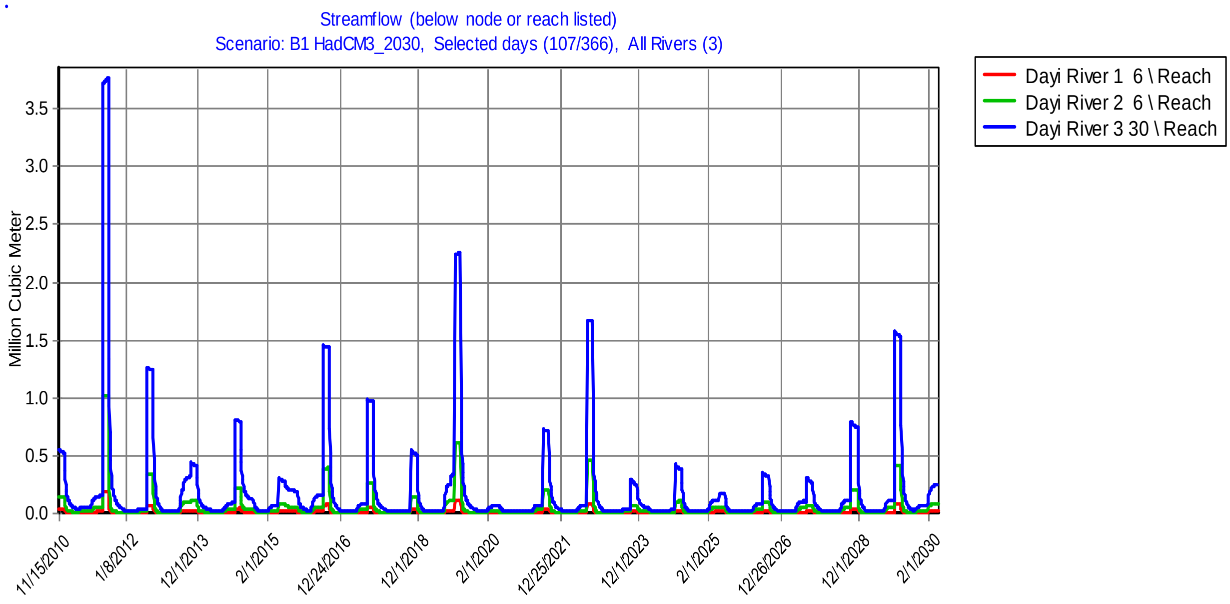


Figure 3.4 Daily streamflow in the main rivers from November to February in a typical year under low climate change scenario

Figure 3.4 shows that the daily average volume of streamflow within the reach of the rivers range from 0 Mm^3 to 0.8 Mm^3 during the dry season especially in the Dayi river tributaries in the Kpando and Ho areas which implies "dryness" as well as "no rains" since the model was constructed with daily time series data. However it should be noted that the riverflows during this period is very critical to irrigation activities in the basin.

3.3.5.3 Domestic water demand coverage

Having a projected population growth rate of 1.9% per annum for Hohoe town coupled with increasing water demand per capita, domestic water demand is fully satisfied for all months of the year over the projected period as shown in figure 3.5.

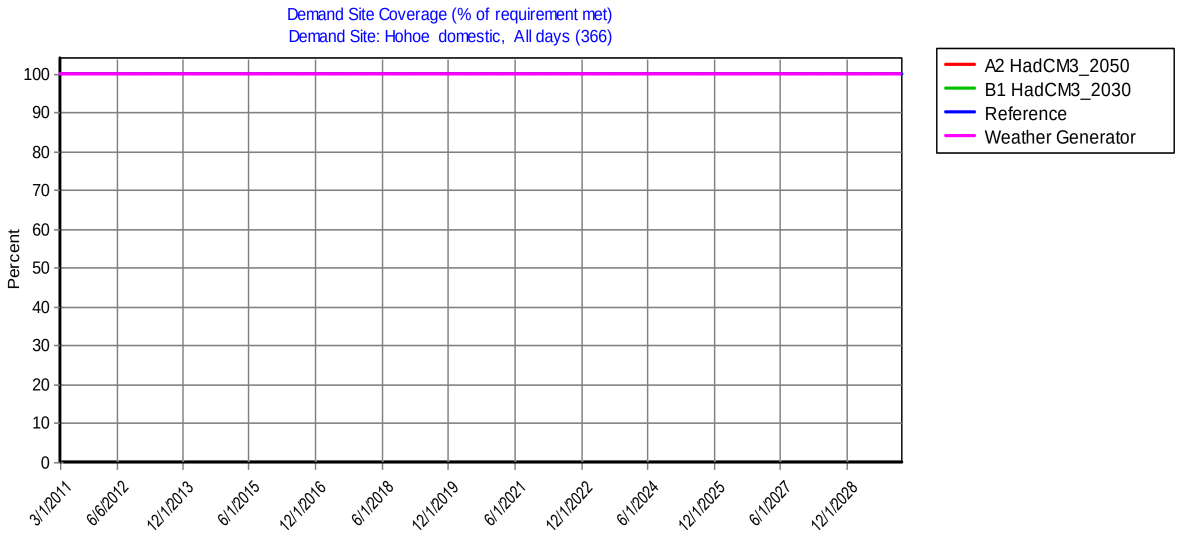


Figure 3.5 Domestic water demand coverage for Hohoe for all climate change scenarios

The installed weir by the Ghana Water Company Limited on the river upstream is serving its purpose. However, the information and data including its dimension was not available for incorporation in the present modelling. Thus it is not conclusive whether there may be the need for expansion to cater for the growing population and the increasing water demand to support irrigation development.

3.3.5.4 Livestock water supply coverage

The livestock populations in the basin are threatened by water shortages from November to March in the tributaries of the Dayi River over the projected period in the areas of Kpando and Ho. However, the livestock in the Hohoe and Afeyi areas are fully satisfied.

The shortage is explicit for the two areas and begins in early November towards early March when the rains set in to replenish the river water. Water supply coverage ranges from 100% in mid-March to October, and decreasing to 8% in January over the projected period. In this regard, animals may depend on other sources of water for their nourishment including wetlands and ponds. Environmental flow may also support livestock water needs, and in case of absolute drought they may migrate southward where water availability is assured.

3.3.5.5 Water demand coverage for irrigation schemes

Two sets of irrigation developments are identified in the basin. The irrigation schemes notably New Baika, Lolobi Kumasi, Ve Koloenu, Gbefi and Vakpo, whose water demand coverage are shown in figure 3.6 are designed within the ADAPTS programme. New Baika abstracts water directly from the main Dayi River upstream of the GWCL weir while Lolobi Kumasi abstract water from the dam. The rest of the three are located downstream of the GWCL weir in the middle portion of the basin. The water demand coverage for all the schemes during the greater parts of their operations were 100 % and reduced to about 23 % in times where the precipitation fell below the average for the basin.

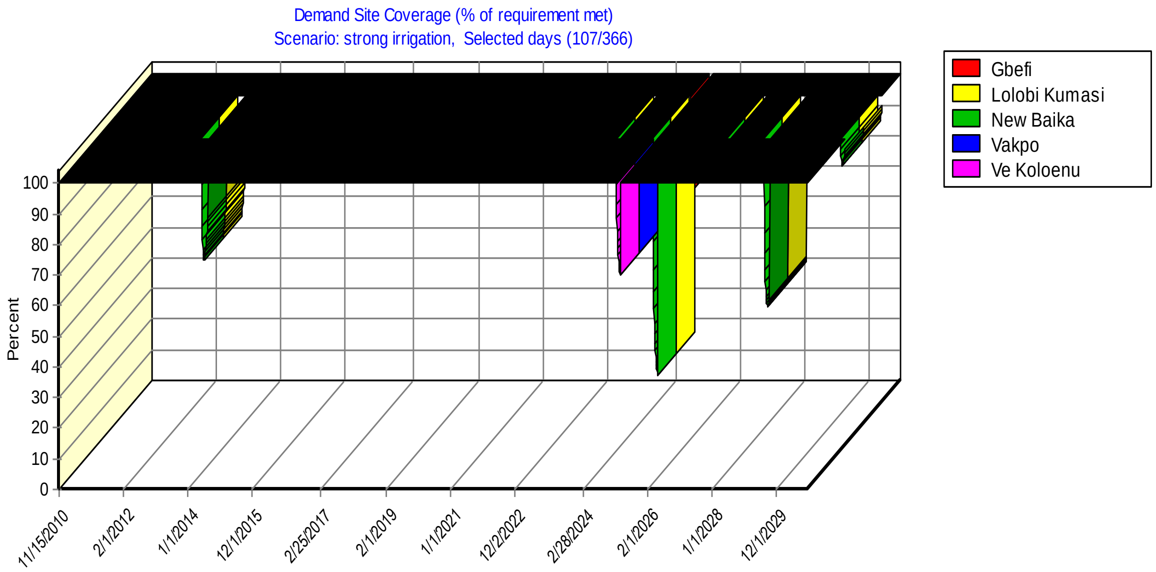


Figure 3.6 water demand coverage for ADAPTS irrigation schemes in the basin under high climate change scenario

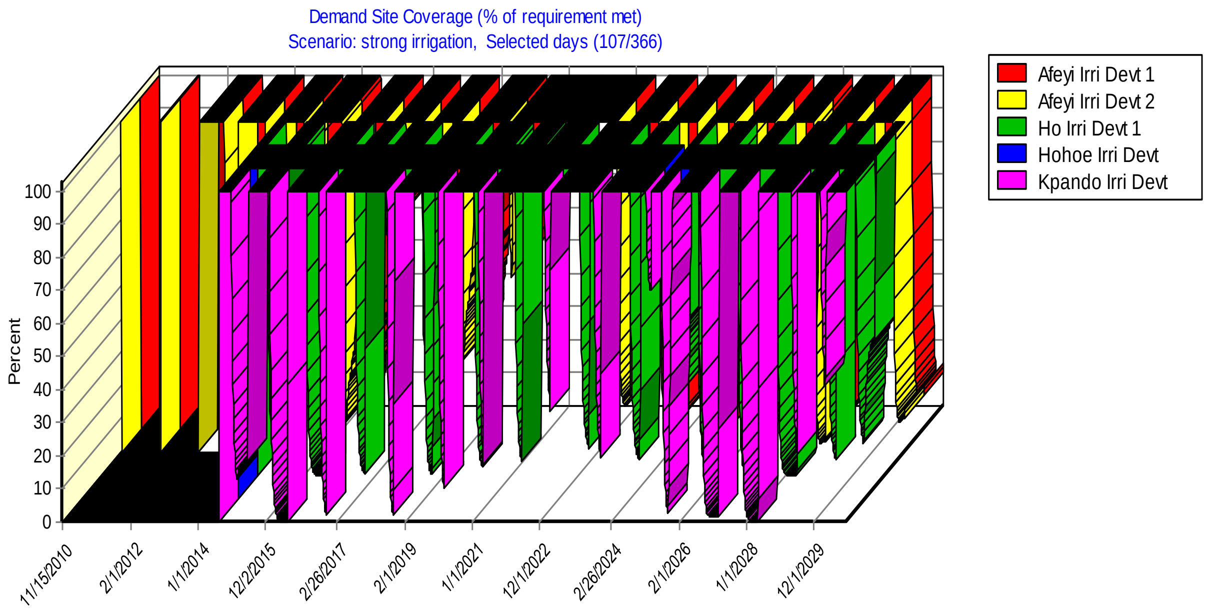


Figure 3.7 Water demand coverage for projected irrigation schemes under high climate change scenario

Figure 3.7 shows projected irrigation schemes other than the ADAPTS programme and distributed in the basin. From the configuration of the model, the irrigation schemes of ADAPTS have higher priority relative to these other schemes as they occur in the sub-catchments. Figure 3.7 depicts rather low water demand coverage for these irrigation schemes and ranges from 100 % at the beginning of the lean season to nearly 0 % in the areas of Ho and Kpando. By January, the water available for productive activities reduces with the consequence of limited irrigation unless other sources of water are harnessed to supplement abstractions from the rivers.

From the assessment above, surface water resource available for exploitation is concentrated in the main channels of the Dayi River. River flows are however, reduced decreasing to ‘zero’ especially in the tributaries, which implies ‘dryness’ in very dry years over the projected period and is pronounced in January among the dry months from November to February.

The water demands of Hohoe Town, the livestock populations and future irrigation schemes on the main Dayi river were satisfied all year round over the simulation period. However, water deficit was recorded in the dry months becoming pronounced in mid January for livestock watering as well as the irrigation schemes in the Kpando and Ho areas, although the irrigable lands did not experience any expansion over the simulation period.

It is important to note that the weir in the upper catchment of the Dayi River was installed purposely to store water to serve Hohoe Township. However, with the development of irrigation schemes downstream, it is necessary to review the operations of the infrastructure to make room for downstream water requirements. It may be important also, to develop other water structures to undertake irrigation activities in the basin especially along the tributaries during the dry season. This includes small dams or groundwater resources. Although surface water may be scarce in the basin during dry months, groundwater resources appear to be in abundance given the sedimentary character of the geological formation of the Dayi basin. However, investment is required to tap into this resource to meet the demands to assure household food security needs. Hence groundwater could be harnessed to buffer the ever increasing demand for water for various uses in the basin including livestock, domestic water supply and irrigation activities.

Rainwater harvesting is an option but may be relatively expensive which may necessitate rehabilitation of broken dams at strategic locations in the basin whiles new ones could be built. These dams could serve multiple purposes.

For now, the Dayi River tributary that drains the Ho region is the most stressed given the population of the area and the water requirements. The same could be said in the Dayi tributary originating from the Kpando area.

The installation of formal irrigation schemes downstream of the weir may necessitate a review of the operations of the weir towards meeting the water requirements of downstream users, as was the case for this exercise.

4. CONSULTATIVE PROCESS

4.1 Application of SEA in the IWRM planning process

This IWRM plan is based on hydrological and other technical data, socio-economic trend analysis, and population census information that only partly has been presented earlier and not as an integrated assessment with the purpose of describing the present and future situation within the Dayi Basin concerning the availibility and quality of the water resources.

In parallel with the technical assessments and description of the water resource-related challenges as presented in Chapters 2 and 3, a consultative process has been carried out with the involvement of “grass root” basin-based stakeholders aimed at capturing the local perception of water resources management issues and actions required in addressing the identified water management issues and problems areas. A series of workshops were organized at Hohoe in 2009, 2010 and 2011 aimed at collating views of local people as to how to address climate change and water management issues confronting vulnerable communities within the basin.

The Strategic Environmental Assessment (SEA) process presented a participatory platform for thorough public discussions often in workshop settings. The SEA procedures and tools[10] have been adapted and applied as part of the Dayi Basin IWRM planning process.

A SEA approach for planning is defined as:

“*A systematic process of evaluating the environmental effects of a policy, plan or programme and its alternatives, including documentation on findings to be used in publicly accountable decision-making”.*

Furthermore, the application of SEA procedures in IWRM planning means that the evaluation of environmental effects has an additional social dimension, viz.

“…to safeguard the future sustainable use of water resources aimed at maintaining the economic and social welfare within a basin without compromising the preservation of vital aquatic ecosystems”.

The district-based planning by District Assemblies is the cornerstone of the decentralised governmental approach for which the overall legal framework and institutional delegation of responsibilities are proven and understood - although gaps in legislation, overlapping responsibilities, lack of capacity/resources and enforcement still exist.

An IWRM plan for a basin addresses the basin-wide water management problems to be taken into account to achieve a future sustainable management of the basin’s water resources, and as such provide a framework for local water management planning at district level.

Consequently, the effects of the IWRM plan should not be restricted to a description of broad existing and projected future environmental and social impacts, but should also try to

[10] *Support and Capacity Building to apply SEA Principles and Tools in preparing IWRM Plans at River Basin Level*. *WRC (October 2006).*

describe the effects of the IWRM planning on other existing plans and programmes. The IWRM plan may entail legal and institutional consequences that might cause conflicting management structures, which then need to be coordinated and adjusted to ensure an efficient implementation of the plan.

4.2 Water Resources management issues as identified by stakeholders

In adherence with the SEA principles and embracing a participatory approach, a number of stakeholder meetings with planners from District Assemblies, governmental departments, farmers groups, Dayi River Basin Board and water user organisations were convened by WRC during elaboration of the IWRM Plan.

Table 4.1 presents the identified issues and problems within the Dayi Basin as perceived at the stakeholder workshops at the onset of the IWRM planning process. The information in the table reflects the answers as provided by three working groups.

Table 4.1: Water resources management problems as formulated by stakeholders

Group1	Group 2	Group 3
Environmental Issues		
1) Clearing of vegetation along the river banks for agric purposes.	1) Unpredictable rainfall pattern	1) Inappropriate farming practices
2) Low flows and flooding due to climate change.	2) Disposal of liquid and solid waste	2) Inconsistent rainfall pattern
3) Sand winning and soil erosion.	3) Farming Activities on river banks	3) Washing / Swimming in Rivers
4) Irregular rainfall pattern	4) Unapproved Fishing methods	4) Poor fishing practices
5) Water pollution	5) Tree Felling	5) Land litigation – (prevents protection)
6) Industrial waste into water bodies	6) Sand Winning	6) Flooding due to changing rainfall and disappearance of perennial streams
	7) Flooding due to high intensity rains and drying	7) Chainsaw / timber

7) Lack of enforcement 8) Inappropriate domestic waste discharge	of streams during dry season 8) Water weeds 9) Building close to River	operations 8) Some activities undertaken by small scale industries eg. akpeteshie, tie and dye 9) Improper drainage systems in catchment area

In summary, the problems to be addressed can be grouped as shown in Table 4.2. The numbers indicate ranking of the problem which reflects how often a specific category of problem was counted among the working groups. Number 3 is the highest rank and 1 is the lowest ranked problem as perceived by the stakeholders in the basin.

Table 4.2: Main categories of identified problems

Category of problem	No.
Environmental Issues	**24**
river banks degradation	2
deforestation and bush fires	2
Inappropriate farming methods and sand winning	2
Inappropriate fishing and fishing methods	1
Variability of rainfall	3
Effects of Sand wining	2
Water pollution	3
Water weeds	1
Domestic animals	2
Flooding during rainy season and drying of streams during dry seasons	3
Encroachments of river banks	1
Lack of enforcement of environmental laws	1

Based on the summarised presentation of the identified problems in Table 4.2, it can be concluded that:

- Greater attention is paid to problems related to flooding during rainy season and drying of streams during dry seasons as well as irregularity of the rainfall pattern. Other issues of priority concern are the water pollution, river bank degradation, bad farming methods and other land use activities
- economy as the main tool for initiating any new or additional management activities is not addressed as a problem at all; and
- lack of resources and capacity and coordination among institutions are to some extent seen as the reason for management problems within the basin, but not as described above, as a consequence of insufficient economic resources.

4.3 IWRM Action program

Based on the stakeholder workshops, a series of relevant actions were recommended for implementation in the first stage. These prioritised actions are listed in Table 4.3. The table also provides some explanatory remarks to be taken into consideration when the planning is further detailed towards implementation of the actions.

Table 4.3 Prioritised list of proposed actions/measures

Action	Explanatory remarks related to implementation of actions
Promote water harvesting techniques to store water for irrigation and educate vulnerable communities on other coping strategies Build capacities of vulnerable communities on climate change adaptation	Small scale adaptation measures have proven to be cost effective and manageable by the communities themselves as demonstrated by pilot irrigation activities in the basin through the ADAPTS initiatives. Up scaling of these activities are recommended in the basin and other parts of Ghana.
Public Education/ Awareness creation and intervention measures (provision of toilet facilities and disposal sites)	An extensive public education is required to change attitudes and also there is the need to provide alternative sites for waste disposal and other sanitary facilities
Enacting of bye-laws	The District Assemblies have by laws which when enforced will help manage water resources and preserve the environment
Regulations on activities near river basins should be enforced e.g. distance from river to nearest farm. Any economic activity should be at least 50m from the River basins.	Develop and enforce buffer zone policy to minimise impacts of flooding and implement structural and non structural measures to minimize flooding. In addition, develop early warning systems
Develop early warning systems to minimize the impact of floods	Flood models are necessary to demarcate flood prone area based on which early warning system will be developed.
Develop water harvesting and conservation techniques	Water conservation techniques which are resistant to the impact s of climate change should be development to provide water during the low flows.
Proper disposal of liquid and solid waste.	The Commission needs to collaborate more effectively with the MAs, and DAs to ensure proper disposal of liquid and solid wastes

The above prioritised list of actions and measures attempt to address a broad spectrum of the water management issues identified for the Dayi River Basin, such as flooding, drought, irregular rainfall pattern, river banks degradation and water quality/pollution.

5.0 Implementation

5.1 Economic and financial Considerations

Implementation of the actions listed above requires funding. Some of the activities can be initiated directly through normal budget allocations at District Assemblies level and through proceeds from the water abstraction licence fees lodged in the Water Resources Management Account. Further detailing of the action programme will have to incorporate ways and modalities of the financing.

Furthermore, where relevant, the actions shall be analysed for their economic implications and/or values. The contribution from an economic analysis can well induce other considerations, which were not directly included during preparation of the plan.

5.2 Role of WRC and the Dayi River Basin Board

It is important for proper implementation of the IWRM plan that the Dayi River Basin Board is mobilised with a clear mandate from WRC to address common problems to be solved through interactive collaboration between the Board and the District Assemblies. The mandate of the Board shall in addition to coordinating activities include obligations to initiate campaigns and to contribute towards elaboration of best practice in the conservation of water resources.

Another precondition for successful implementation of the plan is that a platform for inter-institutional cooperation is established to solve a number of specific tasks outlined in the IWRM plan.

5.3 Preparing project/action summary

An immediate first activity required in spearheading the way forward towards initiating implementation of some of the actions in the IWRM plan is for WRC in close collaboration with the Basin Board and other involved partners to prepare concise descriptions of the portfolio of the prioritised actions (Table 4.3). This should be done in a structured, easily understandable way using standardised format (“project/action summary sheet”) providing information about the action as follows:

- main objective and expected outputs;
- existing activities linked to the action;
- time duration and milestones;
- modalities for implementation and involved/collaborating partners;
- inputs and estimated costs;
- mode of financing/funding;
- modalities for monitoring and evaluation; and
- assumptions and risk factors associated with implementation of the action.

5.4 Monitoring and regular reviews of the plan

As part of the further detailing and preparation for commencing implementation of the prioritised actions, the milestones mentioned above should be detailed and expanded to provide information about progress indicators and sub-outputs to be achieved. It is against this background that progress in carrying out the plan's activities can be monitored.

It is proposed that the Board at its regularly convened quarterly meetings as a fixed agenda item should review the progress made in this regard and discuss the efforts made in carrying the IWRM Plan forward towards implementation. Additionally, once a year the action programme should be reviewed and updated. In practical terms it would entail a revision of and/or amendment to the project/action summary sheets, time schedules etc.

The present document constitutes the first version of the Dayi River Basin IWRM Plan. In as much as IWRM is a cyclic and long-term process, the document can be seen as a milestone in this process, in which the status of the water resources situation is documented – a process that should be subject to continuous updates as the need arises in the future.