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WATER & FOOD

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CPWF WORKING PAPERS
BASIN FOCAL PROJECTS SERIES

Water-use accounts in CPWF basins

Simple water-use accounting of the Volta Basin

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1. ABSTRACT

This paper applies the principles of water-use accounts, developed in the first of the series, to the Volta River basin in West Africa. The Volta Basin covers six countries, with 85% of its area in Ghana and Burkina Faso. The three main tributaries, the Black Volta, the White Volta and the Oti Rivers, all rise in Burkina Faso. The major feature of the Basin is the Akosombo Dam, which creates the world's largest man-made lake. Precipitation increases strongly from the dry upper reaches in the north of the Basin towards the south, where the river discharges into the Gulf of Benin.

Runoff in all three tributaries increases from 2-7% in the drier north to 12-26 % in the higher-rainfall south. Grassland is the dominant land use throughout Basin ranging from 76% of the Delta catchment in the south to 98% of the Arly catchment with corresponding water use of 55% and 92% of the water used in each. Water used by rainfed agriculture ranges from 1 to 18% of the water available. Water use by irrigated agriculture is negligible.

Climate change, if it is assumed to increase annual precipitation by 7.5% will increase the frequency of spill from the Akosombo Dam and make more water available for hydropower generation. Increasing irrigation in the basins of all three tributaries to about one-third of the land identified by FAO as potentially irrigable gives lower flows and storage in the Dam.

Keywords: Water use accounts, Volta basin, top-down modeling, basin water use.

2. INTRODUCTION

In this note, we describe a simple water-use account for the Volta Basin.

The Challenge Program on Water and Food (CPWF) aims to catalyse increases in agricultural water productivity at local, system, catchment, sub-basin, and basin scales as a means to reduce poverty and improve food security, health, and environmental security. The Basin Focal Projects of the CPWF works in several priority basins: the Indo-Gangetic Basin, the basins of the Karkheh, Limpopo, Mekong, Nile, Niger, São Francisco, Volta, and Yellow Rivers, and a collection of small basins in the Andes.

A useful output for each basin, and a key element of the understanding of basin function, is an overview of the water account. Water-use accounts produced in the same way for each basin would have the further benefit of making easier the development of syntheses of understandings from all the basins.

Water-use accounting is used at national (ABS 2004; Lenzen 2004) and basin (Molden 1997; Molden et al. 2001) scales to:

- Assess the consequences of economic growth;
- Assess the contribution of economic sectors to environmental problems;
- Assess the implications of environmental policy measures (such as regulation, charges, and incentives);
- Identify the status of water resources and the consequences of management actions; and

- Identify the scope for savings and improvements in productivity.

However, these accounts are static, providing a snapshot for a single year or for an average year. Furthermore, they do not link water movement to its use. In contrast to the static national and basin water-use accounts referred to above, our accounts are dynamic, with a monthly time step, and thus account for seasonal and annual variability. They can also examine dynamic effects such as climate change, land-use change, changes to dam operation, etc. The accounts are assembled in Excel spreadsheets, and are quick and easy to develop, modify, and run. We have applied this accounting method to several major river basins including the basins of the Murray-Darling, Mekong, Karkheh, and Limpopo Rivers (Kirby et al. 2006a; Kirby et al. 2006b). Here we describe its application to the Volta Basin.

As we shall describe below, the account has been developed using existing data, and gives an overview of water uses within the Basin. The account can be improved with better data and calibration. We recommend that, should it be intended to use the account for any purpose beyond developing an understanding of the broad pattern of water uses in the Basin, that effort be directed to obtaining better data.

2.1. OTHER MODELS

A WEAP model of the Volta Basin was used by Andah and others (2003).

3. BASIC HYDROLOGY AND AN OUTLINE OF THE SIMPLE WATER-USE ACCOUNT

3.1. BASIC HYDROLOGY, IRRIGATION, AND LAND USE

The Volta Basin covers 394,098 km^2, and is drained by the River Volta and its three main tributaries, the Black Volta, the White Volta, and the Oti Rivers, and their tributaries (Figure 1 and Table 1). The Basin Covers six countries (Benin, Burkina Faso, Cote d'Ivoire, Ghana, Mali and Togo), with Burkina Faso and Ghana between them accounting for 85% of the total Basin area. The main tributaries discharge into Lake Volta, which occupies the lower-middle reaches of the river system, with an area of about 8,000 km^2 and a volume of about 150 km^3 (both fluctuate as the lake fills and empties). The Lake was created by damming the Volta River in the mid-1960s and took several years to fill.

The annual rainfall of the Volta Basin reduces from about 1400 mm in the south to about 400 mm in the north. The rain comes in a distinct wet season which peaks around July-August each year (Figure 2), whereas potential evapotranspiration is high all year round, peaking in March to May. The wet season affects the whole of the Volta Basin more or less simultaneously. The consequence is that the Volta and its tributaries have a very pronounced seasonal variation in flow, with negligible flows during the dry season. The rainfall and flows vary considerably from year to year. The rainfall declined from the 1950s to the 1980s (Figure 2), and the river flows have likewise fallen.

Prior to the creation of Lake Volta, the annual variation affected the river throughout its course. Since the mid-1960s, however, the flow in the Volta below the dam has been more uniform, reflecting the discharge from the lake for hydropower generation, diminishing somewhat since the 1970s. Water was spilled from the lake (or, at least, the flow in the Volta peaked sharply in the wet season) in the first few years after it filled, but since then there has been no spill. The flow record available to us stops in 1984, so we are unsure of the behaviour in the last 20 years or so.

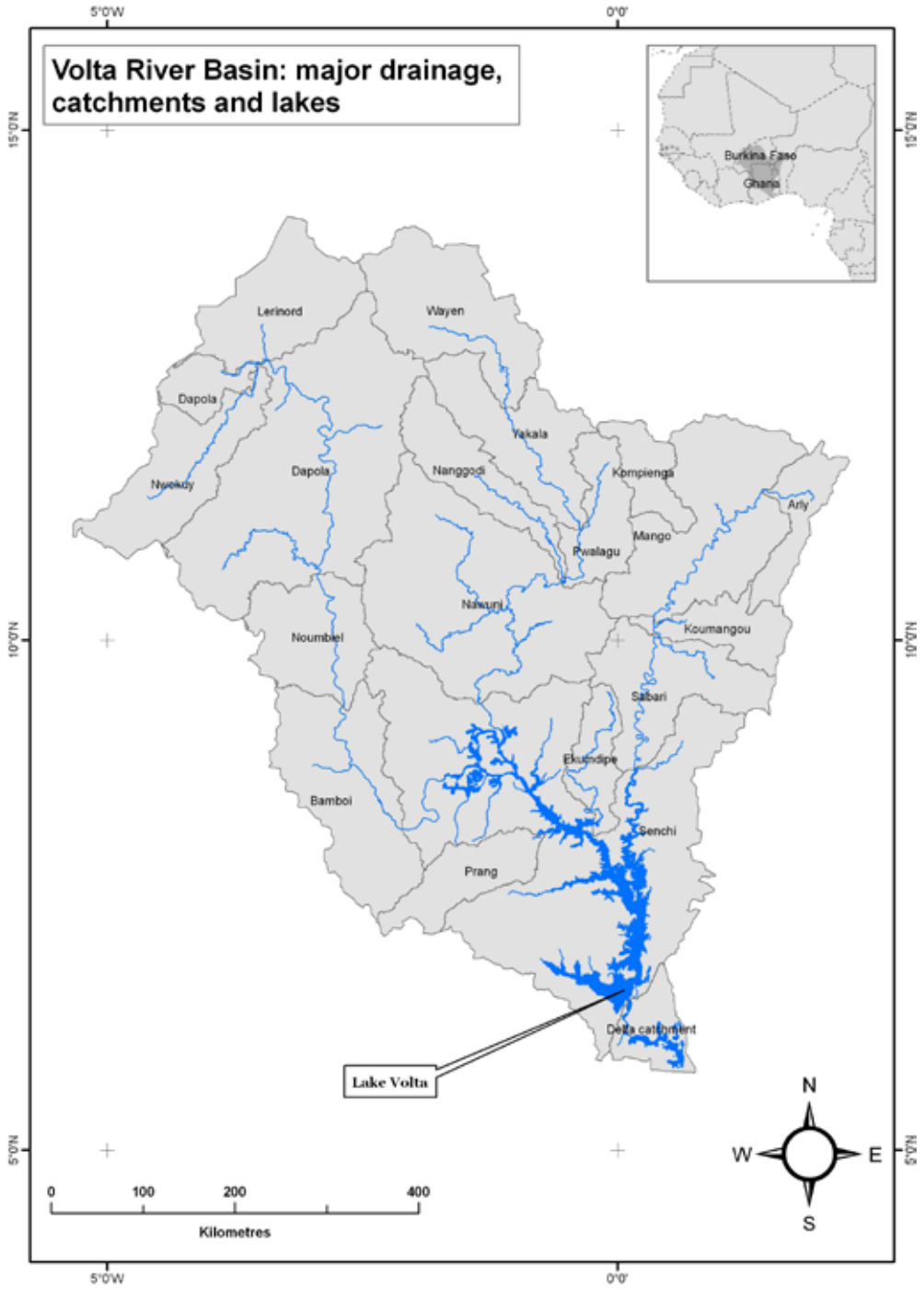

Figure 1. The Volta Basin, with the catchments used in the water-use account.

Table 1. Catchments in the Volta Basin with their areas.

Catchment	Area km^2
Lerinord	16,163
Nwokuy	16,126
Dapola	55,368
Noumbiel	14,268
Bamboi	23,739
Wayen	20,045
Yakala	15,408
Nanggodi	11,205
Pwalugu	89,88
Nawuni	43,146
Arly	6,818
Kompienga	5,772
Mango	27,533
Koumangou	7,542
Sabari	16,169
Prang	9,193
Ekumdipe	6,350
Senchi	84,229
Delta catchment	6,034
Total	394,098

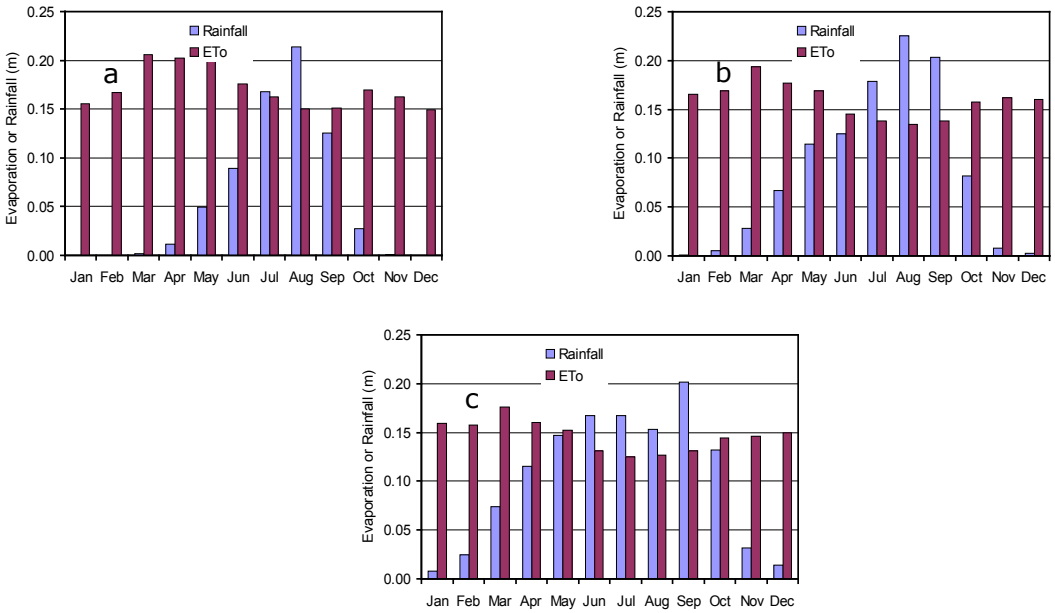

Figure 2. Monthly average rain and potential evapotranspiration in the Volta Basin. a). Northern Volta (Lerinord); b). Central Volta (Nawuni); and c). Lower Volta around Lake Volta. Each graph shows the spatial average for the region indicated.

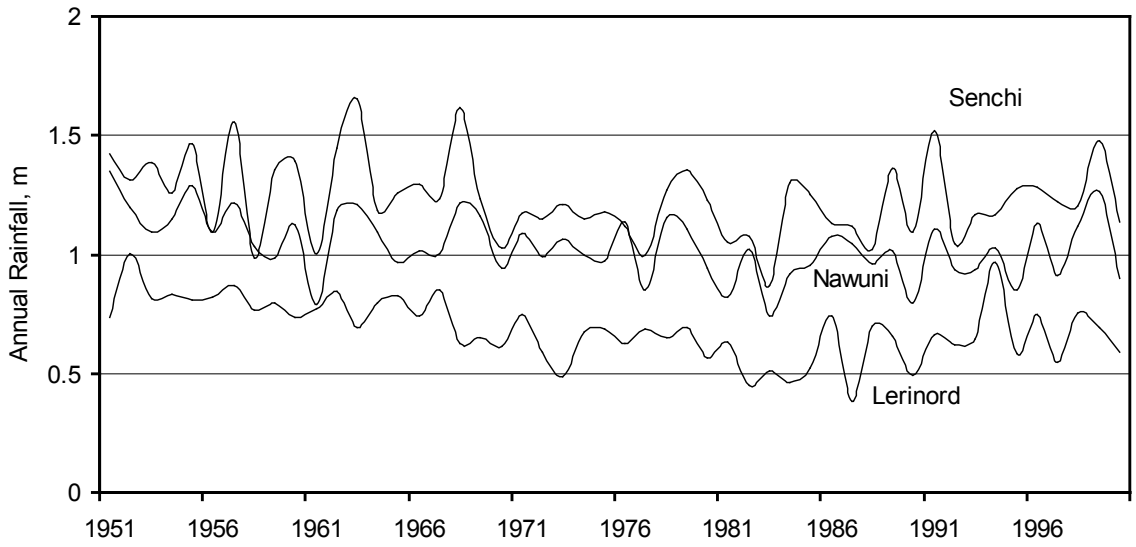

Figure 2. Annual rainfall in the Volta Basin in the Lerinord, Nawuni, and Senchi (around Lake Volta) catchments.

3.2. SIMPLE WATER ACCOUNT

The simple water account has two parts:

- A hydrological account of the water flowing into the basin (primarily rain), flows and storages within the basin, and water flowing out of basin (primarily as evapotranspiration and discharge to the sea); and
- A further partitioning of the evapotranspiration into the proportion of evapotranspiration accounted for by each vegetation type or land use, including evapotranspiration from wetlands and evaporation from open water.

The simple hydrological account is based on a monthly time step, which we consider adequate for our purpose.

The account is a top-down model (Sivapalan et al. 2003), based on simple lumped partitioning of rainfall into runoff and infiltration into a generalised surface store. This is done at the catchment level, with no attempt to model the spatial distribution of hydrological processes and storages within a catchment. We estimate total catchment evapotranspiration from potential evaporation and water supply from the surface store, and partition it between rainfed and irrigated land uses based on the ratio of their areas. We further partition the rainfed component of evapotranspiration between land uses/ vegetation types (agriculture, forest/woodland, grassland, other) based on the ratio of their areas and using crop factors to scale their evapotranspiration relative to other land uses.

Runoff flows into the tributaries and then into the Volta River, and we calculate downstream flows by simple water balance. We assumed that the base flow in a catchment came from a notional groundwater store whose discharge was equal to the base flow and was constant throughout the year. We estimate deep drainage to the groundwater store as a proportion of the surface water store. During periods of high flows, some of the flow is stored in the channels, which we estimate, together with

losses from the river, as functions of flows. Inflows are stored in reservoirs, and are balanced by evaporation and discharge at the dam. Water is spilled if the capacity of the dam is exceeded.

We base diversions for irrigation on crop water requirements calculated from cropped areas, crop coefficients, potential evaporation, and irrigation efficiencies. Maximum irrigated areas are defined based on land-use data, but the area irrigated may be reduced in any one year to match supply if the volume stored in the reservoir at the beginning of the season is insufficient to meet crop water requirements. If reservoir storage becomes insufficient to meet crop demand during the season, irrigation applications are reduced to match the supply.

The model is described in detail in a companion report *Water-use accounts in CPWF basins: Model concepts and description* (Kirby et al. 2010). Here we describe only that part of the model that differs from the general set of equations. The behaviour of, and equations for, Lake Volta are unique to the Volta Basin.

3.2.1. UNITS

Rain, evapotranspiration and potential evapotranspiration are given in mm.

River flows and storages, and lake storage, are given in mcm (million cubic metres). 1 mcm is equivalent to one metre over one square kilometre. 1000 mcm = 1 bcm (billion cubic metres) = 1000 m over 1 km^2 = 1 km^3.

3.3. LAKE VOLTA AND DAM DISCHARGES

In the 1970s, the average annual discharge from the dam was a little over 2000 mcm per month, with only small variation. We therefore assume that

$$Q_o = C_3 \qquad S + Q_i - C_3 \leq S_{\max} \qquad (1a)$$

$$Q_o = C_3 + \left(S + Q_i - S_{\max}\right) \qquad S + Q_i - C_3 > S_{\max} \qquad (1b)$$

where Q_i is the sum of the inflows from the Black Volta, the White Volta, and the Oti Rivers.

Equation 1b gives the flood spill when the storage capacity of the lake is exceeded.

Lake Volta also receives inflows directly (i.e., other than from the Black Volta, the White Volta, and the Oti Rivers) from local runoff calculated by equations in Kirby et al. 2010.

The change in storage of the lake in the month is:

$$S_{LV}^{t} = S_{LV}^{t-\Delta t} + Q_i - Q_o - E_{LV} - D \qquad (2)$$

where the evaporation, E_{LV}, is given by equations in Kirby et al. 2010.

4. DATA SOURCES

The datasets used in this water-use account were all readily available on the internet.

4.1. RAINFALL

The rainfall and other climate data were taken from the Climate Research Unit at the University of East Anglia (specifically, a dataset called CRU_TS_2.10). They cover the globe at 0.5° (about 50 km) resolution, at daily intervals for 1901 to 2002. The dataset was constructed by interpolating from observations. For recent decades, many observations were available and the data show fine structure. For earlier decades, few observations were available and the data were mostly modelled and lack fine structure.

We sampled the rainfall and other climate surfaces for each catchment within the basin, and calculated catchment area-means of rainfall and potential evapotranspiration for each month. The method is described in more detail in Kirby et al. (2007).

4.2. FLOWS

Reach flows were taken from a dataset called ds552.1, available on the internet (http://dss.ucar.edu/catalogs/free.html) (Dai and Trenberth 2003). The dataset also gives contributing drainage areas for each flow gauge. Flow records were not available for the Lerinord, Kompienga, and Delta catchments

4.3. LAND USE

Land use was taken from the 1992-3 AVHRR dataset (IWMI 2006), which has more than 20 land-use classes, many of which have similar patterns of water use. The land-use classes were therefore aggregated into rainfed agriculture, irrigated agriculture, grassland, and woodland and other. The aggregated class of grassland contains important areas of other land uses including shrubland and barren land.

Next, as areas of rainfed cropland did not match the cropped areas of Burkina Faso and Ghana, values in each catchment were modified to correspond with national statistics. Crop coefficients for each land-use unit were as follows:

- **Rainfed cropland:**
- In the north and middle of the Volta basin, Kc = 1.0 (millet), growing season June to September,
- In the southern part, Kc = 1.2 (mixture of maize and cassava), growing season from March to December.
- **Savannah:**
- In the north, Kc = 0.6 (native grass), growing season from June to November,
- In the middle, Kc = 0.6, growing season from April to November,
- In the south, Kc = 0.6, growing season from March to December.
- **Woodland:** Kc = 1.0 during the rainy season, 0.3 otherwise.

5. COMPONENTS AND RESULTS IN DETAIL

5.1. FLOW

The flow in the Volta Basin is fairly similar from one catchment to the next. Flow in the rivers follow the rainfall distribution with an annual flow peak followed by nearly no flow in the dry season (Figure 3). As shown in Figure 4, there is a small lag between rainfall and flow.

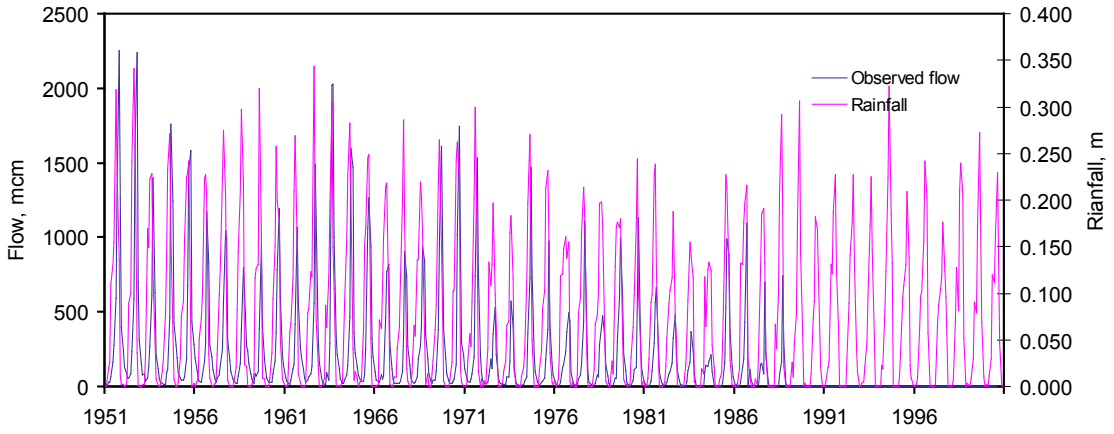

Figure 3. Rainfall and observed flow in the Dapola catchment.

While the overall behaviour of the catchments is similar, there appears to be a difference between the catchments in the Black Volta and those of the other tributaries.

5.1.1. CATCHMENTS IN THE BLACK VOLTA SUB-BASIN

The catchments in the Black Volta Sub-basin, in order from the upper part of the sub-basin to the lower, are Lerinord, Nwokuy, Dapola, Noumbiel, and Bamboi. The observed and calculated flows at Dapola are shown in Figure 5, and at Bamboi in Figure 6. The Lerinord catchment is ungauged, and so we based its flow behaviour on:

Assuming that it behaved like the nearby Nwokuy and Dapola catchments (that is, we have used similar coefficients in the rainfall-runoff and flow equations); and

On the requirement that the flows at Dapola (which receives the discharge from Lerinord) must equal the observed values.

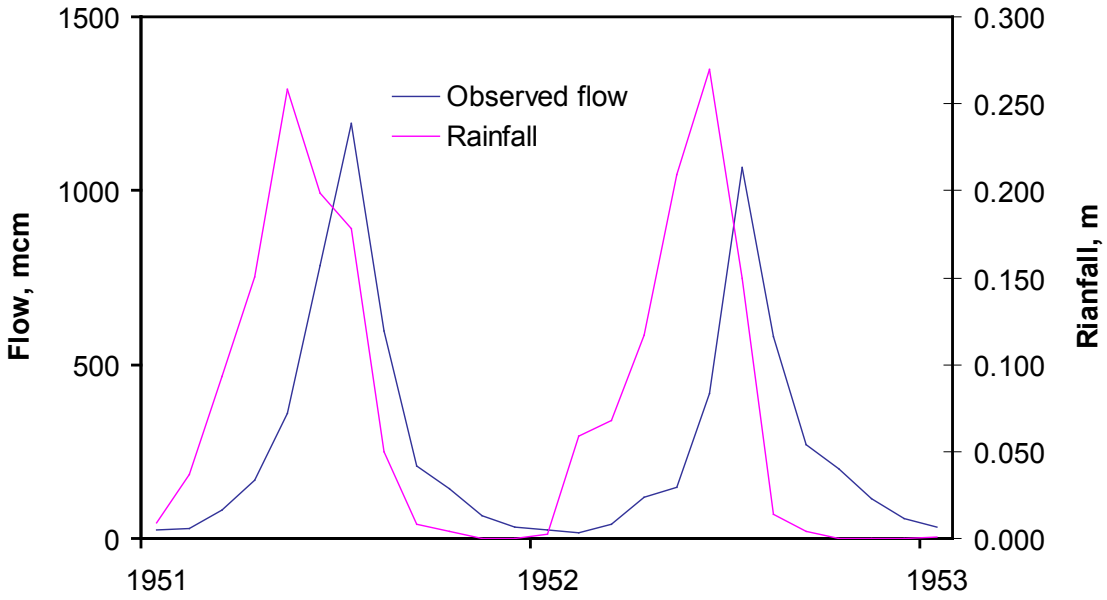

Figure 4. Rainfall and observed flow in the Dapola catchment. Detail over two years showing that flow lags rainfall.

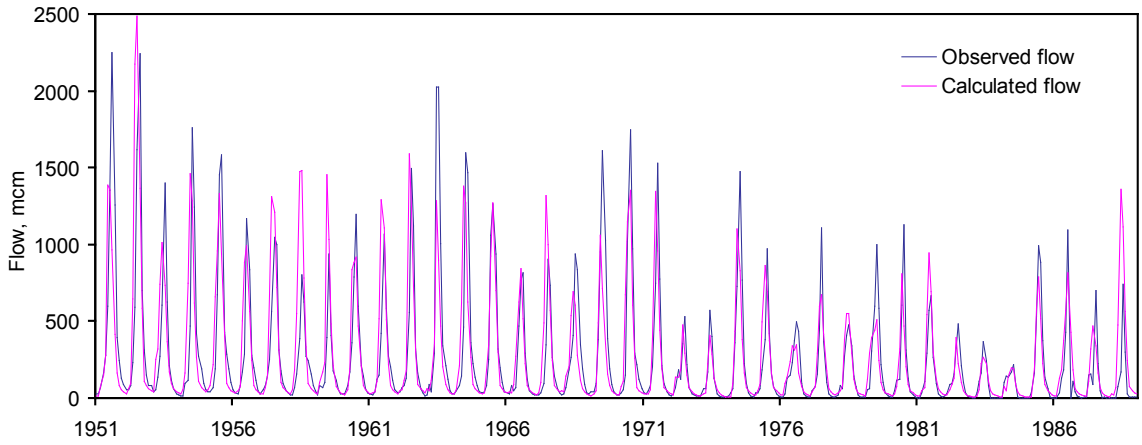

Figure 5. Observed and calculated flow at Dapola.

The flow records of all catchments of the Black Volta Sub-basin show a small flow in the dry season, indicating a base flow component. Flow arises from springs located in a relatively wet region in the south of the Nwokuy catchment. The flow records also show the diminished flows with the drier conditions since the 1970s.

5.1.2. CATCHMENTS IN THE WHITE VOLTA SUB-BASIN

The catchments in the White Volta Sub-basin, in order from the upper part of the sub-basin to the lower, are Wayen, Yakala, Nanggodi, Pwalugu, and Nawuni. The observed and calculated flows for Wayen and Nawuni are shown in Figure 7 and Figure 8. The flow is similar from catchment to catchment. Unlike the flows in the catchments of the Black

Volta Sub-basin, none of the White Volta catchments shows a base flow component. In the upper catchments, the period without flow is several months every year. Otherwise, the flow behaviour is similar to that in the Black Volta catchments.

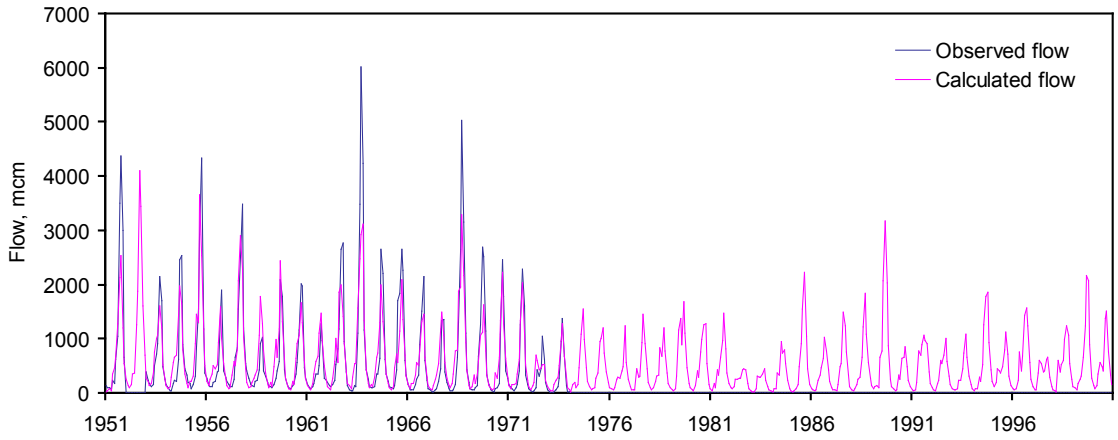

Figure 6. Observed and calculated flow at Bamboi.

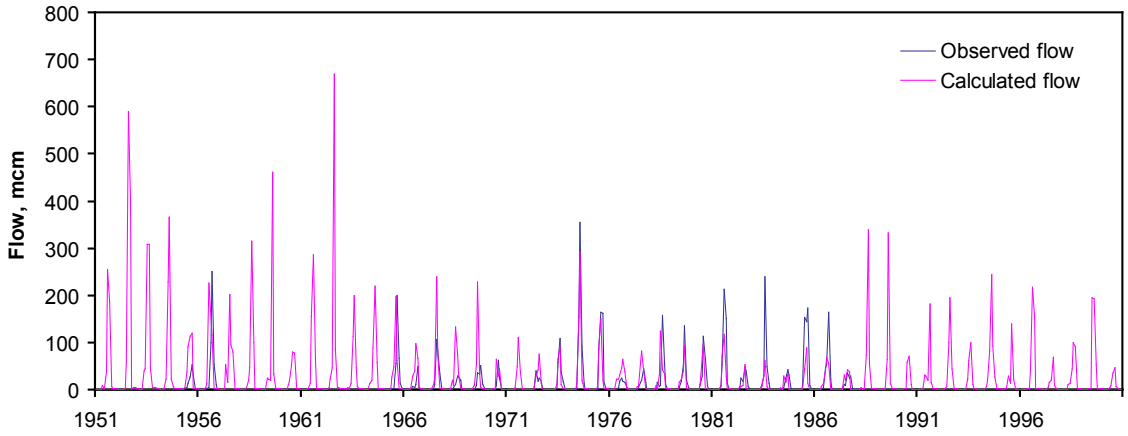

Figure 7. Observed and calculated flow at Wayen.

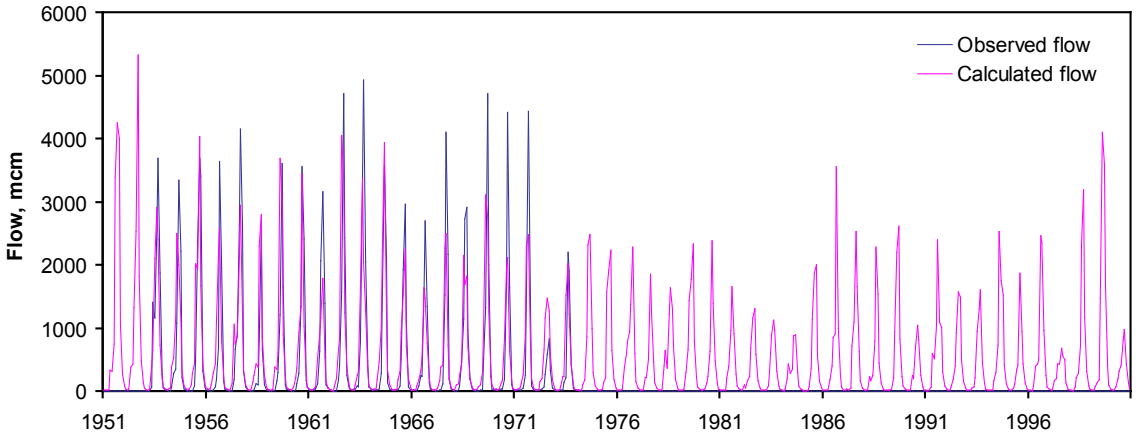

Figure 8. Observed and calculated flow at Nawuni.

5.1.3. CATCHMENTS IN THE OTI SUB-BASIN

The catchments in the Oti Sub-basin, in order from the upper part of the sub-basin to the lower, are Arly, Mango, Koumangou, and Sabari. The observed and calculated flows at Arly and Sabari are shown in Figure 9 and Figure 10. The flow is similar from catchment to catchment. Like the Black Volta Sub-basin, the Oti catchments also show a base flow component.

5.1.4. CATCHMENTS DISCHARGING DIRECTLY INTO LAKE VOLTA

The Prang and Ekumdipe catchments feed directly into Lake Volta. The observed and calculated flows are shown in Figure 11 and Figure 12. The flow is similar to that in the catchments of the Black Volta and the Oti Sub-basins.

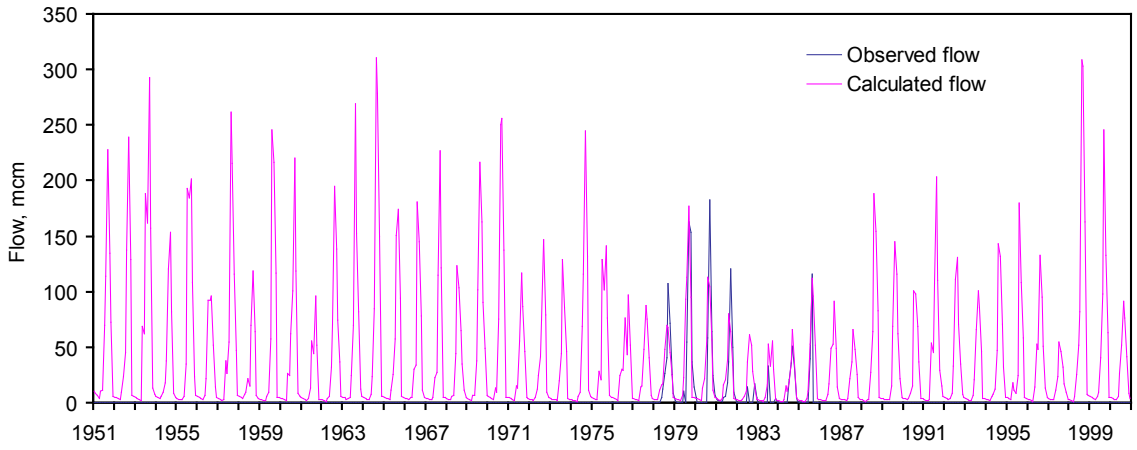

Figure 9. Observed and calculated flow at Arly.

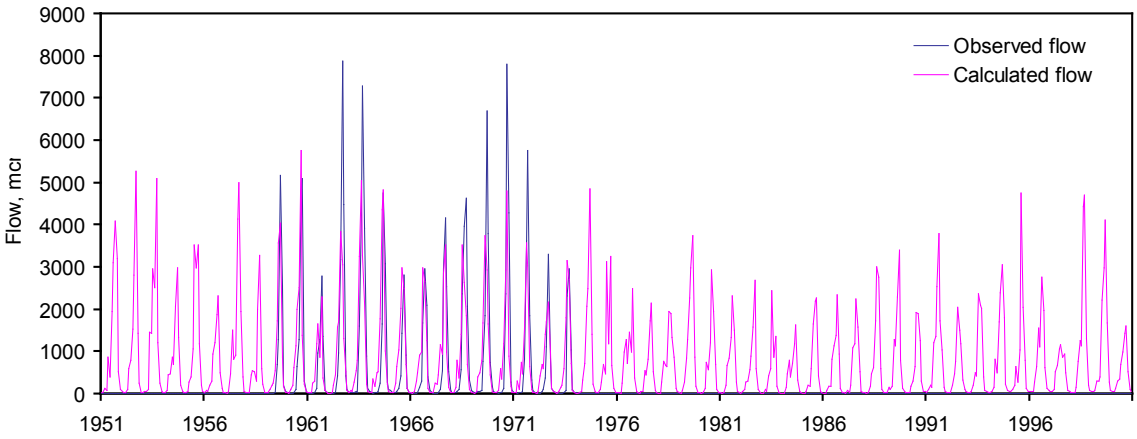

Figure 10. Observed and calculated flow at Sabari.

5.1.5. LAKE VOLTA

The discharge from Lake Volta is measured at Senchi. As described previously, prior to the creation of Lake Volta, the flow varied annually in a manner similar to the upper

catchments. Since the mid-1960s, however, the flow in the Volta below the dam has been more uniform, diminishing somewhat since the 1970s (Figure 13). Water was spilled from the lake (or, at least, the flow in the Volta peaked sharply in the wet season) in the first few years after it filled, but has not spilled since. It appears that since the early 1970s the Lake has always had enough unfilled capacity to store a wet season's flow without spilling. The drying trend in the Volta Basin, combined with increasing discharges in the early period, appears to have reduced the volume of water stored in the lake from about the mid 1970s (Figure 14).

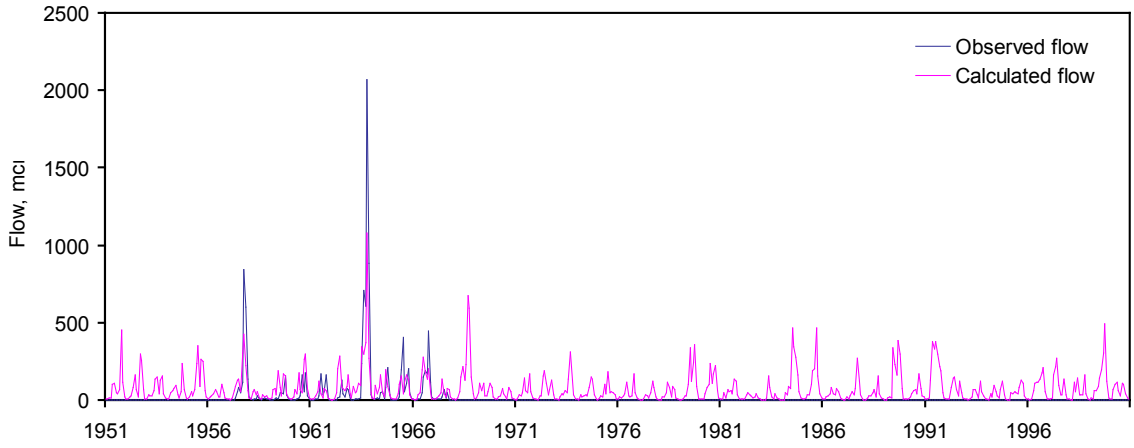

Figure 11. Observed and calculated flow at Prang.

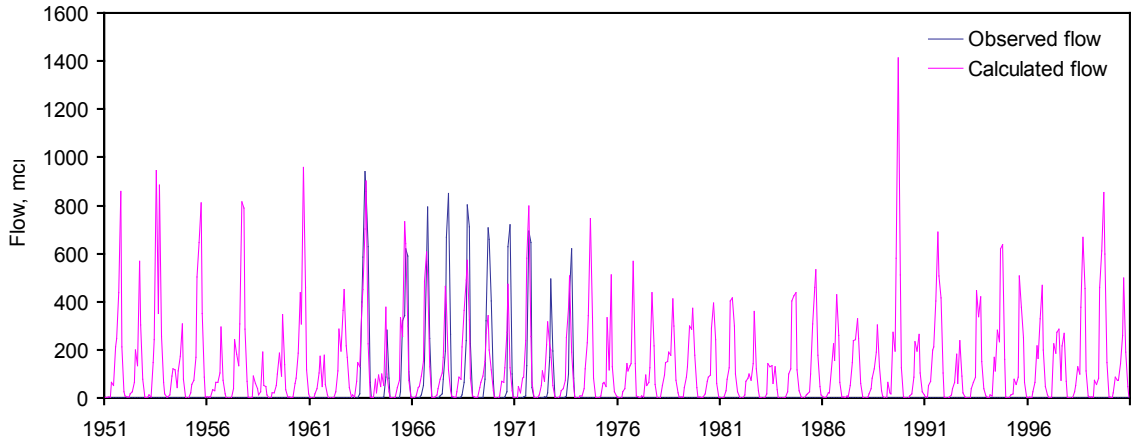

Figure 12. Observed and calculated flow at Ekumdipe.

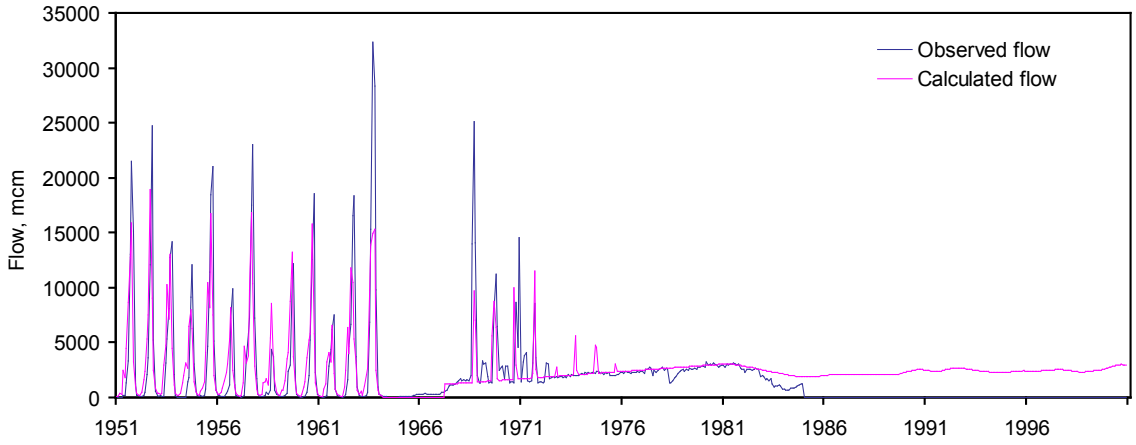

Figure 13. Observed and calculated flow at Senchi. The gap in the records from 1964 to 1967 was the period of filling Lake Volta.

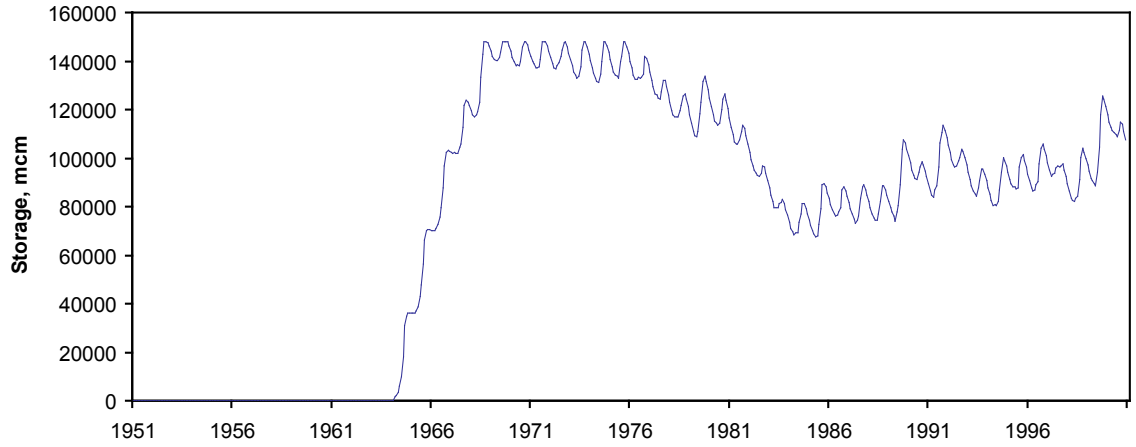

Figure 14. Calculated volume stored in Lake Volta.

5.1.6. CATCHMENT FROM LAKE VOLTA TO THE MOUTH

The lower part of the Volta Basin, from Senchi to the mouth, is ungauged. However, the catchment is small, and the discharge is nearly equal to that at Senchi.

The overall calculated mean annual runoff from the Volta and its tributaries from 1951 to 2000, and that estimated by Andah et al. (2003) for the period 1961-1990 is shown in Table 2. The values estimated here are somewhat less than those estimated by Andah et al., except for the lower Volta but the period they considered appears to be somewhat wetter than average. The relative contribution from the different sub-basins is similar. This is not a verification of the model used here, but it does suggest that the basic approach leads to plausible results.

Table 2. Mean annual runoff (mcm/yr) for the Volta River and its tributaries including a comparison with data from Andah et al. (2003).

	Calculated here	Andah et al. (2003)
Black Volta Sub-basin	6,926	7,673
White Volta Sub-basin	7,088	9,565
Oti Sub-basin	10,047	11,215
Prang, Ekumdipe, Lake Volta	10,221	9,842

5.1.7. WHOLE BASIN RUNOFF

Whole basin annual runoff and precipitation show similar trends from 1951 to 2000 (Figure 15), with peaks in annual rainfall generally resulting in peaks in runoff. Mean annual runoff is 33,300 mcm, but runoff shows large temporal variation ranging from 15,500 mcm in 1983 and 64,600 mcm in 1963.

5.2. WATER USE

The mean annual input by precipitation to the Volta Basin totals 407,600 mcm. Figure 17 summarizes how this water is partitioned amongst the major water uses in the basin. Net runoff comprises the runoff remaining after all the water uses in the basin have been satisfied, and includes all other storage changes and losses. Net runoff from the basin is 38,900 mcm or 10% of the total precipitation input. The aggregated class grassland, which includes shrubland and barren land, is the most extensive land use, covering 85% of the basin. Its water use is correspondingly high, with a mean annual water use of 329,500 mcm, or 81% of the water used in the basin (Figure 16).

Rainfed agriculture, the next most extensive land use covering 14% of the Basin, uses 8% of the water in the Basin. Land uses included in the 'woodland + other' class are woodlands and forests; wooded wetlands; urban; bare ground; barren and sparsely vegetated land. This land use class covers 1.5% of the basin and uses 7,000 mcm or 2% of the available water. Irrigated agriculture is minimal in the Basin, and its water use negligible at less than 1 mcm.

Figure 18 depicts the uses of water in each catchment, and the distribution of water uses across the Basin. Note that the figure does not represent the water balance at a basin level, since water represented as net runoff in the upper basin may be used in downstream catchments. For example, runoff from upper basin catchments may contribute to irrigation in downstream catchments, and thus is double counted at the basin level.

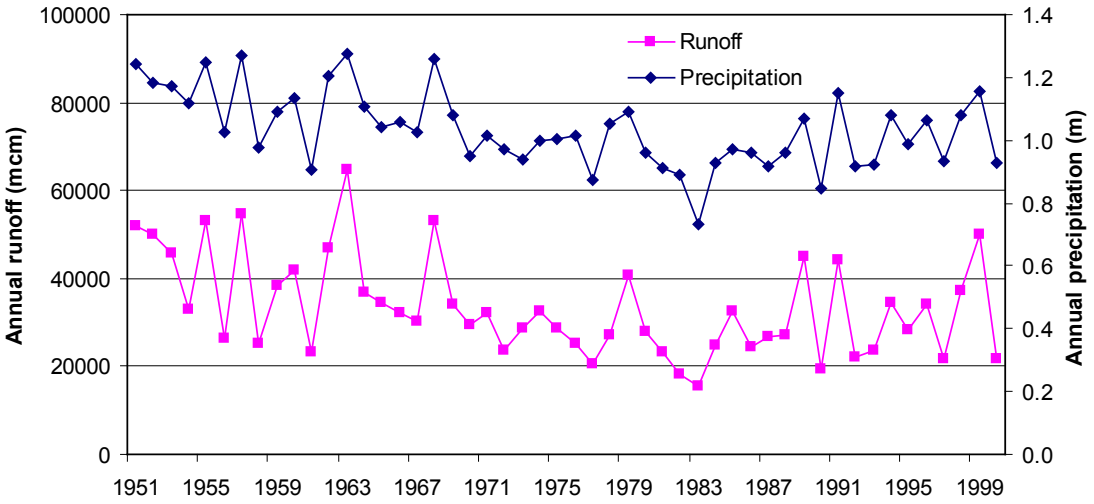

Figure 15. Whole basin annual precipitation and runoff from 1951 to 2000.

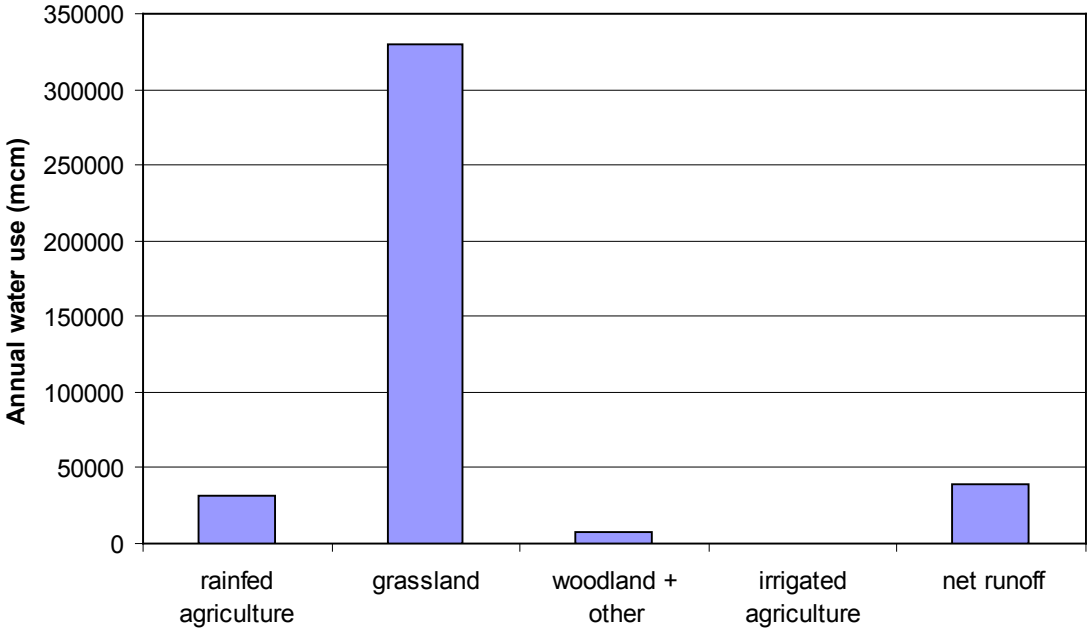

Figure 16. Summary of major water uses in the Volta Basin. Grassland includes shrubland and barren land (see Section 4.3).

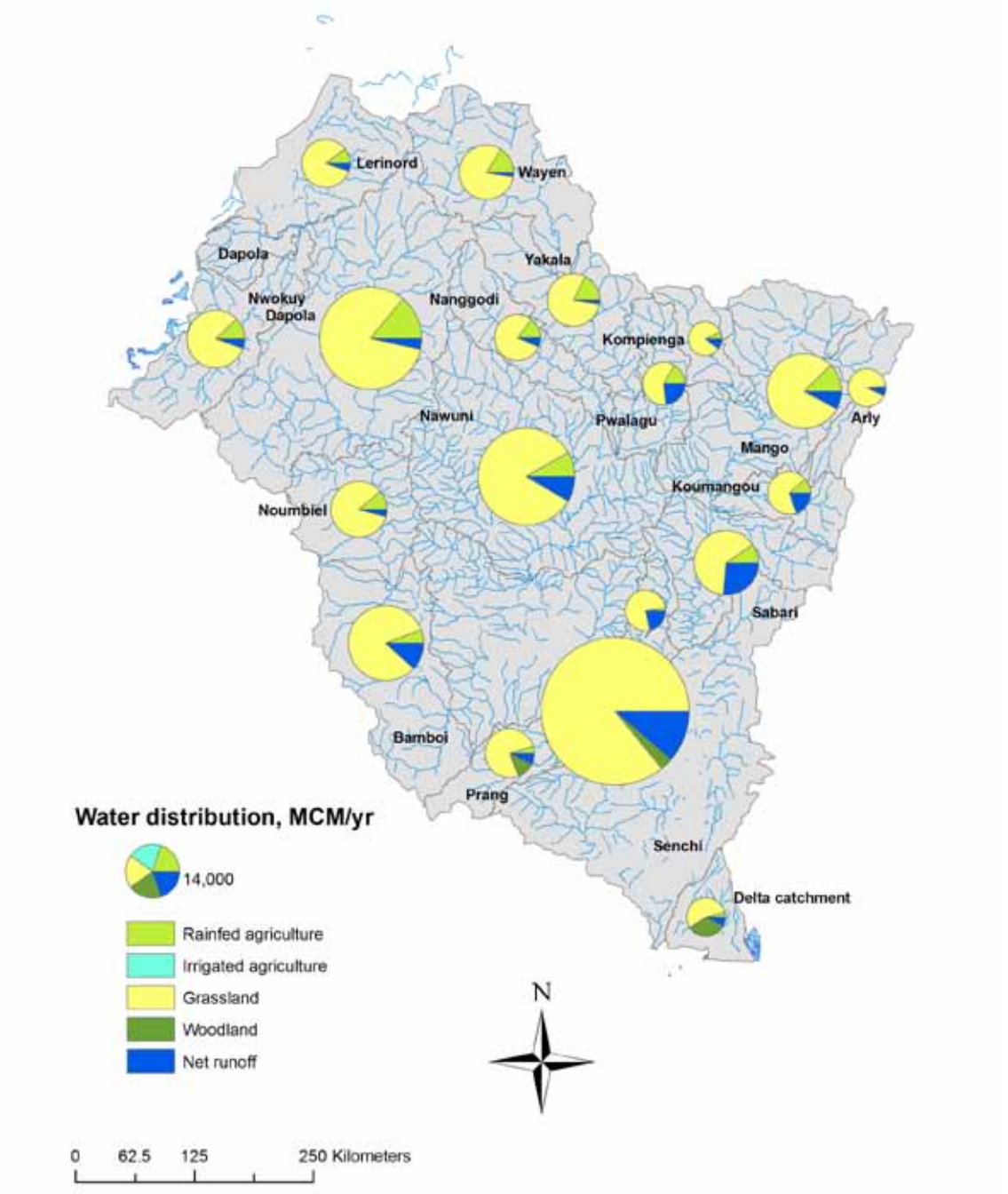

Figure 17. Spatial distribution of major water uses across the catchments of the Volta Basin. Grassland includes shrubland and barren land (see Section 4.3).

The relative size of each of the major water uses varies for different catchments in the Basin. Net runoff is generally a smaller proportion of the available water in the northern catchments, and tends to increases on moving downstream towards Lake Volta on the Black Volta, the White Volta, and the Oti Rivers. This corresponds with a gradient of increasing precipitation on moving from the northern to the southern catchments of the basin. Net runoff is low in all catchments of the Black Volta Sub-basin, increasing from 3% of the total water available in the Dapola catchment to 12% in Bamboi. Net runoff is also low in the northern catchments of the White Volta, being 2% of the water available

in the Wayen catchment, increasing downstream to 23% and 8% in the Pwalugu and Nawuni catchments respectively. Net runoff from the catchments of the Oti River Sub-basin increases from 7% of the water available in the Arly catchment to 26% in Sabari.

Water use by grassland is the most important use of water in all catchments of the Volta Basin. Grassland is the dominant land use in these catchments, ranging from 76% of the area of the Delta catchment to 98% of the Arly catchment. Water use by grassland as a percentage of all water used in the catchment ranges from 55% in the Delta catchment to 92% in the Arly catchment. The extent of rainfed agriculture in catchments of the Volta ranges from 2% of the Arly catchment to 27% of Pwalugu. Water used by rainfed agriculture ranges from 1% of the water available in the Arly catchment to 18% of the water available in the Yakala catchment. Water used by irrigated agriculture is negligible for all catchments, as the extent of irrigated cropping is minimal across the basin.

The extent of the 'woodland + other' land use is less than 1% in all catchments of the Black Volta, the White Volta, and the Oti Sub-basins. Its water use in these catchments is correspondingly low, and less than 1% of the water used in any catchment. The proportion of land under this use is greatest in the Prang, Senchi, and Delta catchments in the south of the basin, ranging from 4% of the Prang catchment to 15% of the Delta. Water use by this land use class is corresponding greater in the southern catchments, ranging from 3% of the water used in Prang to 33% in the Delta.

5.3. CATCHMENT AND BASIN HYDROLOGICAL CHARACTERISTICS

Selected hydrological characteristics will be useful for comparing the Volta Basin hydrological function and its vulnerability with those of other basins under study in the Challenge Program. Some of these hydrological characteristics are outlined briefly below.

Runoff characteristics for different basins may be compared by comparing their annual percentage runoff ratios (total basin runoff/total basin precipitation). The runoff ratio for the Volta Basin is low at only 8% (i.e. mean annual runoff is 8% of mean annual precipitation). Similarly, comparing annual runoff ratios (Table 3) for the different catchments in the Basin shows differences in their runoff characteristics. The ratios range from 3% in the Dapola catchment to 26% in Sabari. Runoff ratios tend to increase as one moves downstream in the catchments of the Black Volta, the White Volta, and the Oti Sub-basins, a response to the north-south gradient of increasing rainfall and decreasing potential evaporation within the Basin.

Total annual runoff from the Basin reflects the annual variation in rainfall from 1950 to 2000 (Figure 15). A single function may be used to quantify the relationship between whole basin annual runoff and precipitation (Figure 18). The relationship may be used as a first estimate of the impact of changing rainfall under climate change scenarios. If potential evaporation were to change significantly under climate change, the rainfall-runoff relationship may also be expected to change.

6. EXAMPLE USE

We give here two examples of using the spreadsheet to model the impact of change; firstly of climate change, and secondly of a large increase in the areas used for irrigation. Andah et al. (2003) assumed an increase in rainfall of about 7.5% for one climate change scenario. To estimate its effect, we simply increased rainfall by 7.5% in all catchments. The (rather obvious) consequence for flow from, and storage in, Lake Volta is shown in Figure 19 and Figure 20 below. Comparison with Figure 13 and Figure 14 shows that there is a greater incidence of overtopping the dam, and a greater flow for generating hydropower, and that the lake is fuller with increased rainfall.

Table 3. Annual percentage runoff ratios (runoff/precipitation) for catchments in the Volta Basin.

Catchment	Runoff ratio (%)
Lerinord	5
Nwokuy	5
Dapola	3
Noumbiel	4
Bamboi	12
Wayen	2
Yakala	3
Nangodi	7
Pwalugu	23
Nawuni	8
Arly	7
Kompienga	8
Mango	8
Koumangou	19
Sabari	26
Prang	7
Ekumdipe	21
Senchi	6
Delta Catchment	5
Whole Basin	8

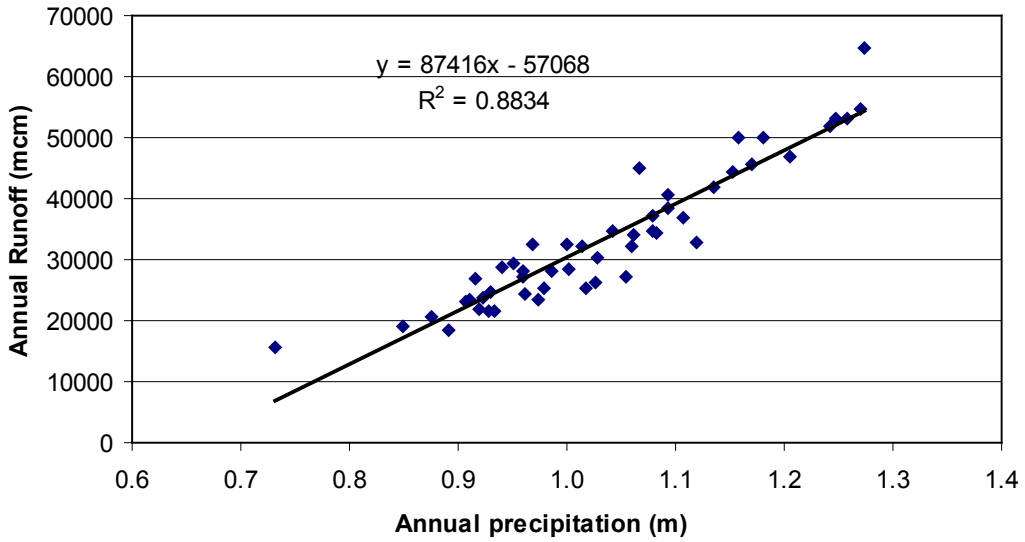

Figure 18. Whole basin annual runoff as a function of annual precipitation.

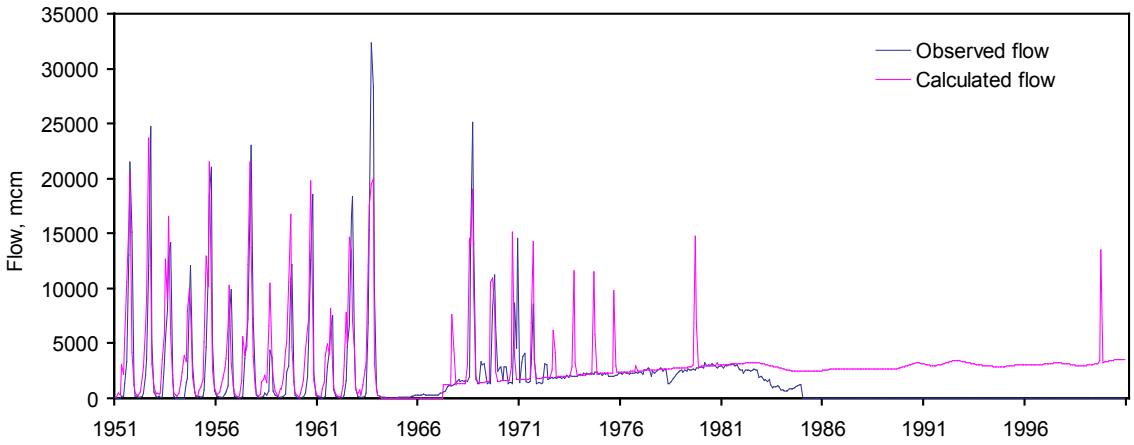

Figure 19. Calculated discharge from Lake Volta with increased runoff as a result of 7.5% increase in rainfall caused by climate change.

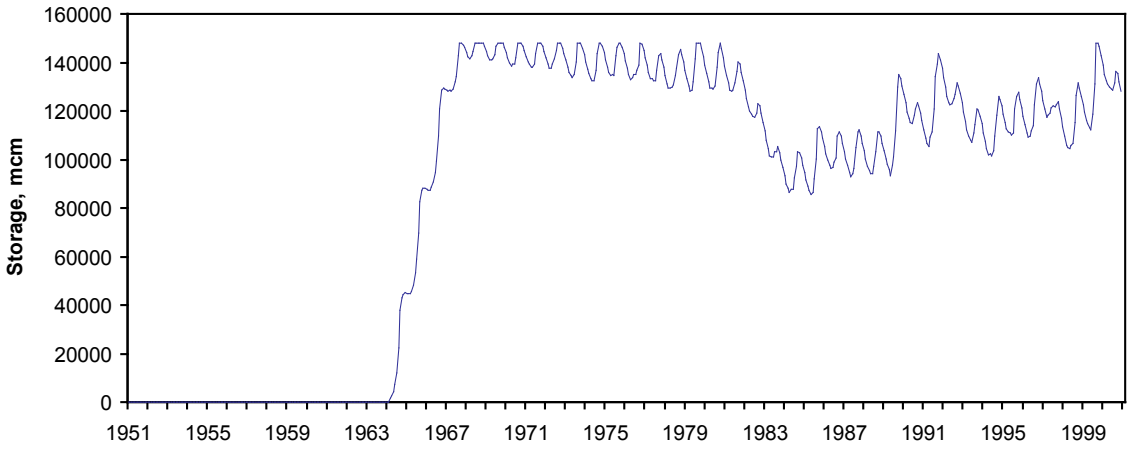

Figure 20. Calculated storage in Lake Volta with increased runoff as a result of 7.5% increase in rainfall caused by climate change.

To estimate the effect of increased irrigation, we assumed that in each Sub-basin, apart from Lake Volta itself, the area available for irrigation increased to 500 km^2 (250 km^2 each of rice and maize) and that the Sub-basin storage increased to 1000 mcm. We assumed that the area available for irrigation in the Lake Volta Sub-basin increased to 4000 km^2. These areas of irrigation are consistent with using perhaps a third of the land identified by FAO as potentially irrigable. The decline in flows and storage resulting from reduced inflows and increased abstractions from the lake are shown in Figure 21 and Figure 22.

We warn that these examples are demonstrations and not predictions of what will happen. Of course, the "prediction" that increased rain would lead to more water stored in the Lake is safe enough, as is the prediction that increased diversions will lead to less water in it. We emphasize that it is the actual magnitudes of change that we do not claim to predict. We would require better data before we could reliably estimate such effects.

7. CONCLUSIONS

A very simple spreadsheet model with few adjustable parameters has produced plausible simulations of runoff and river flow in the Volta Basin. The partitioning of catchment evapotranspiration between various land uses in any catchment relies on the crop coefficients that we have assumed for each land use type. Similarly, the amount of water applied as irrigation in any catchment also depends on the selected crop coefficients. Thus the summary of water uses at both the basin and catchment scale presented in section 5.3 may be further developed to include estimates of crop coefficients derived from local data to give a better representation of water use by different land uses.

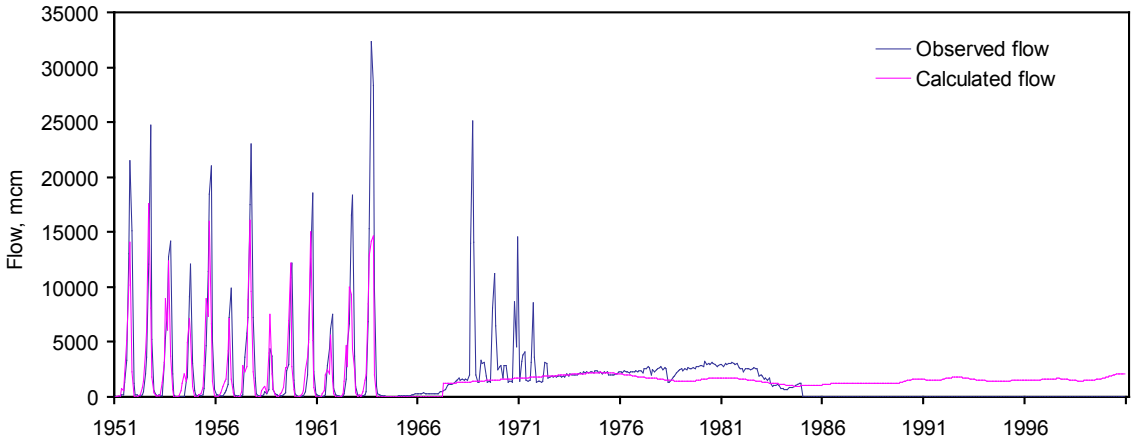

Figure 21. Calculated discharge from Lake Volta with decreased flows as a result of increased irrigation as described in the text.

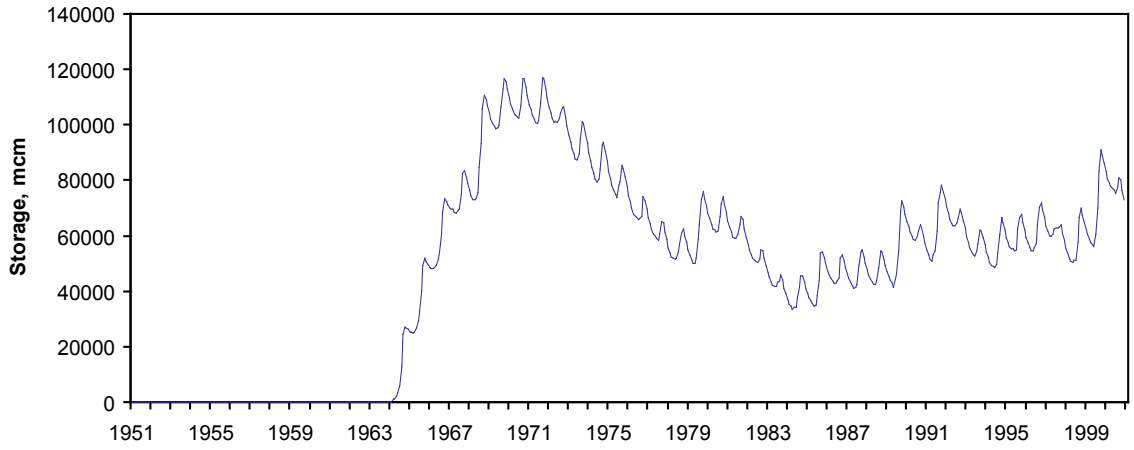

Figure 22. Calculated storage in Lake Volta with decreased flows as a result of increased irrigation as described in the text.

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