CPWF Project Report

Basin Focal Project Volta

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The work was developed within our laboratory, Unité Mixte de Recherche Gestion de l'Eau, Acteurs et Usages (G-Eau), which belongs to IRD, CIRAD, CEMAGREF and SupAgro in Montpellier, France.

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PROGRAM PREFACE

The Challenge Program on Water and Food (CPWF) contributes to efforts of the international community to ensure global diversions of water to agriculture are maintained at the level of the year 2000. It is a multi-institutional research initiative that aims to increase water productivity for agriculture—that is, to change the way water is managed and used to meet international food security and poverty eradication goals—in order to leave more water for other users and the environment.

The CPWF conducts action-oriented research in nine river basins in Africa, Asia and Latin America, focusing on crop water productivity, fisheries and aquatic ecosystems, community arrangements for sharing water, integrated river basin management, and institutions and policies for successful implementation of developments in the water-food-environment nexus.

PROJECT PREFACE

Challenge Program Water and Food: Basin Focal Project Volta

The Basin Focal Project Volta (BFP Volta) was developed along three main steps:

- Assessment of present conditions of the distribution of rural poverty, of farming systems with their productivity and water productivity;
- Analysis of opportunities and risks, especially under the double pressure of demography and possible climate change, and modeling of water resources to identify sensitivity of water allocation to development and climate scenarios; and
- Identification of research gaps and implementation plan.

The study indicated that while many technical solutions are available and identified, their socio-economic acceptability and implementation still need further research and efforts.

CPWF Project Report Series

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PROJECT HIGHLIGHTS

1. Basin Focal Project Volta

The Basin Focal Project Volta analyzes poverty, water availability and agricultural water use to help understand how agriculture and water in the Volta basin support livelihoods. The project team was led by IRD (France).

The Volta basin lies predominantly in Ghana and Burkina Faso, with small areas in Benin, Côte-d'Ivoire, Mali and Togo. These countries rank amongst the poorest in the world. The Basin is inhabited by 19 million people, of whom 70% are rural. Poverty remains strongly rural and increases from south to north. Economies are reliant on rain fed agriculture. Rural poverty occurs because of low agricultural productivity, limited market access and price variability. Population density is generally low but is expected to increase as population increases to a projected 50-60 million by 2050. The ratio of rural:urban population will decrease dramatically from 2.3 now to 0.5 in 2050. The main forces of change are a combination of demography with increasing urbanization, and the impacts of climate change.

2. Water availability

Rainfall in the Basin varies between 500-1100 mm/year. The Basin crosses four agro-ecological zones going from the wetter Guinean zone to the arid Sahel, with high rainfall variability both between years and within the rainy season of any one year.

Less than 10% of the total rainfall ends up in the river. Run-off increases from north to south, accounting for less than 5% of rainfall in the upper basin, increasing to 15% in the lower reaches. River discharge is highly sensitive to variations in annual rainfall. A large number of small-size reservoirs have been developed for small-scale irrigation, especially in the northern part of the Basin. Ground water resources are poorly quantified and seem to be under exploited. At the basin scale, a very small fraction of the renewable water is stored in reservoirs for uses other than hydropower, while in most developed countries this fraction amounts to 70-90 % (World Water Assessment Programme, 2009).

Lake Volta plays a key role in the economy of Ghana but flows and revenues from hydro-electricity from the Akosombo-Kpong schemes are less than were anticipated. Low inflows to the dam seem to be a consequence of long-term reduction in annual rainfall. The much smaller Bagré and Kompienga reservoirs are important in Burkina Faso for hydropower and for irrigation.

Lack of access to potable water, and diarrhea from unsafe domestic water, are recognized causes of poverty, with important consequences for health and manpower, and with a strong economic impact at both the family and the basin scales. In the Basin, the proportion of households using poor-quality water is close to 50% both in Ghana and Burkina Faso.

The other main water-related diseases in the Basin are malaria, schistosomiasis (bilharzia), onchocercosis (river blindness), and trypanosomiasis. Malaria occurs throughout the basin, with a 100% prevalence in the central part of the Basin. The cost of malaria in Ghana hits poor households hardest.

The new Volta Basin Authority is a main stakeholder for basin-wide and transnational matters. At the national scale, the legal state and traditional hierarchy coexist in a dual system, that leads to institutional difficulties.

3. Water productivity

Most people in the Basin rely on rain-fed cropping for their livelihoods. The main crops follow the distributions of rainfall and soil type: from north to south, pasture, millet, sorghum, maize, cotton, cassava, yam, and plantain. Irrigation is still very little developed in the Basin, covering less than 0.5% of the cultivated area.

Yields and water productivity are low, often 10% or less of potential. Rain-fed cropping occupies only about 14% of the Basin area. Most of the production increase of the last decade has come more from an increase in the cropped area than from increased productivity. The low yields result from risk avoidance strategies adopted by the farmers to cope with uncertainties about water availability (variability of rainfall in time and space), poor and degraded soils, with no or low input of fertilizers, and poor productive assets (draft animals, man power limited by frequent diseases).

The low productivity coupled with limited market access, unstable prices, and insecure land tenure in some regions worsen the effects. At the basin scale, because only a small percentage of the basin's area is cropped, overall crop water productivity is even lower.

4. Policy recommendations

Improvements in the rain-fed systems, coupled with investment in fertilizers and small-scale irrigation, offer the main opportunity for development. Other positive measures include improvements in infrastructure, secure and transparent land tenure, access to agricultural water and affordable micro-credit. The technical possibilities for improvement have been well identified, but the social and economic conditions for their implementation are still lacking.

Small reservoirs require careful monitoring to prevent them reducing flows into hydro-electric projects but these risks seem modest compared to rainfall variability and the possible effects of climate change. Ground water resources should be assessed as a possible tool for extensive development of small-scale irrigation.

Contributions from fisheries and livestock seem to be underestimated and need careful socio-economic appraisal.

The Basin states have a limited ability to implement and enforce policies and reforms at the local level. Social control is highly fragmented, and policy implementation, if sincerely attempted at all, takes place in the context of multiple foci of power and multiple institutions. In the Volta basin, the duality between the legal state and the traditional hierarchy impacts every day life and a number of social determinants such as land tenure and access to water.

Institutional development is therefore key to assist development, which in turn depends on strong political will.

EXECUTIVE SUMMARY

1. Basin Focal Projects

CPWF Basin Focal Projects (BFPs) are designed to perform two functions: (1) provide whole-basin assessments of water availability, poverty, food security, and water productivity, and (2) examine water-related institutional and technical interventions, to ascertain the extent to which they might contribute to poverty reduction, resilient livelihoods, and environmental conservation. A first round of BFPs was implemented in the basins of the Karkheh, Mekong, São Francisco and Volta Rivers. This paper summarizes some emerging results from the Volta BFP. In the Volta BFP, hydrological and water allocation models were used to analyze basin-wide options for water management in different climate change scenarios. National economies rely heavily on agriculture, which contributes 30-40% of GDP. Crop modeling was used to identify factors limiting water productivity as the farming systems change in response to decreasing and more unreliable rainfall as one moves from south to north across the Basin.

2. Background

The Volta basin, which covers 395,000 km^2, is shared by six West African countries, with Ghana and Burkina Faso occupying 83% of the area. At present, 19 million people inhabit the Basin, but by 2050 this will increase to 50-60 million people. In 2005, there were 2.3 rural inhabitants for each urban resident. By 2050 this ratio is expected fall to 0.5. Currently, population density is rather low at about 48 persons per km^2. The main driving forces for change are demography, urbanization, migration, and climate change.

2.1. Ecological zones and water availability

The Basin contains four agro ecological zones: the Sahel (annual precipitation less than 500 mm), located in the northernmost part of the basin, dominated by livestock grazing and some millet production; the Sahelo-Sudan (500-900 mm), covering most of Burkina Faso and the small part of the Basin in Mali; the Sudan (900-1,100mm of rainfall per year), covering the northern half of Ghana and the parts of the Basin in Côte-d'Ivoire, Benin and Togo, dominated by sorghum, millet, maize, cotton and groundnut production; and the Guinean zone (above 1,100mm with a bi-modal distribution), covering southern Ghana, and dominated by root and tree crops. Apart from the Guinean zone, rainfall distribution is unimodal with the short growing season (June to November) becoming even shorter in the north.

Average runoff in the upper basin is about 5% of rainfall, increasing to over 15% in the lower reaches. River discharge is sensitive to variations in annual rainfall, with a ±10% change in annual rainfall leading to about ±40% change of river discharge. Most rivers in Burkina Faso dry up during the dry season, except where hydropower reservoirs maintain continuous flow. With higher rainfall, Ghana aims to maximize energy production from the Volta Lake with its Akosombo-Kpong hydropower scheme. Groundwater resources are poorly quantified and under exploited.

The rainfall regime in West Africa has varied over the years, changing from a relatively wet period (1950-69) to a drier period (1970-90), which effectively moved the isohyets 150 km to the south. Changes in rainfall patterns associated with climate change have not yet been modeled definitively at the basin scale. Most models indicate either a slight positive or a slight negative change of rainfall for 2050, with an increased probability of extreme events. We used a plus or minus one degree latitudinal shift of the isohyets as an hypothesis in the climate change scenarios we examined for the Volta Basin.

2.2. Agriculture

Natural rangelands cover nearly 85% of the basin while cropping covers about 14%. Crop selection varies from the drier north to the wetter south in roughly the following sequence: pasture, millet, sorghum, maize, cotton, cassava, yam, plantain and cocoa. Farm sizes are small. The median rain fed area cultivated by a family in Burkina Faso is 3.1 ha. The smallest farms are less than 1.4 ha.

A large number of small reservoirs have been developed in the upper basin for small-scale irrigation, which has helped some farmers to improve their incomes. Where large-scale irrigation exists, it typically competes for labor with traditional rain-fed farming. Overall, however, only 0.5% of the cultivated area is irrigated.

In most of the Basin, total annual rainfall is sufficient to obtain high crop yields. Nonetheless, yields are typically low. Average maize yield in Ghana is 1.5 t/ha, in Burkina Faso 1.2 t/ha. Water productivity of maize is less than 0.2 kg/m^3. This is attributed to rainfall spatial and temporal variability, poor soils, low input use, poor market infrastructure and low labor productivity. Typically farmers use low planting densities, which is a risk-avoidance strategy where rainfall is unreliable, but also entails that yields will always be low. In addition to low inherent fertility, soils in the Basin suffer from negative nutrient balances: more nutrients are taken off than are applied. Increase food production has come from increasing the area under cultivation rather than increasing yields.

2.3. Water-Agriculture-Poverty links

According to national poverty standards, about 50% of people in Ghana (1998) and Burkina Faso (2003) are poor. The World Bank, however, places poverty rates much higher: 63% for Ghana and 85% for Burkina Faso. Poverty is strongly rural and increases from south to north. Rural poverty is caused by low agricultural productivity, limited market access, price variability and insecure land tenure. Cash-crop farmers are less poor than subsistence farmers. The poorest farmers, fishermen or livestock farmers have similar poverty attributes : vulnerability resulting of a total dependence on the yield or catch, insufficient assets and low productive capacity..

Lack of access to clean water is another cause of poverty, through its impact on health and hence on farm labor. Access to domestic water was analyzed with respect to distance or time to fetch water, and the quality of the water. About 50% of households in the Basin use poor quality water, i.e. open wells and surface water. Principal water-related diseases in the Basin include malaria, schistosomiasis (bilharzia), onchocercosis (river blindness), trypanosomiasis and diarrhea. Malaria covers the whole basin, with a 100% prevalence in a large area of the central part of the Basin. The cost of malaria treatment is about USD$7 per treatment – out of the reach of most poor households.

Improvements in rain-fed agriculture appear to provide important opportunities for improving livelihoods. Soil and water conservation practices, at present used only on the most degraded soils, have the potential to improve yields and decrease vulnerability. Fertilizer use has been shown to increase potential yields, though such gains become increasingly risky north of Ouagadougou because of rain variability.

Investments to alleviate poverty are constrained by the high cost of developing infrastructure as well as by other institutional limitations such as land tenure insecurity for farmers and insecure access to water for herders. Apart from poor infrastructure, subsidized agriculture in developed countries hampers Basin farmers' access to national and international markets. This is particularly the case for cotton.

Basin states have a limited ability to implement and enforce policies at the local level. Social control is highly fragmented, and policy implementation must take place through a complex of multiple institutions. The duality between the legal state and the traditional hierarchy impacts every aspect of life and a number of social determinants such as land tenure and access to water. The new Volta Basin Authority is the main stakeholder for basin-wide and transnational matters.

3. Opportunities

It is forecasted that the rural population will increase slightly during the next 40 years. Opportunities to reduce rural poverty and improve livelihoods through water-related interventions and research are:

Irrigation development: The World Bank Africa Region irrigation business plan (2008-2012) for poverty reduction ranks Ghana, Burkina Faso, and Mali in Group 1 countries, where investment in irrigation and rain-fed cultivation is recommended.

Groundwater development: The groundwater resource should be assessed as a possible tool for extensive development of small-scale irrigation. The geological setting has some similarity with central India where the Green Revolution occurred.

Fertilizer use and micro-credit: An important opportunity is to develop incentives for smallholder farmers in rain-fed systems to invest in fertilizers and small-scale irrigation. Research is needed to reduce barriers to fertilizer use, and increase its socio-economic acceptability.

Livestock and fisheries: Livestock and fish systems support many of the poor. Fisheries need to be monitored to allow sound management to be implemented. Services provided by the aquatic ecosystems are not well understood and need socio-economic appraisal. A better use of forage browse for livestock would improve water productivity and animal production. Increasing conflict between nomadic herders and sentient farmers for access to drinking water for the nomads' livestock requires resolution at the institutional level.

Institutional and market development: Institutional development is key to resolve the ubiquitous traditional/legal duality. The national or regional food market has to be organized in the same way as the cash crop market. Pro-poor activities will involve combined improvements in the access to land, to agricultural water, and to affordable micro credit for this part of the population.

Small reservoir management: Small reservoirs require careful management to prevent exclusion of the poorest and careful monitoring to reduce the threat to flows on which Akosombo, Bagré, and other large hydro-electric schemes depend.

Water governance: Strong political will is needed to implement successful water reforms that mirror the principles and objectives of IWRM. These reforms will create mechanisms to involve local water users and to mediate conflicting interests effectively under the current institutional, administrative, and political conditions. The simulation tool developed by BFP Volta in collaboration with IUCN-PAGEV for analysis of transboundary water-sharing may foster dialogue on IWRM.

SYNTHESIS REPORT

1 Introduction and overview

1.1 The CPWF

The CGIAR Challenge Program on Water and Food (CPWF) brings together scientists, development specialists, and river basin communities in Africa, Asia and Latin America to address challenges of water scarcity and food security. It is an institutional innovation that deals in an integrated fashion with multi-scale water problems and their effects on agriculture. It helps build a water dimension into on-going research on food, poverty, the environment, and livelihoods. It breaks down boundaries between institutional structures and mobilizes the efforts of a diverse group of stakeholders. In these ways, it contributes to the institutional reform of the CGIAR system.

CPWF activities include competitive grant projects, commissioned synthesis research, and Basin Focal Projects (BFPs).

1.2 Basin Focal Projects

The purpose of BFPs is to identify and evaluate, across scales, strategies for addressing water, food and poverty problems in specific basins. In 2005, BFPs were launched in four benchmark basins: Karkheh, Mekong, São Francisco, and Volta. In 2008, additional BFPs started in another six basins (Figure 1). This report focuses on the Volta.

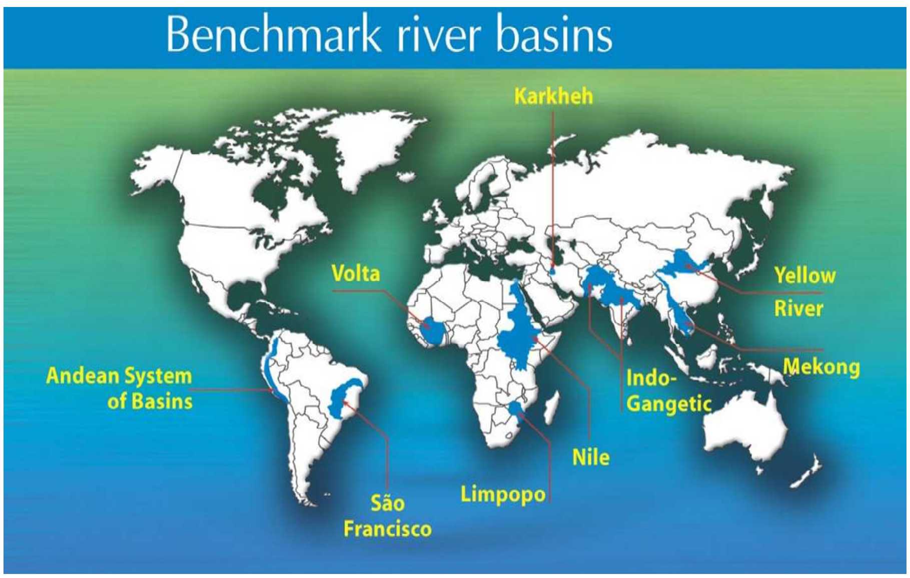

Figure 1. CPWF benchmark basins. Source: CPWF.

Basin Focal Projects were designed to answer three specific questions:

1. How are water, food and poverty related?
2. What are the principal links between a globally-defined water crisis, and conditions on the ground in specific basins?
3. How can the study of river basin function help identify actions for addressing water, food and livelihood issues, and illuminate the consequences of taking these actions?

1.3 Overview and outline

This report is organized according to the general schema shown in Figure 2. To facilitate comparison between basins, this logic is replicated in other basins as far as allowed by the context, depth of analysis and availability of data.

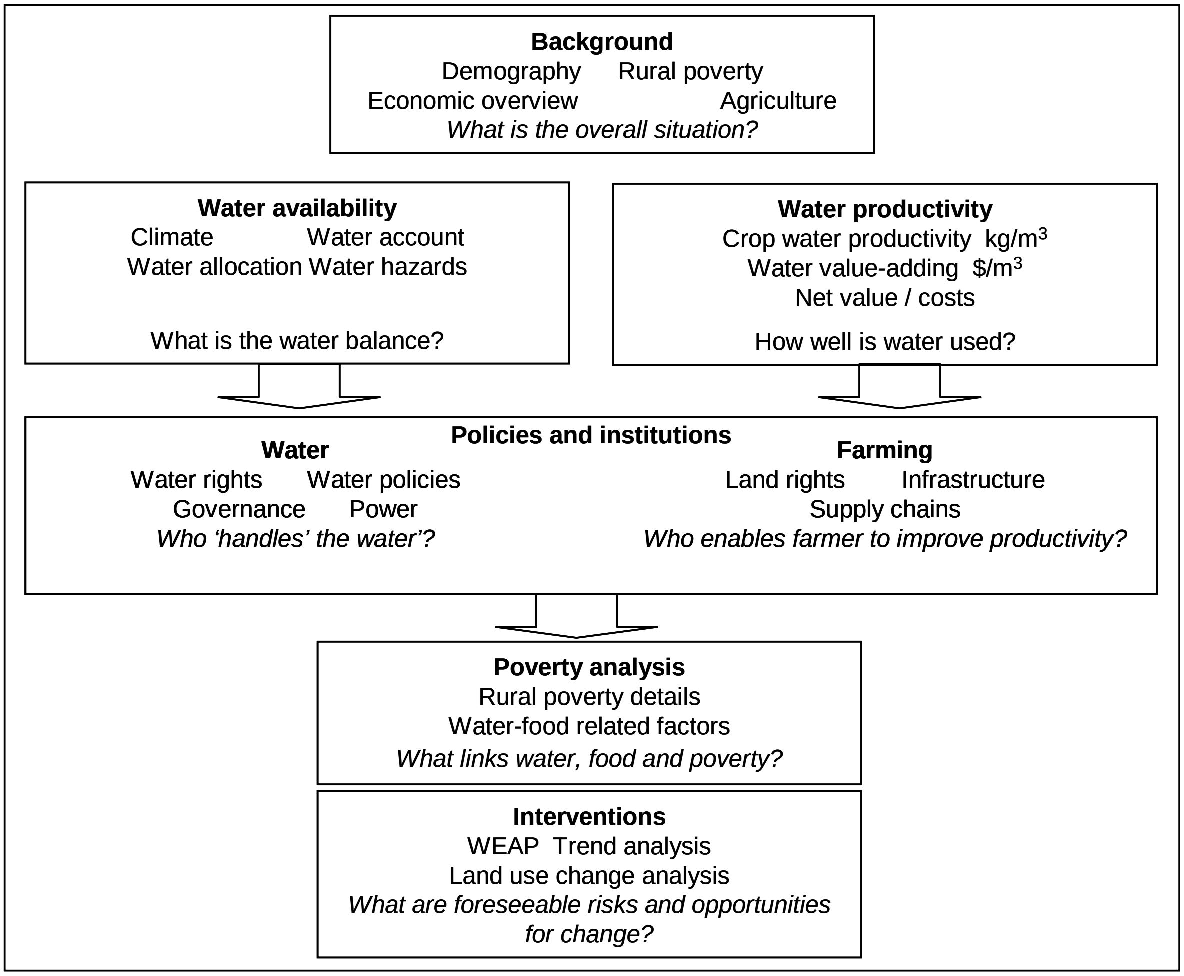

Figure 2. Flow diagram of the BFP analysis.

First, the Volta Basin is introduced using broad background statistics that help put the Basin in a regional or global context. Then the report provides information on water availability in the Basin, including rainfall quantity and distribution, water use or water accounting, and equity of access to water for different users. Drought appears important in parts of the Volta, and this hazard demands particular attention.

In parallel, water productivity estimates are described in relation to farming practices, and the combined insight of water and agricultural factors is used to help explain the condition of rural poverty in the Basin. Policies and institutions in the Basin, both formal and informal, are important conditioning factors that influence the link between water, agriculture and poverty, and therefore institutional drivers of water allocation and features described such as land tenure, access and markets. Finally, opportunities for using water-related interventions to address water and food problems in the Volta are identified, and the consequences for different water users of major changes are analyzed.

2. The Volta Basin introduced

The Volta Basin, located in West Africa, covers an area of around 395,000 km^2 across six countries: Benin, Burkina Faso, Côte-d'Ivoire, Ghana, Mali, and Togo (Figure 3). Among them, Burkina Faso and Ghana account for 83% of the Basin area, but the Basin also covers 47% of Togo. For a major river basin, the Volta is not particularly large: it covers about the same area as the Limpopo and is far smaller than the Ganges, Mekong or Nile basins (1.0, 1.8 and 3.2 million km^2, respectively).

About 20 million people live in the basin. Most (13.5 million) are rural. While inroads have been made to reduce poverty in some areas, rural poverty remains high, especially in Burkina

Faso. Population density is around 48 persons/km², higher than in the Limpopo but far lower than densely-populated basins such as the Ganges (32 and 401 persons/km² respectively).

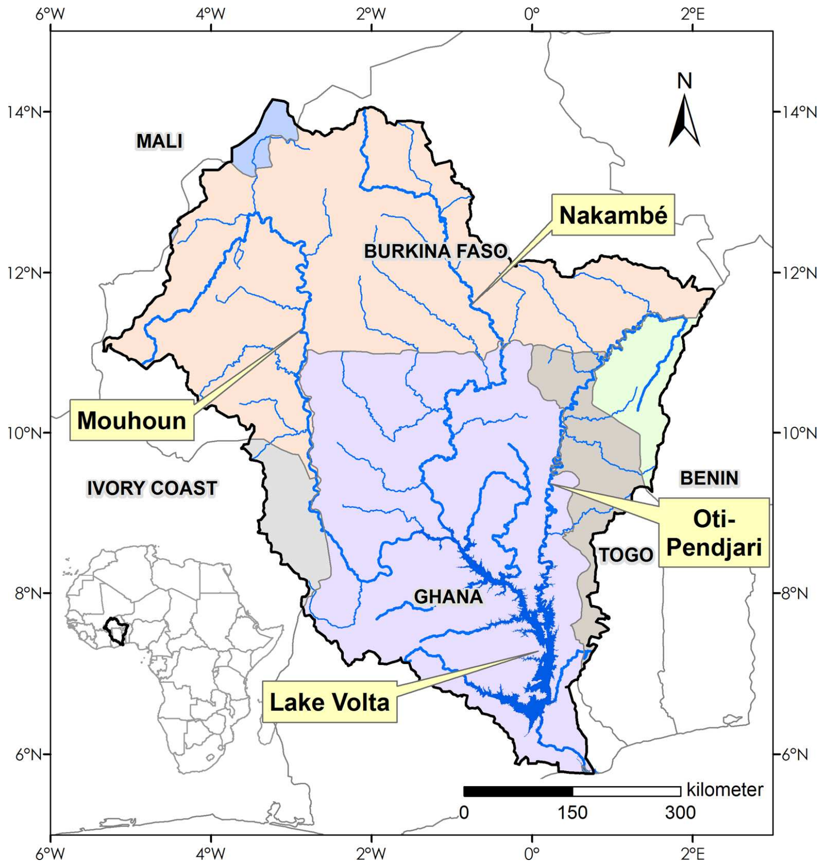

Figure 3. The Volta basin and its political boundaries. Source: BFP Volta with the river systems from Dieulin, 2007.

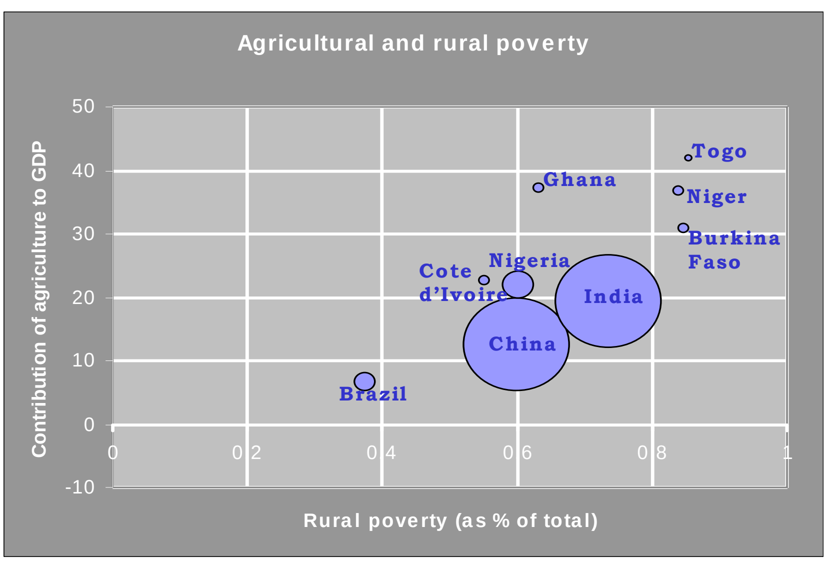

Figure 4. The relationship between the relative importance of agriculture and the incidence of rural poverty in some emergent and developing countries. Rural poverty and agriculture contribution to GDP decrease when urbanization and industrialization develop. The size of bubbles represents the rural populations Source: World Development Report 2008: Agriculture for Development. The World Bank.

About 30-60% of the total land resources in the basin, are considered arable. A large proportion of this, however, is left uncultivated (Table 1 and Figure 5).

Expansion of cultivated area over the past 30 years is related to population growth. There has been little if any increase in cultivated area per capita (Serpantié 2003)(Figure 11). It would appear that scarcity of productive assets and water, not land, are the factors that limit production.

In comparison with so-called transitional economies (such as India or China) or industrialized economies, countries of the Volta Basin remain predominantly agricultural (World Bank, 2008). Most of the poor are rural. Commercial agriculture has influence in parts of Ghana and with cotton in southern Burkina Faso.

Table 1. Land use in the countries of the Volta basin (data for 2003-07, modified from FAO Aquastat 2005).

Country	Arable % of total country	Cultivated (% of arable)	Cultivated area (1000 ha)	Irrigable (1000 ha)	Actually irrigated % of irrigable
Benin	62	40	2,815	322	1.3
Burkina Faso	33	49	4,700	165	n.a.
Côte-d'Ivoire	65	33	7,100	475	n.a.
Ghana	42	63	6,331	1,900	1.5
Mali	35	11	4,840	566	n.a.
Togo	60	77	2,450	180	3.4

n.a. = not available

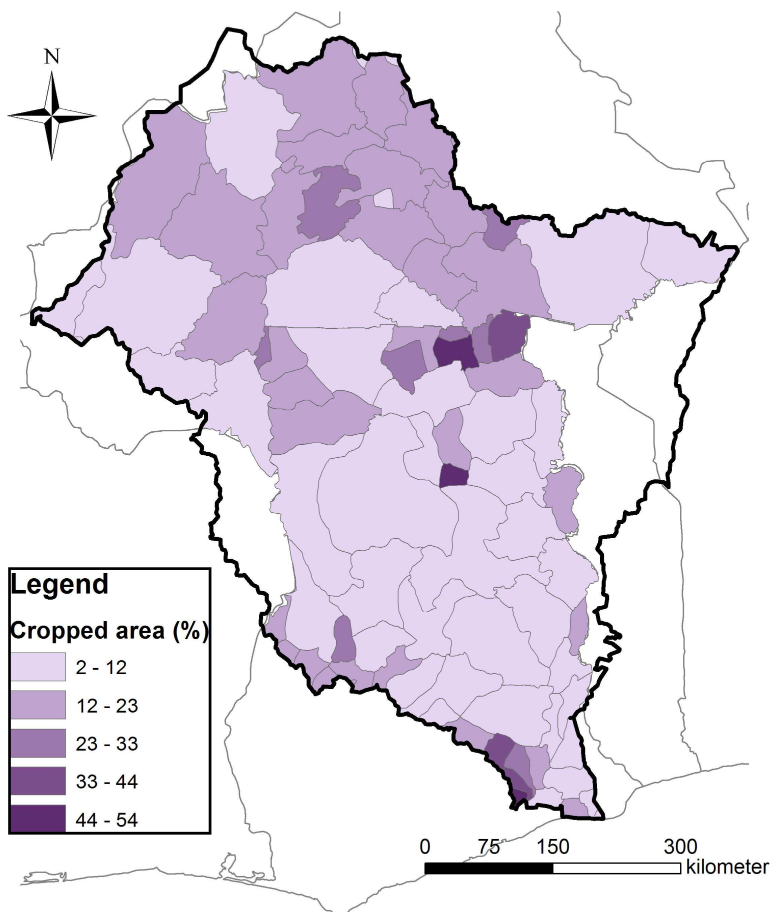

Figure 5. Spatial distribution of area cropped for food production in Burkina Faso and Ghana. Source: map by BFP Volta with data from MOFA and MAHRH.

3. Water availability

For the Volta Basin as a whole, rainfall is relatively abundant. Mean rainfall over the basin is about 400,000 Mm^3/year or about 1,040 mm/year, which compared with other CPWF benchmark basins, is roughly twice that of the Limpopo and is nearly as high as for the Ganges. There is a marked gradient between the drier north and the wetter south, however. Annual rainfall varies from about 500 mm in the north of the basin to 1,200 mm in the southern, downstream part of the Basin. Average Basin discharge is about 8 to 9% of total rainfall.

With more than 2,000 m^3 of renewable water resource (surface and groundwater) per capita per year the Volta Basin population may be considered as slightly above the world standards of *physical water scarcity,* which have been set by UNEP at 1,700 m^3 per capita per year.

At the sub-basin scale, however, most of the northern part of the Basin suffers physical water scarcity. The renewable water resource in Burkina Faso is about 900 m^3 per capita per year, with dry river beds for several months during the year. Moreover, the groundwater resource is distributed unevenly, exacerbating the problem in some areas.

Economic water scarcity occurs when water resources are abundant relative to water use, but insufficient infrastructure or financial capacity prevents people from accessing the water they need. This dilemma plagues predominantly the smallholder farmers in the Volta Basin, most of whom rely on low-yield, rain-fed agriculture, and whose livelihoods are constantly threatened by unreliable precipitation, droughts and dry spells and lack of access to good quality household water. For this reason, additional investment in the water sector, especially for small-scale irrigation and dry season crops, could play a transformative role in poverty alleviation (World Resources Institute, 2007).

3.1. Rainfall, surface water and groundwater

The temporal and spatial distribution of rainfall influences agriculture more than total rainfall. Towards the north, rainfall has a unimodal distribution from May to September and the rainy season becomes increasingly. In the south, rainfall is distributed bimodally with “long rains” from April to July and “short rains” from September to November (Figure 6). The risk of within-season dry spells influences cropping choices (see below).

This north to south gradient has been used as the basis for delineating the following agro-ecological zones based on the FAO classification (FAO 1996) (Figure 6):

- The Sahel, located in the northernmost part of the basin, defined as receiving less than 500 mm annual precipitation. The Sahel is a zone of rangeland where livestock herding is the primary activity, complemented with the drought-resistant crops, millet and cowpea;
- The Sahelo-Sudan, covering most of Burkina Faso and a small part of Mali, defined as receiving 500 - 900 mm annual rainfall. Millet, sorghum and maize are the main cultivated food crops, with cotton, groundnuts and some sedentary cattle for cash income;
- The Sudan, including the northern half of Ghana, and those parts of Côte-d’Ivoire, Benin and Togo that lie within the Basin, and defined as receiving between 900 and 1,100 mm annual rainfall. This is a transition zone with production of both cereals and root crops. Some cattle is present seasonally; and
- The Guinean zone, covering the southern part of Ghana, receiving in excess of 1,100 mm annual rainfall. Yam, cassava and plantain are the main crops.

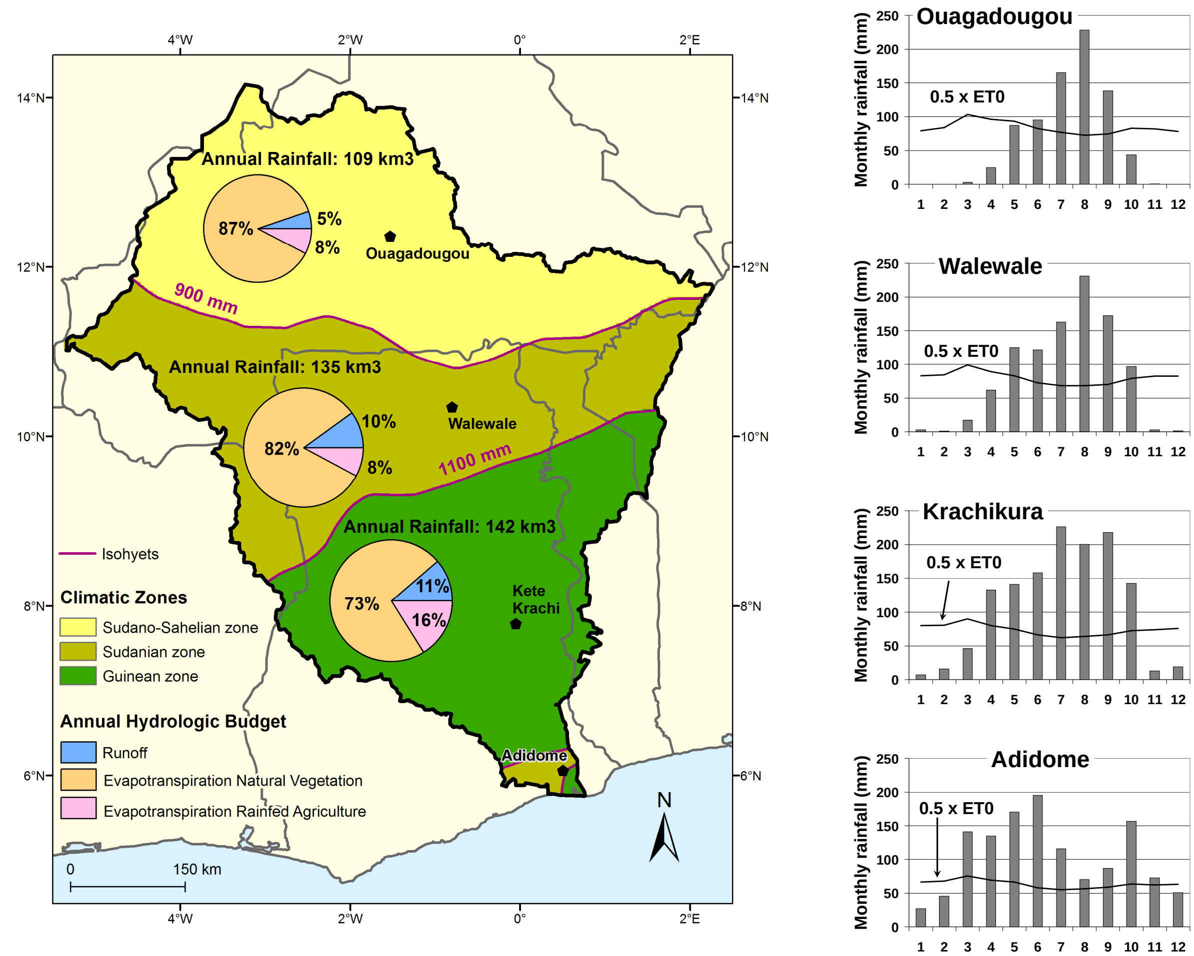

Figure 6. The agro ecological zones with a summary of the water account in the Volta basin, and the distribution of rainfall in four stations along the south-north gradient. ET0 is the reference (or potential) evapotranspiration. The intersection of the 0.5 ET0 line with the rainfall distribution indicates the length of the growing season (map by BFP Volta with data from CRU) (De Condappa et al. 2008).

Surface water in the Volta is largely concentrated in the reservoirs of the hydropower schemes (Bagre, 1700 Mm^3; Kompienga, 2025 Mm^3; and Lake Volta, 148,000 Mm^3). A smaller amount of surface water is stored in about 1100 small reservoirs (90% located in Burkina Faso) that are used for small-scale irrigation, household and cattle watering. Their total storage capacity is 232 Mm^3. Lake Volta is a major component of the aquatic system, with a surface area of 8,500 km^2, in which water has a residence time of 3 years. Many of the rivers of the Upper Volta basin used to dry up during part of the year before being regulated by the construction of the hydropower schemes Bagré on the Nakambe River and Kompienga in the basin of the Oti River.

Major water management issues focus on surface water, on the impact of the development of small reservoirs, and on the possible effects of climate change on the operation of the Lake Volta hydropower system and on the livelihoods of more than 70,000 fishers.

Groundwater resources are poorly understood but appear to be under-exploited. Groundwater recharge is estimated to be 12.6km^3/y or 3.7 percent of rainfall (Martin and van de Giesen, 2005). FAO (Aquastat 2002) gives a figure of 36.0 km^3/y for the groundwater resource in Ghana and Burkina Faso, with good yields from the limestone aquifer up to 184 m^3/h compared with the yield from hard rock (less than 6 m^3/h). Most boreholes are used for rural domestic supply and give access to good quality water to about 44% of the population. The conservative estimate of groundwater use of 88 Mm^3/y corresponds to about 0.7 % of average annual groundwater recharge (Martin and van de Giesen, 2005), which leaves ample opportunities for development.

Potential for groundwater development was estimated through a combination of the amount of groundwater recharge, together with the accessibility to the resource and whether its development was worthwhile (Martin and van de Giesen, 2005). The study identified regions with good potential such as the north-western edge of the basin, and from the eastern shore of the Volta Lake to the eastern corner of Burkina Faso. Some unacceptably high concentrations of fluoride and arsenic occur locally in some boreholes in Burkina Faso.

The fluctuation of the rainfall regime in West Africa has major implications for water resource management. The decades of the 1950s and 60s were relatively wet, while the 1970s and 80s were drier (Figure 7). A comparison of these two time periods for the main tributaries of Lake Volta, the White Volta and the Oti, illustrates the impact of rainfall variation and related factors. In the 1950s and 60s, with higher rainfall, catchments were more densely vegetated, populations were smaller and land use was less intense. In the drier 1970s and 80s, populations were larger, land use more intensive, and land degradation more severe. Mean stream flows were substantially reduced in the latter time period: by 32% at Saboba on the Oti River and by 23% at Nawuni on the White Volta near Lake Volta (Gyau-Boakye and Tumbulto 2000). The change in runoff from the wet to dry period was not uniform across the Basin: the runoff coefficient increased during the dry period in the upper basins where annual rainfall is <750 mm/yr, resulting in sometimes higher discharge, while it has not changed in the lower basins (>750 mm/yr) where the coefficient was already higher than in the north.

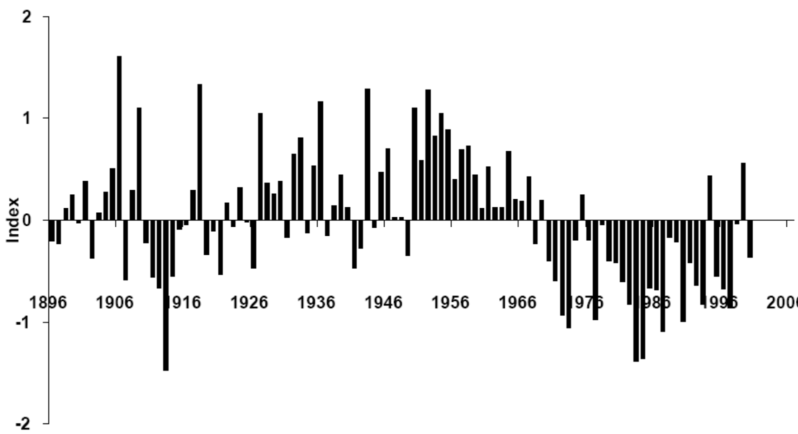

Figure 7. Normalized rainfall anomaly index for the West African Sahel (1896-2000) with a mean value computed for 1921-2000. The normalized anomaly index for a given year is the departure from the mean in mm, divided by the standard deviation (in mm) of the rainfall distribution for the whole period. Source: L'Hôte et al., 2002, as shown in Lemoalle, 2007.

3.2. Water use

A detailed water account for the different agro-ecological zones and the sub-basins is presented in Figures 6 and 8 respectively. Natural vegetation, mostly savannah grasslands, uses the major part of the rainfall (around 80%) throughout the basin. Run-off increases from less than 5% in the northern part of the basin to >10% in the south. Woodland appears as a water consumer only in the southernmost part of the basin. The total available streamflow in the Basin is about 32 km^3 per year during the period 1990 - 2000.

3.2.1 National priorities

Most rivers in Burkina Faso dry up during the dry season, except where the two hydropower reservoirs maintain a continuous flow. A large number of small- and medium-size reservoirs holding 232 Mm^3 have thus been constructed in the upper basin, mainly for small scale irrigation. Burkina Faso has developed small-scale irrigation throughout the country, and some hydropower schemes near its downstream border (Bagré and Kompienga dams).

With Lake Volta and its Akosombo-Kpong hydropower scheme, Ghana aims primarily at producing energy. An annual volume of about 37 km^3 of fresh water was discharged through the turbines and into the sea in the late 1990's, which is above the average inflows during the period 1990 – 2000 and resulted in low lake levels. Another hydroelectric plant is planned at Bui on the Black Volta. There is sufficient rainfall over most of Ghana for a satisfactory production of rain-fed agriculture, except in two regions: the northern regions where some small reservoirs and dug outs have been constructed, and in the south near the coast where supplemental irrigation from the reservoirs or Lake Volta is needed.

3.2.2 Domestic use

From the population in the Basin, the domestic water demand has been estimated as 156 Mm^3/yr in 2005. Large cities in the south, and Ouagadougou in the north, are largely supplied by surface water. Underground water from boreholes is usually considered a good quality or safe water. It supplies most of the large cities in the north and the rural population of the Basin. Although the situation is improving rapidly, many households in the Basin do not have access to this good quality water (see Figure 25), and the present use of underground water has been estimated as 88 Mm^3/yr (Martin and van de Giesen, 2005).

Even with increased urban populations in the near future, the demand for domestic water remains a small fraction of the total resource. The same applies to the watering needs for cattle and livestock, which are widespread in the basin, with a total annual demand of 70 Mm^3/yr (Clanet, 2008).

3.2.3 Rain-fed agriculture

Rain-fed agriculture uses only 14% of the total rainfall of the total basin area. A combination of factors contributes to the gap between potential and observed water productivity. Some of these factors are directly related with the water availability: the inter-annual rainfall variability (droughts) and the intra-seasonal variability (dry spells) lead to low yields, but also a poor water holding capacity. Poor nutrient contents of most soils in the Basin also contribute to the low yields.These low nutrients result from the weathering of the parent rocks by tropical climate and subsequent leaching of the soils (Bationo et al. 2008).

In the near future, gains in the productivity and water productivity particularly in the North of the country of the rain fed agriculture appear to be the main prospect for the food self sufficiency in the basin.

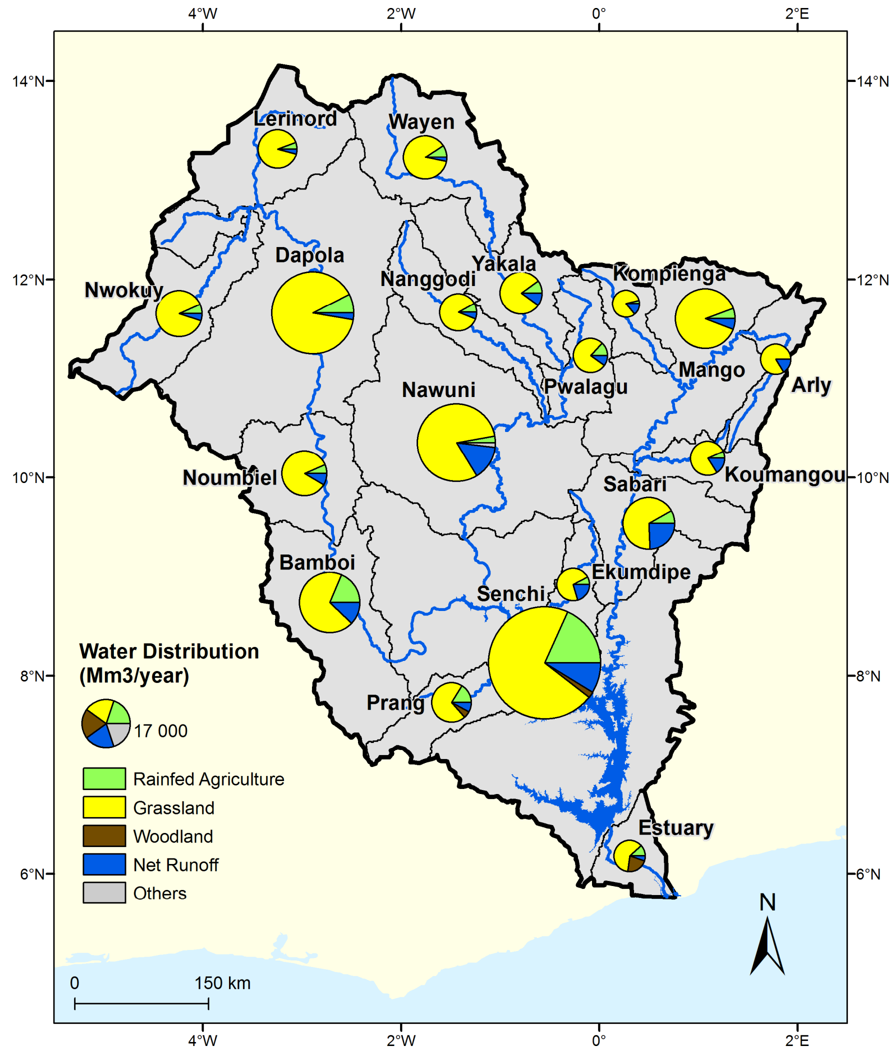

Figure 8. Water accounting in the different sub-basins of the Volta River. Map by BFP Volta with data from CRU for rainfall, Volta Hycos and SIEREM for river discharge, MAHRH-Burkina Faso, MOFA-Ghana and FAO for land use (de Condappa et al., 2008).

3.2.4 Irrigation

As in most other regions of Africa, the irrigated area in the Volta basin is only a small fraction of the total cultivated area, less than 0.5%, and also a small fraction of the irrigation potential. Even the areas for which irrigation water is available from the Bagré and Akosombo/Kpong dams have not been fully exploited. Nevertheless, many of the small farmers in the drought-prone areas of the Basin consider access to dry season irrigation as a means to alleviate vulnerability and poverty and to increase food production (Ducommun et al. 2005).

The formal, state-owned, irrigation schemes amount to 13,000 ha and 6,500 ha respectively in Burkina Faso and Ghana. The associated total water demand is 509 Mm3/yr. It is planned to involve commercial companies as these areas are not all fully exploited by the small farmers. Social, cultural and economic reasons may contribute to the present situation. The policy documents for the development of African agriculture issued by the African Union/NEPAD (2003) and the European Commission (2007) focus mainly on the technical feasibility and on the investments required, but do not take into account the social aspects of the implementation of irrigation in West Africa, where it remains poorly developed compared with other regions in the tropical world.

The reasons of success and failures of large-scale irrigation in the Volta basin, and more generally at the regional scale remain a vital research topic.

About 1,400 small reservoirs have been developed in Burkina Faso and northern Ghana. Approximately 1,100 are within the basin, with a storage volume estimated as 232 Mm^3. They contribute to dry season vegetable production over about 10,000 ha, and usefully complement rain-fed production. The active informal urban and peri-urban irrigation, mostly devoted to vegetable production, remains poorly documented but is rapidly expanding.

The impact of the present and future development of small reservoirs in the upstream part of the basin has been taken into account in the development of the water allocation model, both at the basin and sub-basin scales. A sharp increase (10 % increase in the number of small reservoirs per year during 20 years would decrease the inflow to Akosombo by less than 1 km^3 per year at the end of the period. But other water users, and notably Bagré and the existing small reservoirs in the upper sub-basins, may suffer earlier more frequent unsatisfied demands (De Condappa et al., 2008).

3.2.5 Other uses

A main feature of the basin is Lake Volta, a hydroelectric reservoir with an area of 8,500 km^2 and a residence time of 3 years. The dam was closed in early 1965, which severely impacted the downstream population and its environment. It has been complemented since by the smaller Kpong reservoir (0.19 km^3), a few kilometers downstream. The water released through the turbines amounted to 37 km^3 per year at the beginning of the 2000s. Since 1970, a decrease in rainfall over the basin and probably an increase in electricity production have contributed to a reduction in the water stored in Lake Volta. The energy produced, around 8 billion kWh, is an important contribution to the national income, and this water use is a priority for Ghana. A major threat to the Lake and hydropower is the presence of the water hyacinth (*Eichhornia crassipes*) in the lower Oti River, one of the main tributaries to the lake. The plant is known to be detrimental to the turbines if taken up in the water intakes.

Lake Volta is also home for 70,000 fishermen and their families. With an area of 8,500 km^2, Lake Volta has loses about 2 km^3/yr through net evaporation (rain minus evaporation) during the period 1990-2000 (van de Giesen et al., 2001; de Condappa et al. 2008).

In Burkina Faso, the reservoirs Bagré, for both hydropower and irrigation, and Kompienga (Table 2), only for hydropower generation, contribute also to some inland fisheries. Overspills of the dam at Bagré has caused damage for the downstream populations. Such floods probably result from a recent increase in the runoff coefficient in the watershed, which was not taken into account in the dam design.

Table 2. The main hydropower schemes in the Volta basin.

Reservoir	Volume (Mm3)	Dateconstruction finished	Energy/year (GWh)
Akosombo/Kpong(GHA)	148,000	1965	4,800
Bagré(BFA)	1,700	1993	33-44
Kompienga (BFA)	2,500	1990	48
Samandéni (BFA)	1,050	projected	17

4. Farming systems and food production

Rain-fed production of food and cash crops is largely dominant in the Basin where only a very small proportion of the cultivated area is irrigated. Meat production from cattle, small ruminants and poultry may be considered as partly derived from rain-fed cultivated or wild biomass. Fish catch is also to be taken into account, both as a food production and as an important social and economic activity, especially from the large Lake Volta with more than 70,000 fishers.

As food production is especially vulnerable in the north and central parts of the Basin, due to the rain variability, we have focused on the rain-fed cereal production in this part of the Basin prone to droughts and dry spells. Rain fed agriculture is the main tool for improvement in food security (Rockstrom and Barron, 2007). It is also the activity of the majority of the poor rural populations. The challenge is to improve the use of the available rain water.

The main systems that contribute to food production are described below.

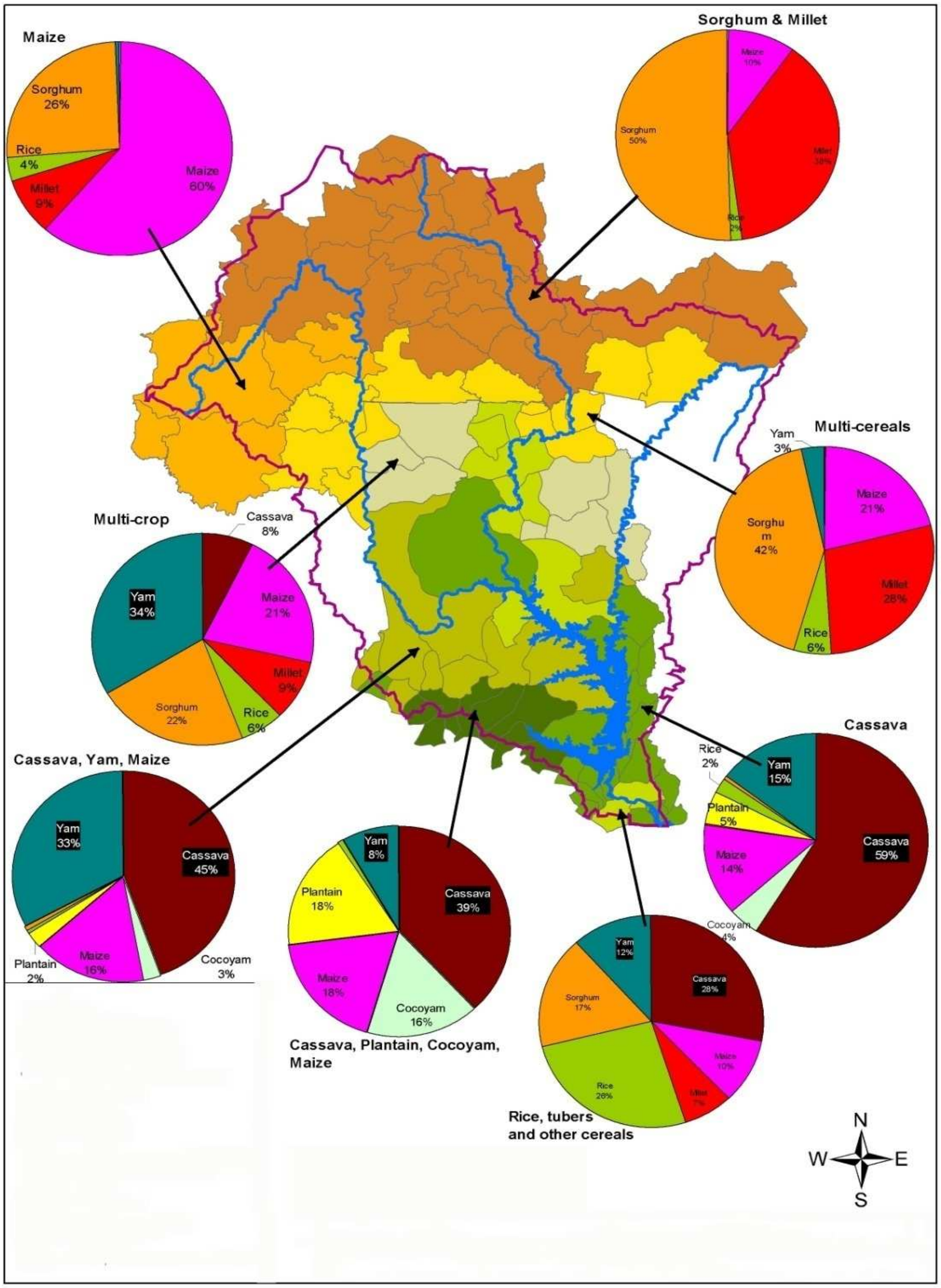

Figure 9. The main cropping systems in the Volta basin. Map by BFP Volta with production data from MAHRH and MOFA data for 1992-2000.

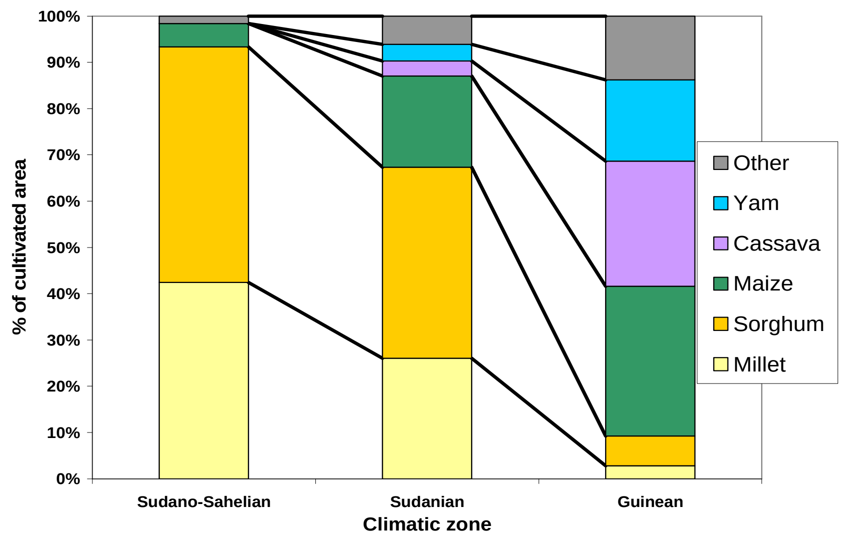

Figure 10. The North-South gradient in agro ecological zones and agricultural systems.

4.1. Rainfed farming systems

Distribution of the main crops varies across the agro-climatic regions of the Basin, mainly as a function of rainfall and soil characteristics, with a successive north-south dominance of millet, sorghum, maize, which are replaced by cassava, yam and plantain in the south (Figure 9 and Figure 10). The overall low production of rain-fed crops in the Basin results from a combination both of a limited use of the arable land and low yields (Figure 12).

4.1.1 The use of arable land

While it is generally accepted that around 50% of a country in West Africa is arable, only a small fraction is cultivated in the countries of the Basin (Table 1)(FAO, Aquastat,2005). The relative increase in cultivated area has been closely related with the demography in South-West Burkina Faso for the past 30 years, with no net increase of cultivated area per rural inhabitant (Serpantié, 2003). More recently, in the Volta basin of Burkina Faso and Ghana, the rate of increase of the cultivated area is very similar to the increase rate of the total population between 1992 and 2003 (Figure 11), although there is an indication of a slight increase of cultivated area per rural inhabitant.

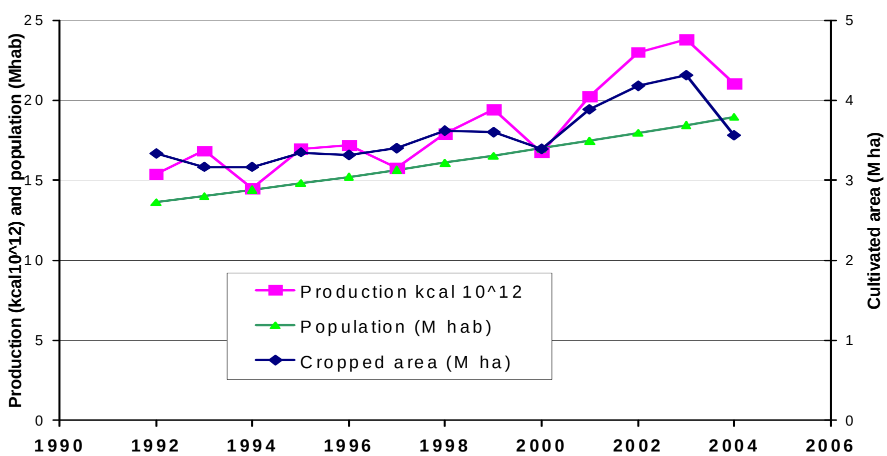

Figure 11. The time trends of cultivated area, total production and increase in population indicate that the increase in production results mainly from increased cropped area. Data from MAHRH and MOFA for cultivated area and production, with Lemoalle (2007) for an estimated demographic increase of 2.8%/yr in the basin.

Some arable land is available at the basin scale for further development of cultivation, taking into account other uses, and especially livestock keeping. This availability leads to some migrations and new settlements within the countries of the Basin.

4.1.2 Low yields

The low yields (Figure 12) result from a number of reasons:

- Water availability (variability of rainfall in time and space);
- Poor and degraded soils, with little or no input of fertilizers; and
- Lack of man power and low work efficiency.

Water availability has been discussed in part in the previous chapter. Water harvesting and soil and water conservation techniques are available to improve the effective use of rain water by crops, especially by increasing the water holding capacity of the soil by using mulches and incorporating crop residues. The farmers also have their fields scattered around the village, so as to minimize the risk resulting from the highly variable spatial distribution of the rain, the distance of independence being approximately 1000m for almost all storms (Sivakumar and Hatfield, 1990).

Most African soils are poor compared to other parts of the world. Lack of volcanic rejuvenation has caused the continent to undergo various cycles of weathering, erosion and leaching, leaving soils poor in nutrients (Smaling 1995; Smaling et al. 1999). In addition to low inherent fertility, the nutrient balances of African soils are often negative indicating that soils are progressively mined. Whereas in the developed world, excess applications of fertilizer and manure have damaged the environment, insufficient use of fertilizer is one of the causes for environmental degradation in Africa (Bationo et al, 1991, 2006).

Simulation with the Decision Support System for Agrotechnology Transfer (DSSAT) for 11 soils, with fertilizer (N40, P13 kg/ha), or without has shown that a significant yield increase could be obtained with moderate application of fertilizers on most soils of the basin (Fisher and Lemoalle, 2008). The increase ranged from twofold for the better soils to almost sixfold for the poorest soils (Figure 13). The results also point to a distinction between the southern region, where yields vary little with latitude (rainfall is abundant), and the central and northern part of the basin where yields decrease rapidly with increasing latitude, indicating a water constraint and a higher susceptibility to climate change. In these drier regions, rain and other factors become more limiting than nutrients.

Field observations in the Sahel have also indicated the high potential of fertilizer use, including local sources of phosphate (Bationo, 1991; Bationo et al., 2008), or micro additions of fertilizers. On-farm trials in Northern Ghana have shown an astonishing fourfold increase in maize, and more than twofold increase in millet or sorghum with micro or normal additions of fertilizers (provisional results of CP 5 of the CPWF, in press).

These technical solutions may however prove impractical because of the social and cultural environment: risk avoidance by small farmers, land tenure insecurity, lack of access to reasonable credit, to market.

A simulation of farmers’ behavior and needs in the central plateau of Burkina Faso points to three variables that may help to a more sustainable agriculture: credit, subsidized fertilizers and land tenure (Ouédraogo, 2005).

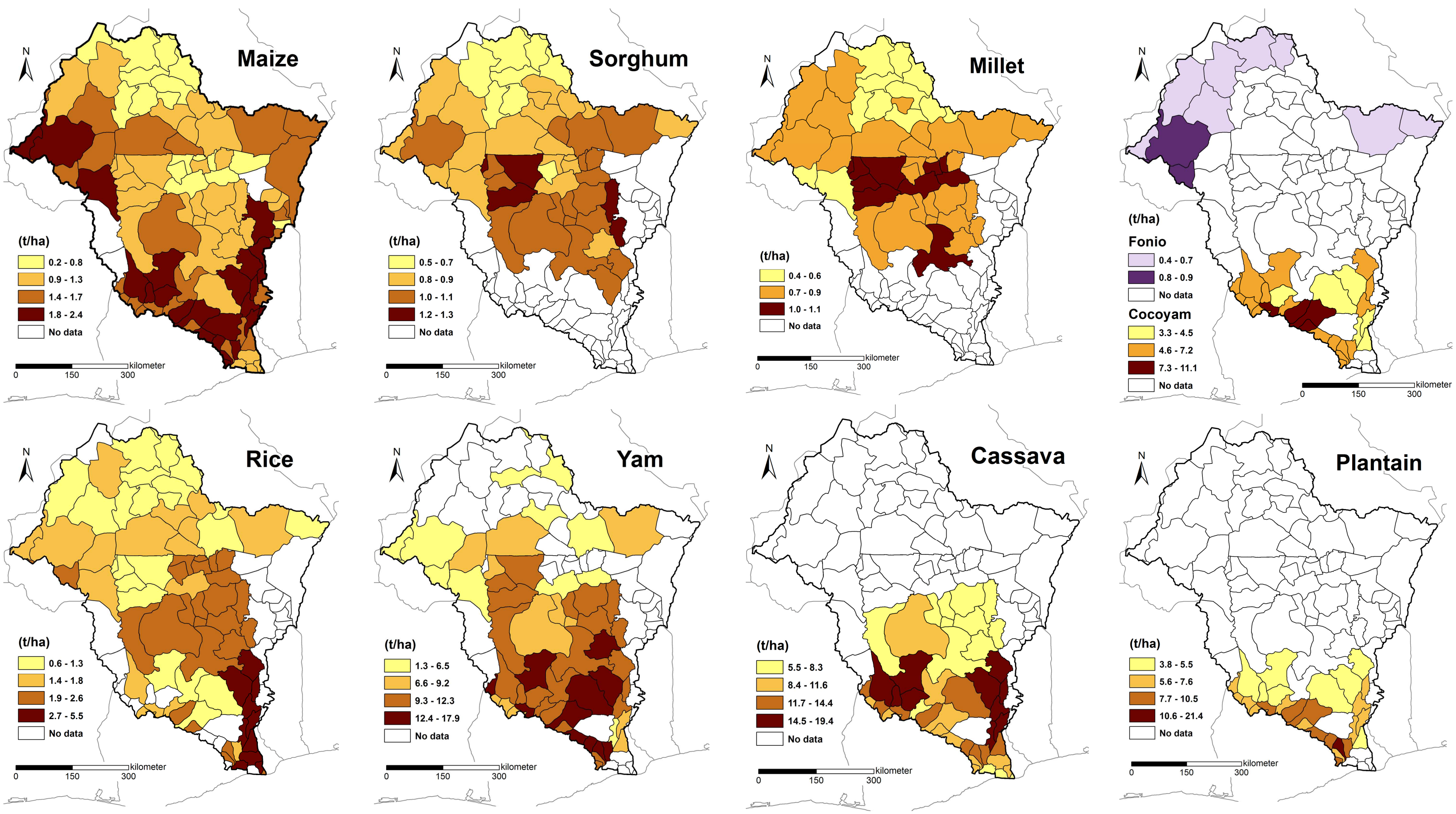

Figure 12. Mean yields of the main food crops in the basin. Map generated by BFP Volta with data from MOFA and MAHRH.

In this heavily populated area of the Central Plateau, where fallow is no longer practiced because of demographic pressure, credit may help the poor in developing more efficient practices. In the simulation, cheaper prices of fertilizers were not sufficient by themselves, even when prices are cut by 50%, but additional aid from credit was required. The present land tenure system, between modern legal law and traditional allocation, is a major obstacle to innovation and investment. In the context of the risk-avoidance strategies of poor farmers, investing in fertilizers increases the risk, so that they need the incentive of stable prices as well as efficient insurance mechanisms to allow them to make the necessary investment. Farmers also consider the lack of manpower, of draught power and of proper tools (plough, carts) major constraints to increased production and yield.

Yam, cassava, and plantain are cultivated in the basin where the rainfall exceeds 1,000 mm/yr and where there is a lower impact of dry spells (Figure 9 and Figure 12). They provide most of the food staples of in the southern part of the basin.

4.2. Other cropping systems

Peri- and intra- urban cultivation is an important component of vegetable production, with an estimated 45,000 ha in and around the main cities in Ghana. Such an area ranks peri-urban cultivation as the main irrigated system in the Basin, when compared with the 10,000 ha irrigated by small reservoirs. Urban production is mostly based on informal irrigation using a waste water. As both the size and the number of cities in the Basin will increase in the future, this activity is likely to develop as well. The research already under way by IWMI and the CPWF (PN 38 and PN 51) on the impact of irrigation by waste water on food safety is particularly relevant in order to improve the health security.

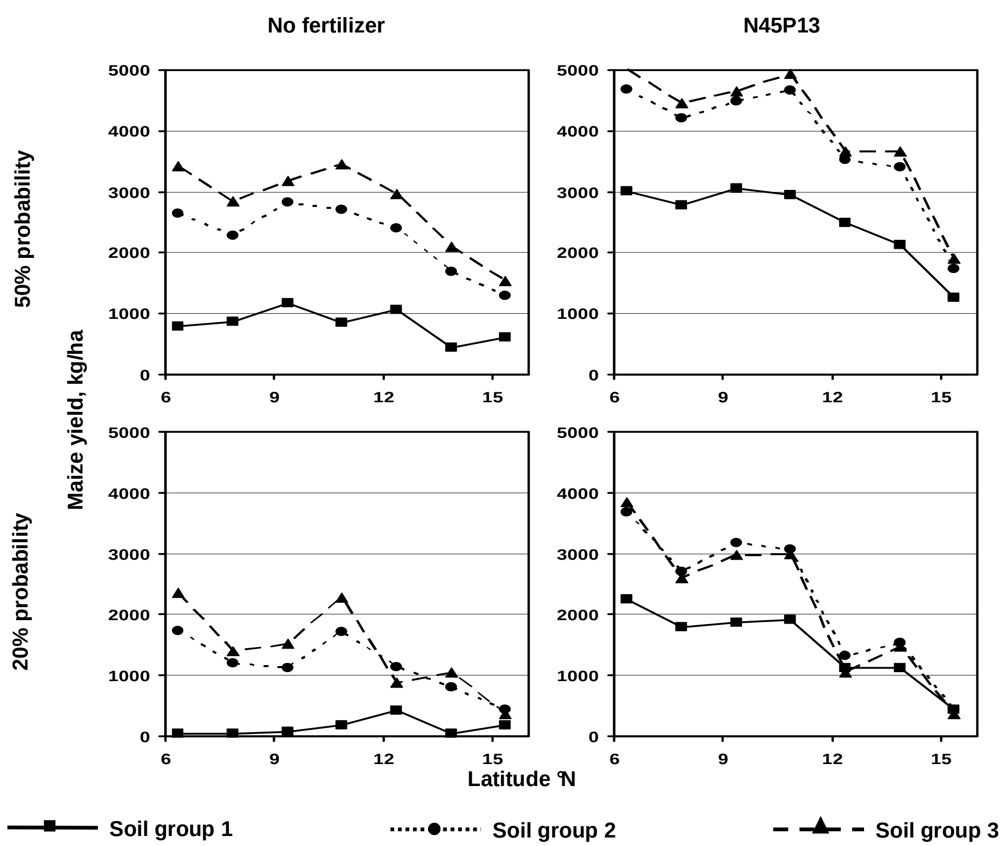

Figure 13. Grain yields at 50 and 20 percent probabilities for simulated crops of maize on a 9-degree transect on the meridian of Ouagadougou (1.53ºW) in the Volta Basin, West Africa, using the maize submodel of the DSSAT4 crop simulation package (Jones et al. 2003). The planting rules, the agronomy and the soil groupings are explained in Fisher and Lemoalle 2008. Soil groups: 1= coarse sand, 2= fine sand and sandy loam, 3= loam.

Although important for the nations' currency income and for the farmers, we paid less attention to cash crops in the analysis of the Volta Basin. In both Burkina Faso and Ghana, cash crop farmers are better off than subsistence farmers. Cotton and groundnut are important in Burkina Faso and Ghana, while cocoa, oil palm, rubber and coffee are also important in Ghana. Cotton culture has some positive side effects on maize, especially in Burkina Faso, where farmers have access to subsidized fertilizers for cotton. Because of the importance of these crops for export earnings, some state investments have been made in improving infrastructure and market access. Such a policy has led to major improvements in quantity and quality of cotton production (Conley and Udry 2004;World Bank 2007). The same policy is needed for food crops and the national markets in order to avoid food crises.

Wild cereals and other sources of food or income, such as wild rice, fonio (*Digitaria exilis*), materials for basketry, may be very important in some periods of the year for the poorest rural people.

A large proportion of the landscape in the Basin is covered by parklands which may be defined as the intentional growing of trees on the same site as agricultural crops and/or livestock. The aim is to increase the total yield, generate short-term income and improve environmental benefits (for example, erosion control). The trees provide some fruits and leaves, which are important for households or even for the national economy (e.g. shea nuts).

4.3. Livestock systems

A thorough survey identified three main complementary livestock systems in Burkina Faso (IEPC, 2007; Clanet, 2008).

The Pastoral System (PS), is driven by highly mobile agro-herders whose priority is to find the best food for their cattle during all seasons. The main objective of these herders is to maintain or increase the herd size and to maintain its capacity to migrate so as to avoid environmental hazards, principally drought. The system occurs between latitudes 6° and 14°N, and covers nine countries in the region, including those that share the Basin (Figure 14). The extent of the system is limited by low rangeland productivity in the north and by trypanosomiasis in the south.

These agro-herders constitute 4% of the Basin rural population and 23% of them are highly vulnerable to droughts (Clanet, 2009). There is a strong trend toward an increase in sedentarity for this system.

The Crop-Livestock System (CLS), where sedentary farmers develop a mix of cultivation, arboriculture and herding around their village. The livestock is fed on crop residues and on the natural rangeland in the village area and is thus vulnerable to occasional droughts. Around 80 to 90% of all livestock keepers belong to this category. Their livestock provide the main monetary income to 86% of the rural household (IEPC, 2007).

The Industrial System (IS) is sedentary, market oriented and has developed mostly in the vicinity of cities, or railways. It is less dependent on the natural rangeland and accounts for about 2% of the total cattle in the basin.

Rangeland provides 90% of the fodder for ruminants in the Basin (IEPC, 2007) The remainder is supplied by cereal stubble, other crop residues and agro-industrial by-products. Forage crops are still an exception, with less than 0.5%. In common with elsewhere in the tropics, only about one third of the range biomass is consumed by the livestock, the rest being lost to stalling, termites and normal senescence processes. There are possibilities to develop complementary fodders such as browse from trees and shrubs that draw water from deeper soil strata than the range grasses and stay green longer into the dry season. This system could substantially increase the water productivity of cattle systems.

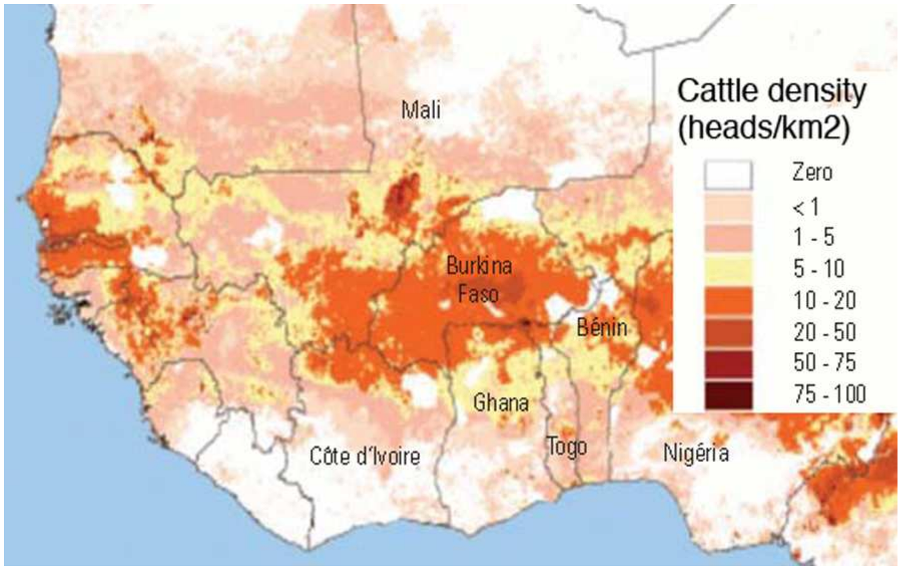

Figure 14. The distribution of cattle density in West Africa, including the Volta basin with decreasing densities from north to south (from Couacy-Hymann et al. 2006).

There is a concern (Clanet, 2008) about crossbreeding between the northern zebu, whose large size and weight fit them for transhumance, with the southern and smaller N'Dama taurine, which is trypano-resistant. The outcome might be that the aptitude of the zebu for transhumance and use of rangelands in the Sahel where almost no cultivation is possible may be lost, but with the acquisition of trypano-resistance, which would expand the range of the PS cattle. In the absence of data, we cannot speculate on the outcome.

The limiting factors for livestock productivity are access to water and animal health. Access to sufficient water of adequate quality is essential for good animal health and liveweight gain. Vaccination (anthrax, brucellosis) and anti-parasite treatments are generally lacking, especially for small ruminants, since the livestock health services have been transferred from the state extension services to private operators Proper treatment applications would greatly increase the livestock productivity (Clanet, 2008).

4.4. Fisheries systems

The species richness of fish in the Volta basin, with 147 species recorded for almost 400,000km^2, fits well with the general relationships observed in Africa between the number of species and either the basin area (Hugueny and Lévêque, 1999). This is an indicator of an overall wealth of the aquatic system.

Béné and Russell (2007) distinguish three different types of fishing communities in the Basin:

i. Fishermen living around Lake Volta who mainly rely on fishing and activities related to fishing, such as processing and trading;
ii. Farmer-fisher communities on the medium to large-scale reservoirs (e.g., Lake Bagré and Kompienga in Burkina Faso) who have integrated fishing and related activities into their local farming livelihoods; and
iii. Farmers living near small-scale reservoirs, seasonal ponds, streams and tributaries of the Volta River who rely on these resources mainly for subsistence fishing. Note that many of these water-bodies dry up during the dry season (October-May).

4.4.1 Fishing communities around Lake Volta

The lake supports about 70,000 active full-time fishers (Braimah, 2003), suggesting a total population dependent on fisheries of about 300,000 people. Pittaluga et al. (2003) estimate that fisheries-related activities contribute on average >70% to the income of these communities.

Braimah (2000) estimated that there were 24,000 fishing canoes on Lake Volta. Ninety-five percent of these canoes are plank canoes without motors, operated on average by three people. In contrast, winch boats represent only 1.8% of the total fleet on the Lake and employ only about 5% of the fishers but represent between 65 and 70% of the total catch (IDAF 1990).

4.4.2 Farmer-fisher communities around medium to large-scale irrigation reservoirs

The main communities in this category live around the reservoirs of Bagré (25,000 ha), and Kompienga (18,000 ha) and the Sourou floodplain (68,000 ha) in Burkina Faso and Mali. Less than 4% of the population living around the lake relies fully on fishing (approximately 500 full-time fishers and 300 fish-processors). The majority rather belong to farming communities for whom fishing is an important secondary activity: about 70% of the households around Bagré diversify their farming activities with seasonal fishing (Béné and Russell 2007).

4.4.3 Fishery in the rest of the Volta basin (small water bodies and river-floodplains)

Apart from Lake Volta and large reservoirs, fishing is mainly a secondary activity in the rest of the Volta basin. It is practiced mainly in the small reservoirs and river floodplains.

The rivers, natural ponds and seasonal floodplains of the whole Burkina Faso cover about 200,000 ha, to which must be added small man-made reservoirs. The fisheries potential of these water bodies is between 3,750 and 6,000 tons per year. There are about 8,000 full time fishers, mainly migrants from other countries and 3,000 processors (Béné and Russell, 2007).

In Burkina Faso, 50,000 to 60,000 people rely on fishing for their livelihoods (de Graaf and Waltermath 2003). The local population living near these water resources is mainly involved in farming activities, and fishing constitutes only an additional (subsistence) component in an integrated, multi-activity livelihood strategy (Morand et al. 2005). Nevertheless, the contribution of these occasional fishing activities to the household and community nutritional security and cash income is often crucial in areas where access to market is not always easy (Béné and Russell 2007).

Studies investigating the links between fisheries, livelihoods and poverty in the Volta basin, conclude that for most households both farming and fishing activities are characterized by extremely low levels of productivity. The following interventions are suggested as the most promising ways to increase water (or fisheries) productivity in a pro-poor manner (Bamfo et al. 2005; Béné and Russell 2007):

- Community-based stock enhancement in small and medium reservoirs;
- Improved post-harvest management and marketing;
- Improved access to financial credit for the poorest; and
- Development of fishers' associations.

4.5. Production and yields

Total production is determined by harvested area and yield per unit area. As noted earlier, harvested area in the Volta basin is relatively low: a large proportion of arable land is left uncultivated. Crop yields are also low, often less than 1 t/ha for maize. The average cereal productivity was 1.4 t/ha in Ghana for the period 2002-05, but only 1.0 t/ha in Burkina Faso (Word Bank 2007). In general, maize yields are higher where rainfall is more abundant (Figure 15). The same is not true for millet, which yields about the same in different parts of the basin, regardless of annual rainfall (Figure16). The spatial distribution of maize, millet and sorghum yields is shown in Figures 10 and 12.

Simulations of cereal growth and production with DSSAT by the BFP team have been applied to 9 soils of Niger from the WISE database, along a North-South transect with 99 years' weather data generated by MarkSim. The following results for the three main cereals, sorghum, millet and maize, were obtained ((Fisher and Lemoalle, 2008).

- Crop response to small doses of inorganic fertilizer is reasonably large across soil types. Soil susceptibility to nutrient leaching has a strong influence on yields and fertilizer stimulation.
- Yield increases are found even in years when average yields are relatively low but the risk increases in the northern part of the Basin. Figure 13 shows the median yield for maize over a 99 year time without fertilizer vs. with small amounts of N and P.

- Crop response along a climatic and rainfall gradient from south to north across the Volta basin is mostly sensitive to rainfall change between 1,000 and 500 mm/y.

Experimental field observations in the Sahel have also indicated the high potential response to fertilizer (Bationo and Mokwunye 1991, Bationo et al. 2008). On farm trials in northern Ghana conducted by CPWF projects have shown two- to four-fold increases in maize, millet and sorghum yields with small amounts of fertilizer (Figure 18).

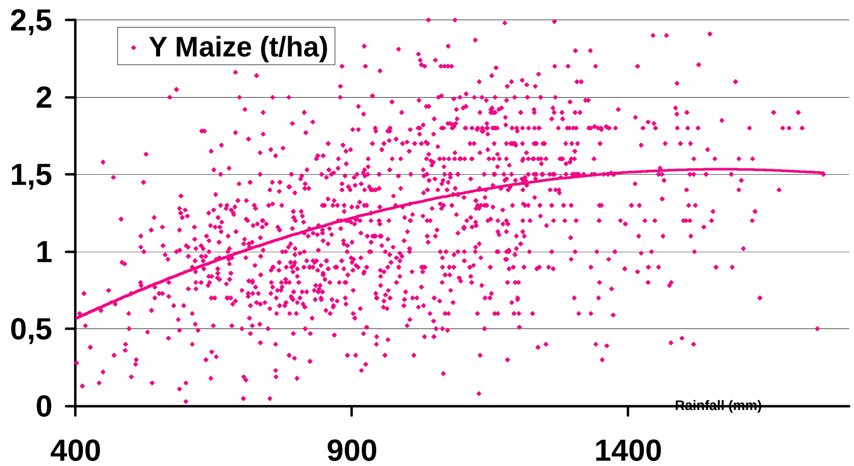

Figure 15. Relationship between maize yields and annual rainfall. Source: BFP Volta using Production data from MOFA and MAHRH, 1990-2002 and rainfall data from CRU.

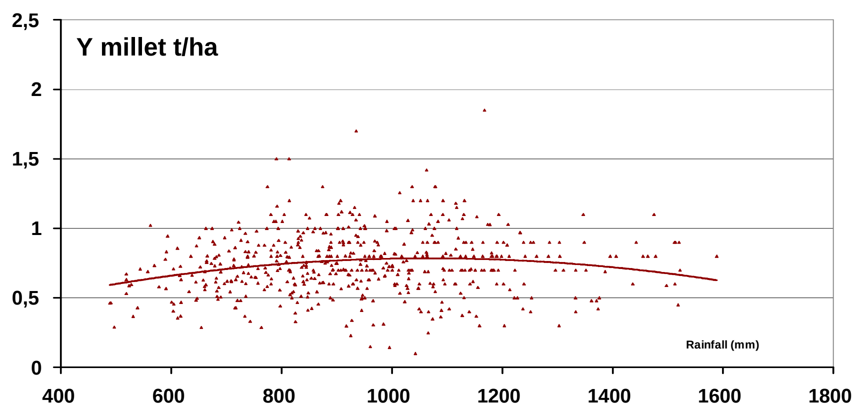

Figure 16. Relationship between millet yields and annual rainfall. Source: BFP Volta using Production data from MOFA and MAHRH, 1990-2002 and rainfall data from CRU.

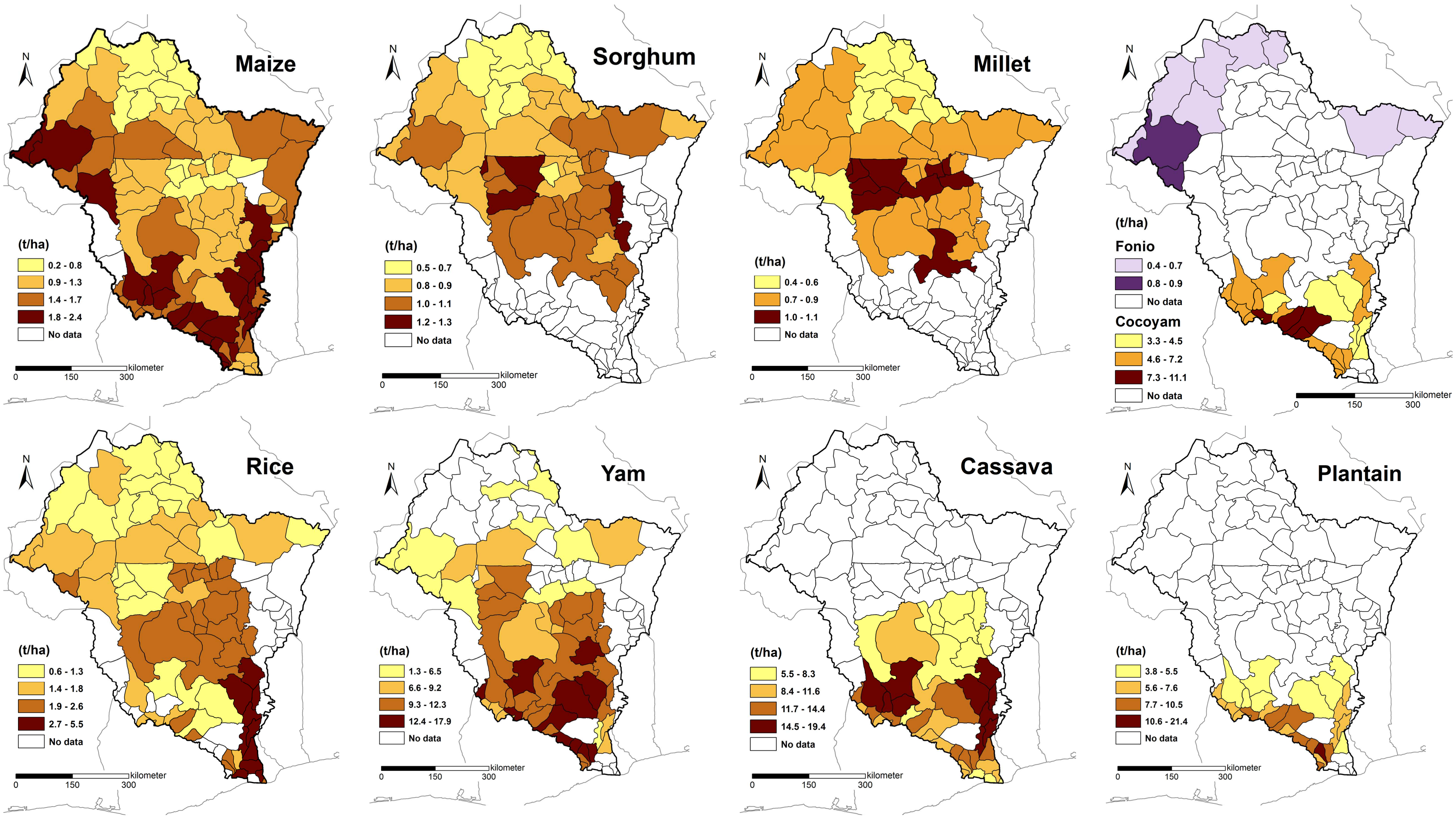

Figure 17. Spatial distribution of crop yields. Source : Maps by BFP Volta using Production data from MOFA and MAHRH, 1990-2002 and rainfall data from CRU.

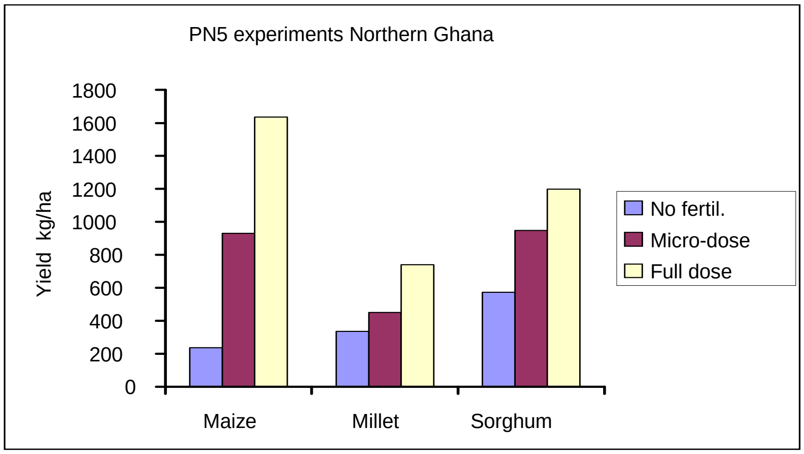

Figure 18. Effect of fertilizer on crop yields in Northern Ghana. Source: CPWF competitive grant project PN5.

4.6. Livestock

Livestock are often the largest non-land asset in rural household portfolios. In Burkina Faso, for example, livestock accounts for more than half of rural households' wealth (World Bank 2007).

The Pastoral System (PS), driven by highly mobile agro-herders contributes 65% of the meat export of Burkina Faso and to 585,000 tons of milk production. The increasing difficulty for herders to access pasture and water during their transhumance is a threat to the sustainability of this activity.

There is an enormous diversity in the intensity of the livestock component in the crop-livestock system (CPS), ranging from large herd owners to small subsistence farmers owning some poultry (chickens, turkeys, ducks, guinea fowl of local breed), with innumerable intermediate gradations (Burkina Faso IEPC, in press, Clanet 2007). Small livestock (sheep and goats) are relatively common, whereas pigs and large livestock are usually the property of the wealthiest members of communities (Béné and Russell 2007). Livestock ownership patterns are important indicators of poverty.

4.7. Fisheries

Actual production data for the fishery sector is scarce, and not entirely coherent.

4.7.1 Fisheries around Lake Volta

About 98% of the inland freshwater fish and 16–25% of the total national fish production in Ghana comes from Lake Volta. The fish catch of Lake Volta is however not properly evaluated, figures ranging between 40,000 and 215,000 tons per year (Braimah, 2000; Barry et al. 2005, and statistics from MOFA). Similarly, the value of fish production in the late 90's has been estimated at somewhere between US$ 30 million (de Graaf and Ofori-Danson 1997) and 160 million (Pittaluga et al. 2003), with revenues ranging from 420 to 2,250 US$/year per fisher.

In the last decades, the numbers of fishermen and fishing boats have steeply increased, and fishing practices have become more intensified, especially with the introduction of winch nets in the mid-1980s (Ofori-Danson 2005). The lake is said to be overexploited, but with no scientific evidence (Barry et al. 2005).

4.7.2 Farmer-fisher communities around medium to large-scale irrigation reservoirs

The majority of fishing is carried out by farming communities that practice mainly rain-fed agriculture and animal rearing (Béné and Russell 2007), but to whom fishing is an important secondary activity. About 70% of the households diversify their farming activities with seasonal fishing activities (Béné and Russell 2007).

The average fish catches provided by the Bagré lake amount to 975 tons annually (mainly small tilapia), but the fishery potential is estimated at around 1,500 tons (Béné and Russell 2007).

4.7.3 Fishery in the rest of the Volta basin

The fishery potential of the rivers, floodplains and natural ponds of the Burkinabe part of the Basin is between 3,750 and 6,000 tons per year. Presently, an annual production of 8,500 tons of fish is achieved in the country (including Bagré). It seems reasonable to estimate that the same level of fishing occurs in the natural water bodies in Ghana.

Experiments on restocking of small reservoirs has not been successful due to the high price of fingerlings and to low survival rates resulting from predation.

5. Water productivity

Water productivity is defined as output per unit of water depleted. Output may be measured in terms of the amount or value of crops or livestock produced or (at least in principle) the value of water in domestic, urban, industrial, hydropower or environmental uses. Water is considered to be depleted when it is unavailable for further use, for example, when it is evaporated or transpired, or polluted to the point where it can no longer be used.

5.1. Basin scale

Water productivity (WP) at the basin scale was estimated as the amount or value of agricultural production divided by the amount of rainfall received.

We have computed from MAHRH and MOFA data that the total production of food in the Basin for the year 2000 was 1.6 x 10^{13} kilocalories. This represents a WP of 52 kcal/m^3 if the whole rainfall over the basin is considered, and a WP of 466 kcal/m^3 if only the rainfall over the cultivated area is taken into account. The amount of water needed per capita for food production, with an average human energy requirement of 2,500 kcal/day, is 2,000 m^3 per year.

In the Volta basin, water productivity is quite low. This is largely because of the small area devoted to crops relative to the area devoted to grasslands and woodlands. Most of the water is depleted through evapotranspiration in non-cultivated areas. At the basin scale, crop water productivity would increase if a larger proportion of arable land in the Basin were to be cultivated. The question is why is it not being cultivated? What are the constraints to the expansion of agricultural area? One of the reasons is low population density in some regions, although some immigration from more densely populated areas has been organized. Another reason is probably the lack of work power in the small farmers families.

The geographic distribution of WP for the different crops is given in Figure 19.

5.2. Field scale

Water productivity at the field scale was estimated as yield per hectare divided by the amount of rainfall per hectare. Crop water productivity is generally higher for maize (up to 0.2 kg/m^3 of water depleted) than for sorghum or millet (rarely exceeding 0.1 kg/m^3 of water). Mean values for crop water productivity were 0.15 kg/m^3 (±0.05) for maize, 0.10 kg/m^3 (±0.03) for sorghum, and 0.08 kg/m^3 (±0.03) for millet, with a high variability around the mean. The spatial distribution in the Volta basin of field scale water productivity for the main food crops is shown in Figure 19.

Relationships between maize, millet and sorghum yields in different parts of the basin on the one hand, and annual rainfall on the other, were analyzed. Using quadratic polynomial regression, maize yields were found to be partly correlated with annual rainfall, with a strong dispersion (R^2=0.2). In other words, maize yields tend to be higher where rainfall is more favorable. No such correlations were found for sorghum and millet yields and annual rainfall, (R^2=0.05 and R^2=0.03 respectively).

If millet and sorghum yields are not correlated with annual rainfall, it logically follows that water productivity for these crops <u>is</u> correlated with rainfall. Statistical analysis confirmed this. Water productivity was found to be partly correlated with rainfall for sorghum and millet (R^2=0.3), but not for maize (R^2=0.06). Figure 20 illustrates the relationship between sorghum water productivity and annual rainfall.

These relationships may be explained as follows. In the northern part of the Basin, maize yields are constrained by inadequate moisture while, in the southern part of the Basin, maize takes advantage of higher rainfall levels and gives higher yields. Because higher rainfall gives higher yields, water productivity (yield divided by rainfall) is relatively flat across the basin. In contrast, yields for sorghum and millet are fairly flat across environments and rainfall levels above a threshold of 400 to 500 mm rainfall per year. Yields do not increase as rainfall becomes more abundant. Water productivity for these crops therefore declines in wetter areas. These crops are less able than maize to take advantage of increased moisture to produce higher yields. But their yields do not decrease as much as that of maize in drier areas or in drier years.

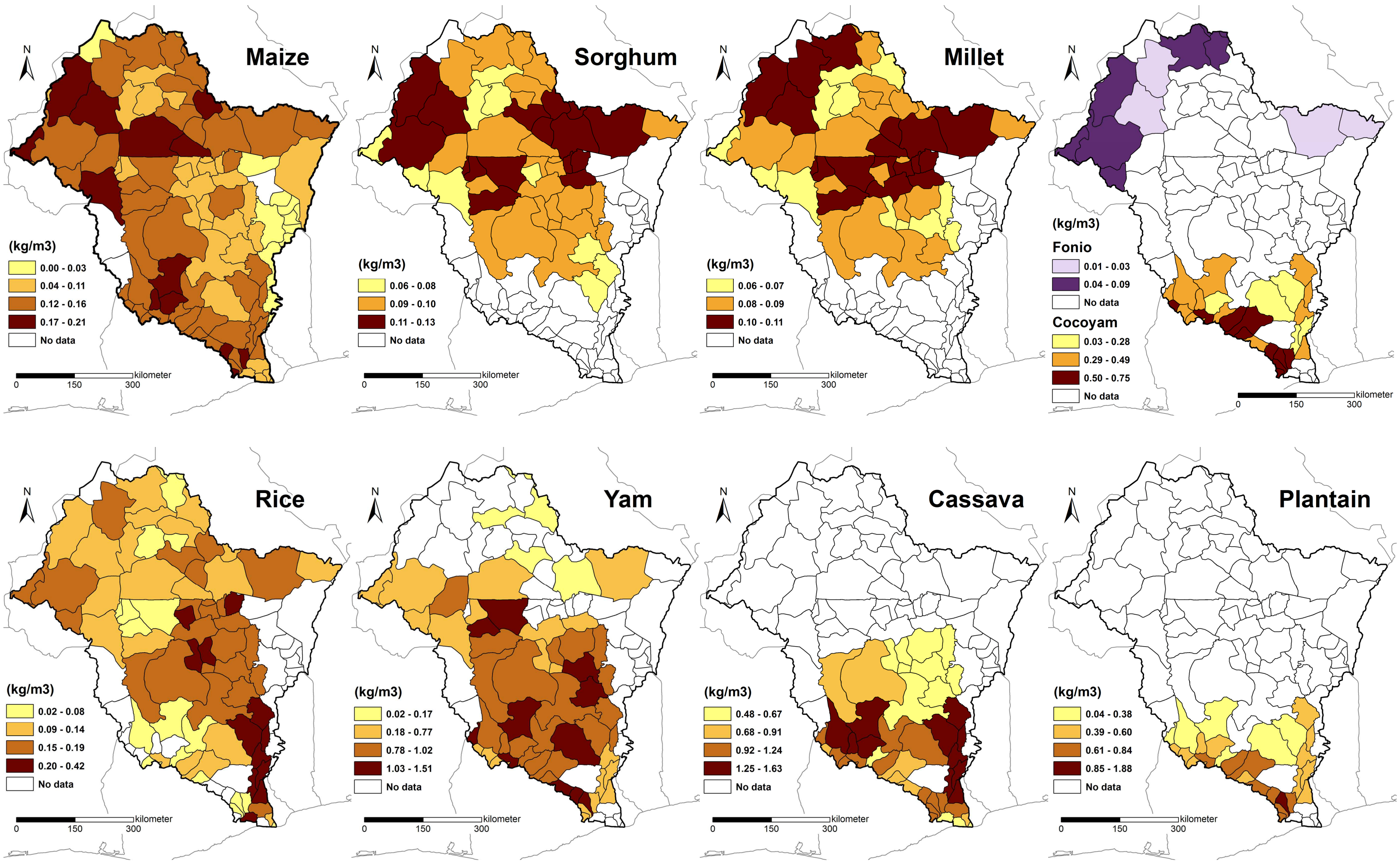

Figure 19. The mean water productivity (1992 to 2000) of the main food crops in the Volta basin. Map by BFP Volta with data from MAHRH and MOFA.

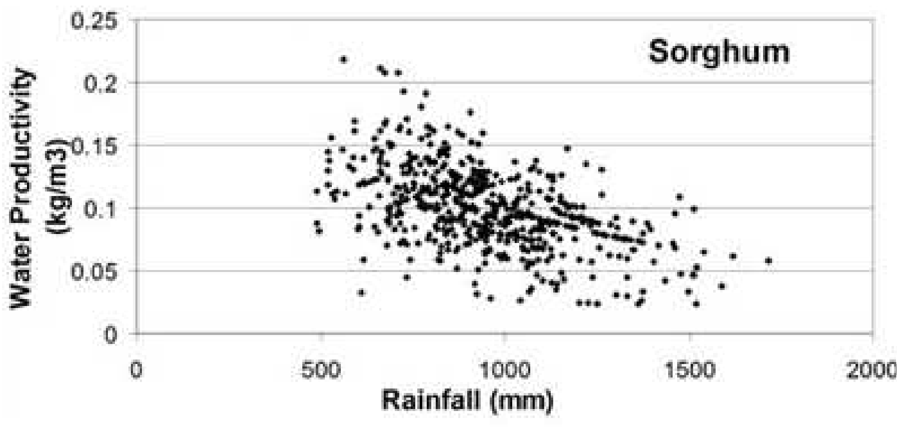

Figure 20. Relationship between sorghum water productivity and annual rainfall. Source: BFP Volta using Production data from MOFA and MAHRH, 1990-2002 and rainfall data from CRU.

6. Water and poverty

Around 19 million persons inhabit the Volta basin and, of these, about 14 million live in rural areas. Most of these are very poor (Table 3). The countries in the Volta basin, in fact, are among the poorest in the world.

Many countries in the Basin have not yet started their demographic transition. This transition, marked by decreased mortality and fecundity rates, is a demographic indicator of development and of poverty reduction as well a tool for long term policy planning (UNECA 2002). Recent analysis suggests that, although development is likely to proceed, it will be slow and from a very low base, whereby this region is likely to remain relatively poor for a long time to come (de Fraiture and Wichelns 2007, Lemoalle 2007).

Three main causes of poverty have been identified in the Ghana part of the Volta basin (Asante and Asenso-Okyere 2003; Asante 2007). These are: low productivity of economic activities (fishing, agriculture); degree of water insecurity (rainfall variability, poor access, health impacts, loss of labor); and water related diseases (malaria, guinea worm, etc.).

Table 3. Information on poverty in Volta basin countries.

Country	HDI	Rank	GDP per capita (USD)	% <national poverty line	% <1 USD/day	% < 2 USD/day
Burkina Faso	0.342	174	1169	46.4	27.2	71.8
Ghana	0.532	136	2240	39.5	44.8	78.5
Togo	0.495	147	1536	32.3	-	-
Mali	0.338	175	998	63.8	72.3	90.6
Côte-d'Ivoire	0.421	164	1551	-	14.8	48.8
Benin	0.428	163	1091	29.0	30.9	73.5

Source: UNDP Human Development Report 2006. HDI = Human development Index, Rank in the 177 countries for HDI, GDP per capita, USD (2004), % of population below national poverty line, % of population living with less than 1 and 2 USD per day.

In each of the countries that comprise most of the Basin, Ghana and Burkina Faso and Togo, national surveys show that the incidence of poverty is higher in the drier north than the wetter south (Figure 21). In Ghana, for example, the proportion of the population below the poverty line is 70% in the rural savannah vs. 38% in the rural forest (Coulombe and Wodon 2007). Here, the poverty line is set at less than USD 100 per year.

In Burkina Faso, 52% of the rural population was considered poor in 2003. Because Burkina Faso is predominately rural, this accounted for around 92% of the poverty found in the whole country. The incidence of poverty was lower among cash crop (groundnut) farmers (46%) than among subsistence farmers (56%) (Lachaud 1998). The poverty line in 2003 was set at 82,672 CFA/year or about USD 165. Reasons for rural poverty included low agricultural productivity, limited access to markets, unstable prices, and insecure land tenure (Burkina Faso, Ministère de l'économie 2004). Actions to alleviate poverty are hindered by financial, infrastructure and institutional constraints.

Poverty and vulnerability are especially concentrated in certain categories of farm families, among them:

- Farmers engaged in subsistence agriculture who own no livestock or draught animals;
- Slightly better-off are subsistence farmers who own poultry or small ruminants;
- Herders who do not own the cattle under their care; and
- Households with a specific vulnerability to environmental or social changes.

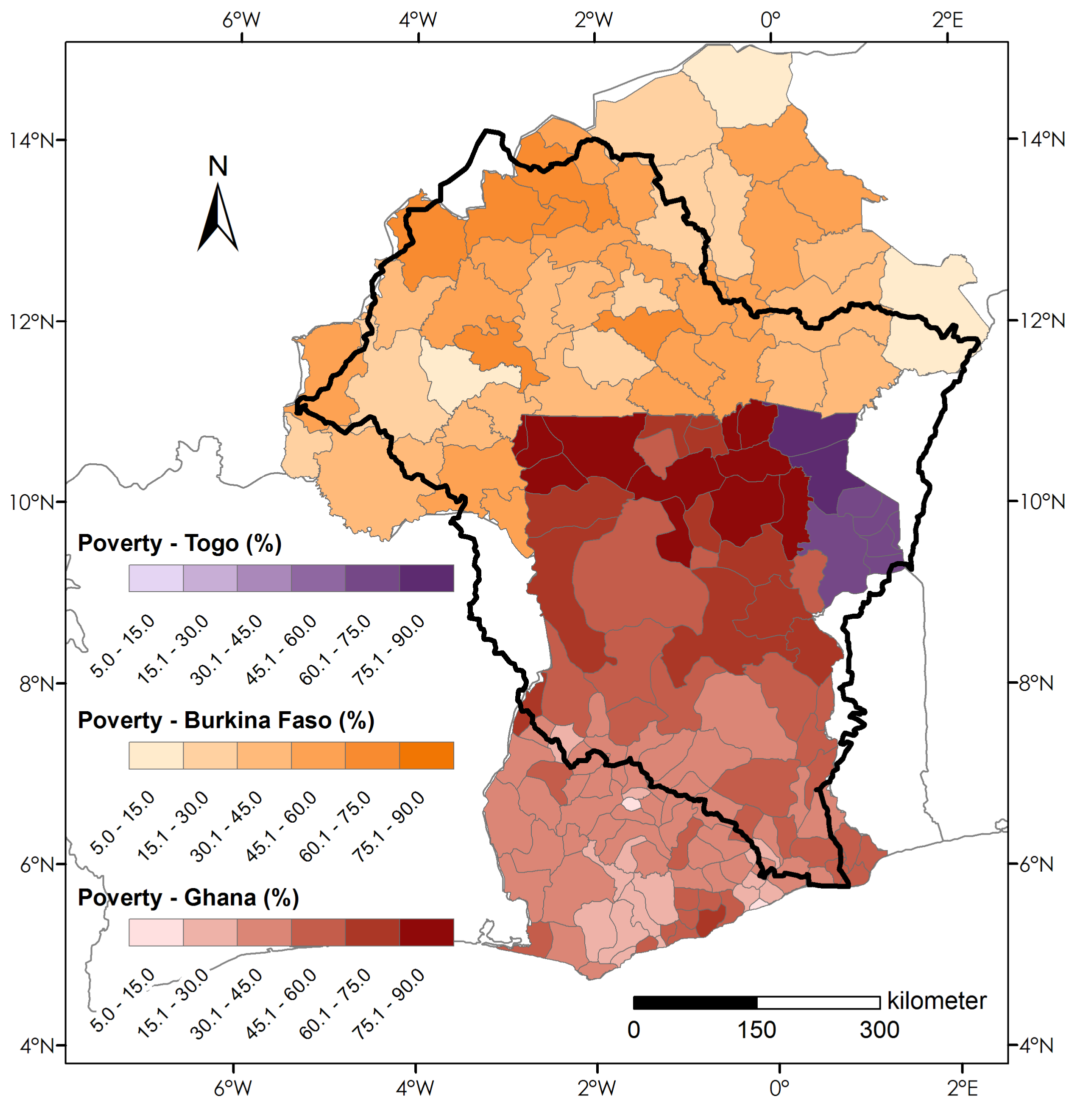

Figure 21. Spatial incidence of poverty in Ghana, Burkina Faso and northern Togo. Source: map by BFP Volta with data from National livelihood surveys (Ghana: GLSS1998, Burkina Faso EBCVM 2003).

6.1. Poverty and land

The area cultivated by a household is mainly constrained by the work power of the family. One of the main characteristics of a poor family is the lack of draught animals and tools such as a cart or plough. Figure 22 shows the Lorenz curves calculated for three different regions in the cereal production zone of the basin, with a Gini coefficient close to 0.4. They demonstrate that the top 10% of the farmers operate 30% of the cultivated land; these are the large farmers. In contrast, the bottom 30% of the farmers operate only 10% of the land; these are the small farmers (Ducommun et al., 2005). In Burkina Faso, median rain-fed cultivated area for a farm family is about 3.1 ha, with the lower quintile cultivating less than 1.4 ha. (data from MAHRH Agristat).

Surveys based on the food sales by the farmers have found that larger income was related with cultivated land area and use of inorganic fertilizers (Figures 23 and 24) (Ducommun et al., 2005).

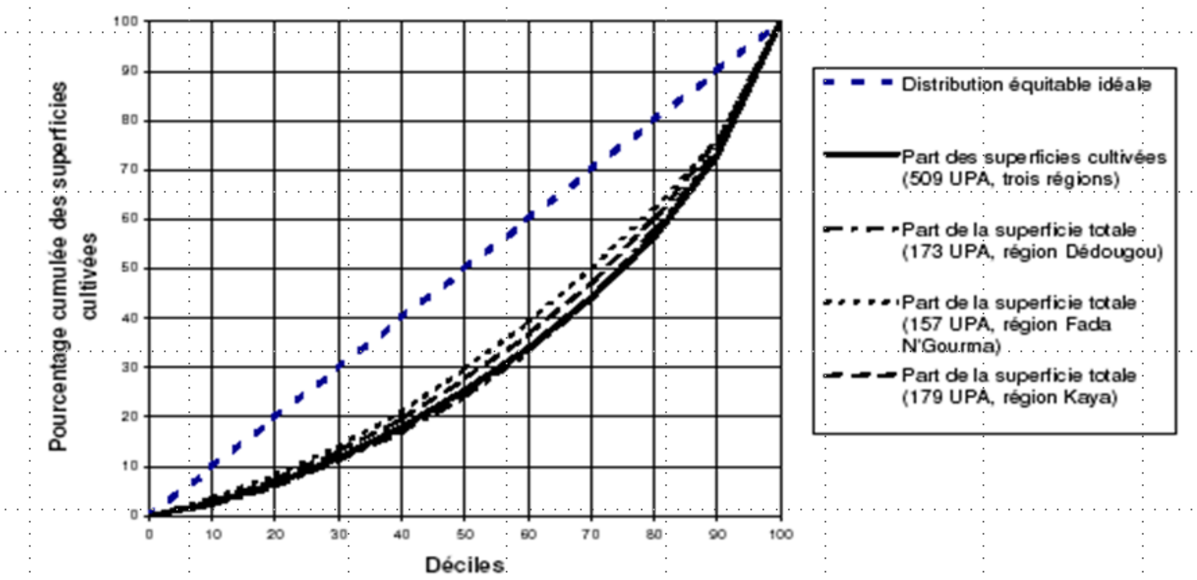

Figure 22. Lorenz curves of farm area for three locations in the Volta basin. Source: H Cecchini (data for 2004, unpublished).

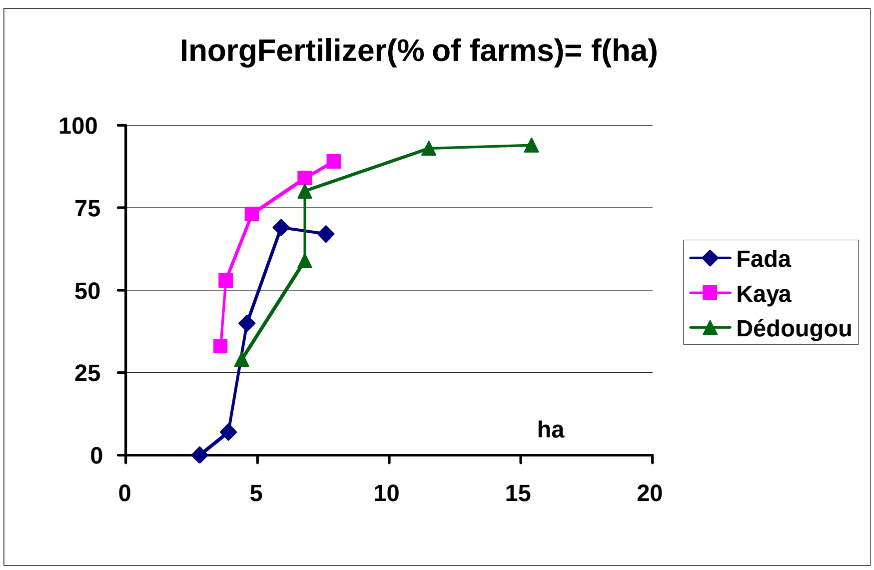

Figure 23. Proportion of farmers in three regions using inorganic fertilizer, by farm size. Source: Data from Ducommun et al. (2005).

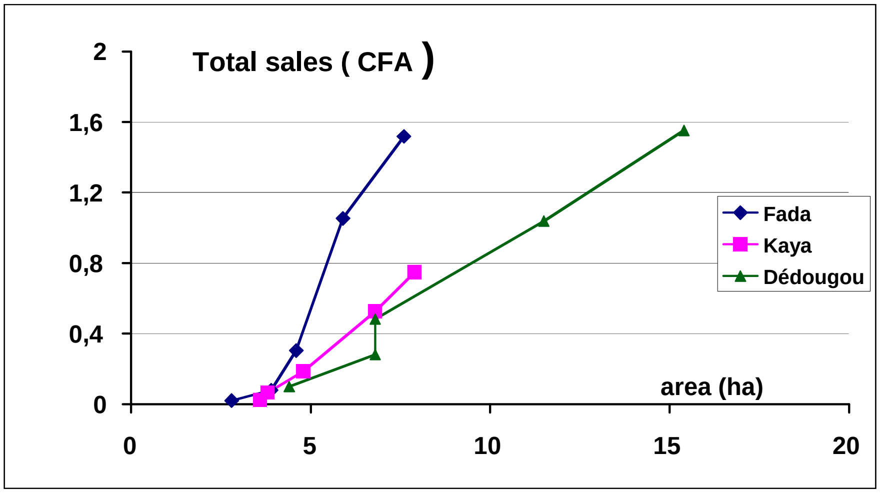

Figure 24. Total farm food sales for three regions, by farm size (in Dédougou, part of the farmed land is used for cotton). Subsistence farming dominates in the smaller farms. Source: data from Ducommun et al. (2005).

6.2. Water quality and access

Lack of access to good quality domestic water is also associated with poverty. Access to good quality water depends on two factors: (a) the distance or time taken to fetch water, and (b) the quality of the water available. Poor quality water is considered to be that from traditional wells or from surface water. Good quality water is that from modern boreholes and standpipes, even if available through vendors.

In the Volta basin, nearly 50% of households lack access to good quality water, especially in the northwest part of the Basin (Figure 25). While 82% of the urban population in Burkina Faso have access to potable water, for the rural population this is only true for 44% (INSD, 2003; Nikiema and Dipama, 2007).

Relationships between poverty and access to good quality domestic water have not yet been explored through statistical analysis. Much depends on the scale considered. In the rural villages, rich and poor households have access to the same water, depending on the source available. In Ghana, more than 95% of households of a village use borehole water when it is available.

6.3. Water related diseases

One important component of poverty, broadly defined, is that of water-related disease. The main water-related diseases in the Volta are malaria, schistosomiasis (bilharzia), onchocercosis (river blindness), trypanosomiasis, and diarrhea from unsafe domestic water (Poda, 2007).

Onchocercosis has been almost eradicated by the World Health Organization through control of the vector (blackflies of the genus *Simulium)*, so much so that valleys where river blindness occurred have now been partially recolonized by people. The new curative treatment that is available provides some security for the durability of the recolonization of these regions. This makes a large area of generally good land available for agriculture.

Malaria and schistosomiasis remain a burden for basin populations both at the micro (household) and macro (state) scale. The spread of schistosomiasis is directly related with the development of irrigation and small reservoirs, with up to 70% prevalence around irrigation schemes in Burkina Faso. It is likely to have reduced labor availability and labor productivity, but its effects have not been as well documented as those for malaria. Malaria is a health problem and a principal constraint to development in the Basin. It is the main cause for mortality of children under five. It is widespread, with high prevalence in the central part of the Basin (Figure 26).

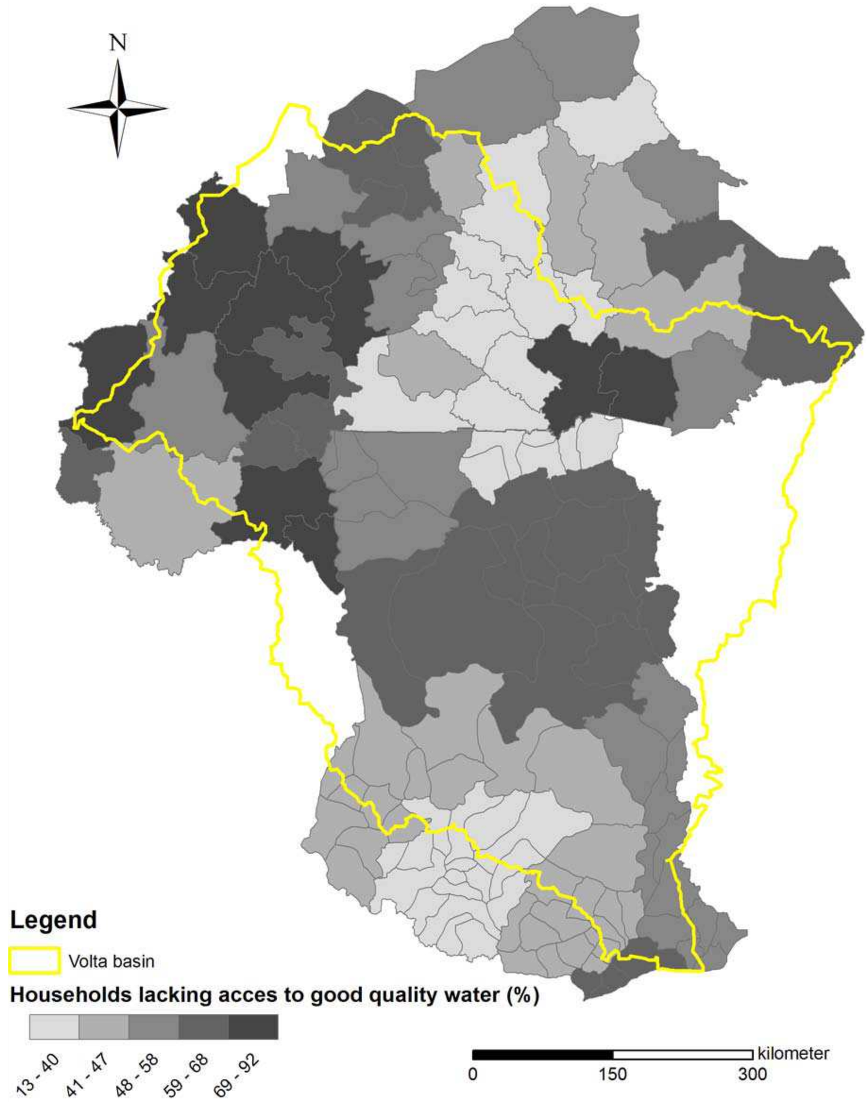

Figure 25. Percent of the population in the department (Burkina Faso) or province (Ghana) who rely on surface water or traditional wells. Source: BFP Volta map drawn from data from Cecchi et al. (unpublished) and GLSS4.

Malaria places significant financial hardships on both households and the national economies. According to a 2003 survey conducted in three regions of Ghana, the direct cost for malaria treatment from an orthodox health care facility is on average about US $6.87. To this must be added the indirect cost (loss of productivity) of about US $8.92, or about nine farm workdays. The mean expense for prevention (mosquito coils) for the household is about US $1.00 per month (Asante and Asenso-Okyere 2003). The burden of malaria therefore is a challenge to human development manifesting itself as a cause and consequence of under-development (Gallup and Sachs, 2000).

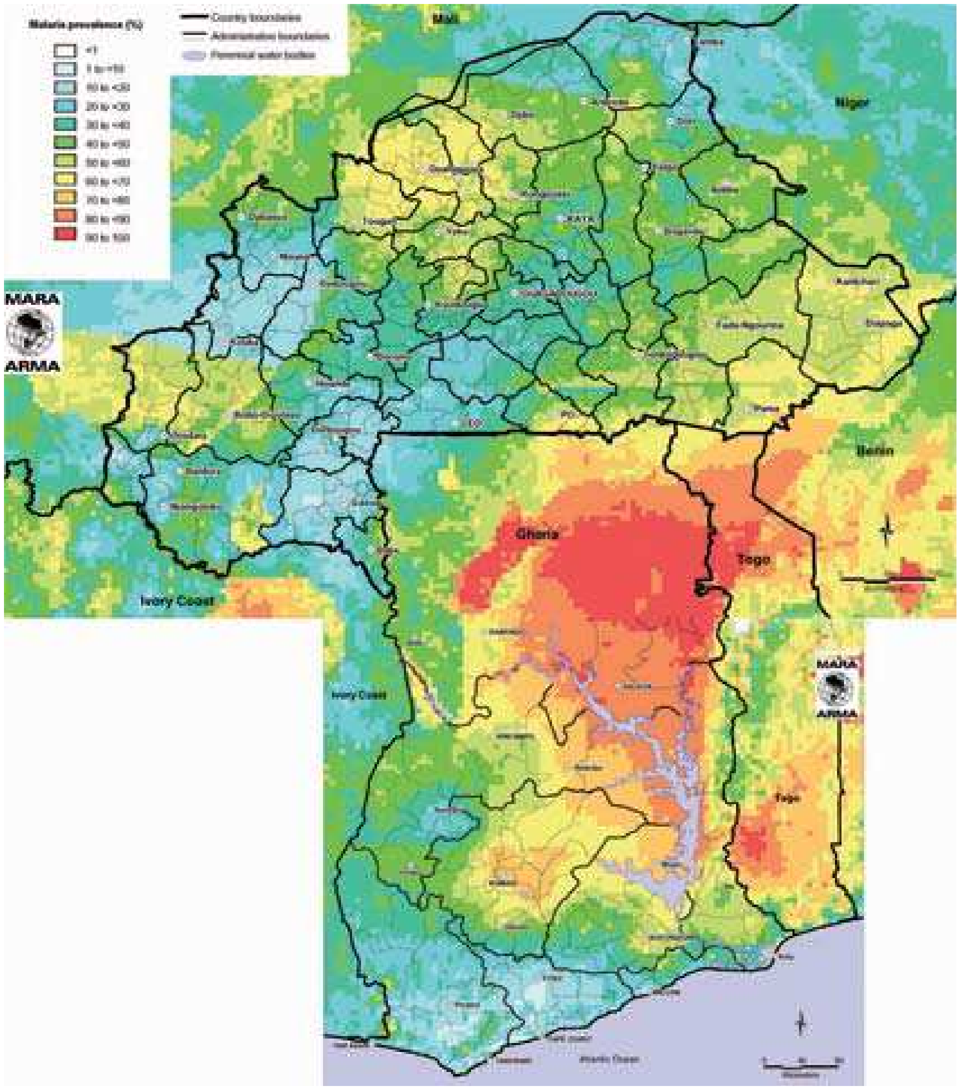

Figure 26. Malaria prevalence in the Volta basin. Source: MARA/ARMA Program (copied from www.mara.org.za).

Poor communities are caught in a vicious circle of disease and poverty. In Northern Ghana, Akazili (2002) found that the cost of malaria care was about 1% of the income of the rich households, but 34% of the income of the poor households. The cost of malaria in Ghana to the entire health system was US $18.4 million direct cost plus US $23.9 million indirect cost for households, and US $7.8 million direct cost for the health institutions of the country (Asante and Asenso-Okyere, 2003).

The technology to prevent and cure malaria exists, but is unevenly applied. National plans are in operation, especially for the children under five and pregnant women. Preventive techniques such as mosquito nets treated with repellent and insecticide are available. New prevention drugs are efficient but expensive and unavailable in most remote areas of the Basin.

The spread and impact of the water related diseases in the Basin may be limited in part by a proper management of the water or of the environment, but also by changes in the social and cultural behavior, and in improvements in the health services.

6.4. Exploring cause and effect

The information provided above suggests that poverty is in part caused by water-related factors. Poverty is relatively high:

- Where the productivity of agricultural activities is low (partly because of water scarcity);
- Where water-related diseases are prevalent; and
- Among farm families with poor access to good quality domestic water.

Other factors are also at work, however, some of them not directly related to water. Poverty is also shown to be high (Clanet, 2007; Ducommun et al., 2005):

- Among farm families who operate relatively small farms;
- Among farm families who do not produce cash crops;
- Where there is no possibility to practice dry season small or large scale irrigation;
- Among farmer engaging in subsistence agriculture who own no livestock; and
- Among herders who do not own the cattle under their care.

Although not explored in BFP analysis, it seems likely that poverty is also relatively high in isolated areas where marketing margins are high, and among families who do not receive remittances from emigrated family members either on long term migration (the relatives just send money) or on seasonal migration (the men of the farm go for jobs in the dry season but come back for the cultivation rainy season). This latter factor is linked to the pace and incidence of overall economic development and growth in secondary and tertiary economic sectors.

6.5. Poverty mapping and Bayesian networks

In seeking to disentangle the cause and effect relationships between water and poverty, in the context of non-water related factors that also cause poverty, the Volta BFP team introduced the use of Bayesian Networks (BN). These have been used in many complex, practical problems to determine causality amongst multiple, interrelated attributes (Heckerman et al 1996). The use of BN methods to explore water – poverty links is described in Cook et al 2007.

"BN methods provide a formalism for reasoning under conditions of uncertainty, with degrees of belief coded as numerical parameters, which are then combined according to rules of probability theory". Bayesian networks are visualized as diagrams that organize knowledge as key variables that are mapped according to the cause-and-effect relationships amongst them. The degree to which one variable is likely to affect the other is determined by set of basic algorithm as known as Bayes' theorem, and the whole network taken to represent what is known about a particular system. Bayes' Theorem states simply that the probability that a particular event will occur can be estimated if some other event with which it has a known association has taken place. It thus uses prior knowledge about events."

A first version of a BN is shown in Figure 27. Here, data from different sources[1] were identified and transformed to make them compatible between countries. Variables were divided into quartiles each containing equal numbers of districts. These data were then converted into 4x4 contingency tables for each variable and imported into the software GeNIe package to make trial runs. Selected variables include NBDRY-MONT (number of dry months); Headcount_p (poverty head count ratio); MAISY (maize yields); MAISWP (maize water productivity); LANDLESS (landless status); UNDEREMPLO (employment status); and Foodneed (food security status).

This BN shows the following:

- Poverty (measured as headcount ratio, Headcount_p) seems related directly to drought (NDRY_Mont), crop yield (MAISY), employment status (UNDEREMPLO) and landlessness (LANDLESS). This is not inconsistent with hypotheses presented in the preceding section;
- Other variables are associated through intermediates. For example, water productivity (MAISWP) is indirectly related to poverty headcount through crop yield; and
- Some associations may be explained by geographical co-variation (NDRY_M and MAISY). For example, the relationship between drought and adult education (EDUC_ADULT) or water access (Acc_30) is difficult to explain unless they are linked by an underlying geographical variable.

[1] The following explanation of data sources is given in Cook et al 2007.

"*In order to analyze the linkages between water and poverty, data from the Volta basin were examined, using the structure of the Water Poverty Index as a conceptual framework. Within the Volta basin, a variety of data sources were consulted from both Ghana and Burkina Faso. These data were generated from government surveys in both countries, including:*

• Core Welfare Indicators Questionnaire Survey (CWIQ, 2003). Report of the Ghana Statistical Service (GSS). The data from this survey are from a two-stage national sample of households aimed at generating welfare indicators at the district level. The first stage was a random, systematic sample of 27 enumeration areas drawn from each district. In the second stage, all households within each selected enumeration area were listed, and 15 households were selected systematically from each, yielding a total of 49,005 households nationwide in 121 districts of Ghana. Out of the 121 districts, 62 fall within the Volta Basin.

• Ghana Census Based Poverty Map, District and Sub District Levels (2005). This report was commissioned by the World Bank and UK Department for International Development, and provides detailed information on the distribution of poverty across the districts of Ghana. These data have been used as a basis of a number of the calculations we carried out at the workshop.

• Ghana Living Standards Survey, 4th round (GLSS 4, 1998/99). This report has been used to provide a number of variables relative to poverty in the Volta basin.

• GSS Housing and population census (GSS ISSER and University of Ghana, 2000).

• Enquêtes Burkinabè sur les Conditions de Vie des Ménages (INSD, 2003).

• La pauvreté au Burkina Faso (INSD, 2003).

In addition to these pre-existing datasets, other data were used from projects carried out for the Challenge Program itself. Information on Ghana is provided in the report Analysis of Water Related Poverty in the Volta Basin of Ghana (Asante 2007), while for Burkina Faso it is provided from the CP report Pauvreté et pauvreté hydrique au Burkina Faso (Nikiema and Dipama 2007).

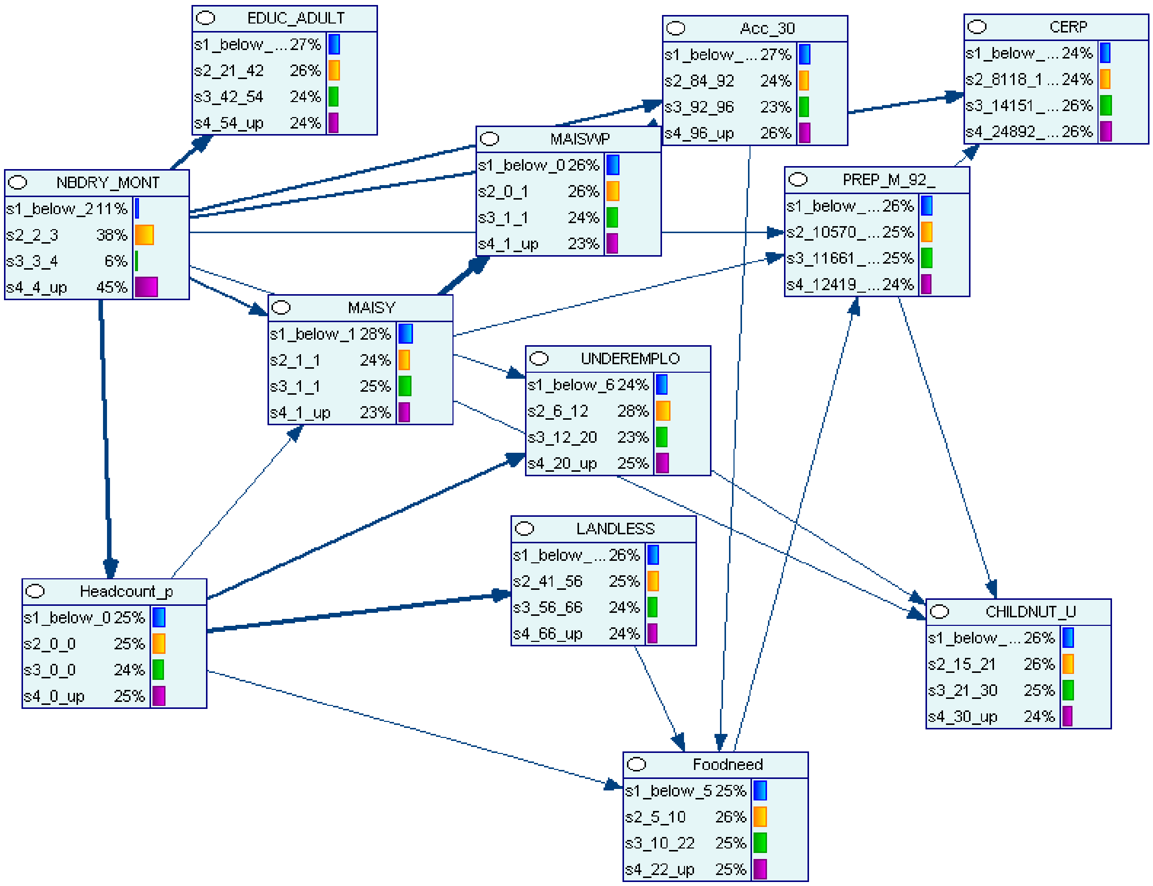

Figure 27. Bayesian Network on water and poverty in Ghana. Source: Cook et al 2007

More generally, it has been shown recently that areas of high poverty may be identified by an association of a small number of variables: high numbers of stunted children, small cropped area and high drought probability (Hyman et al., 2008). This applies in Africa south of Sahara to most of the cropping systems present in the Volta basin, from agropastoral with millet and sorghum to cereal and root crop or to maize mixed crop with drought probability increasing from south to north.

A second version of BN application used sub-models to express Food Needs (FN) as a function of natural, financial, human and market sets of variables for each country. The main conclusions were as follows:

- In Ghana, FN is higher in the Northern province. The probability of a higher FN was found to be associated with a low population density, while access to markets (road density) had no influence.
- In Burkina Faso, large cultivated farm area contributed to lower FN, while FN increased when the distance to water or when road density increased (Rubiano and Kemp-Benedict, unpublished).

7. Institutions

An important part of Basin Focal Projects is an evaluation of the institutional and policy context in which water and food problems unfold – and within which they must be solved.

Institutions and policies typically have important effects on water access, intensification and diversification of agriculture, markets for crop inputs and input use, farmer adoption of resource-conserving technologies, allocation of water resources among different uses and users, environmental conservation, and many more. Institutional and policy changes (for example, "payment for environmental services") are sometimes critically important in accelerating adoption of desirable agricultural and water management practices. "Institutions" are understood here to include informal norms and customs as well as more formal organizations and structures.

Thorough assessments of institutions in the Basin have been provided by Lautze et al. (2004) for the Comprehensive Assessment, and by Dembele et al. (2006) in a case study for a CPWF research action entitled African models of transboundary governance.

In the Volta basin, the main links between rural poverty and institutions have been identified as access to market, to land and to water. Other characteristics of the institutional environment, although not directly related with water, are also important. This section describes the main findings.

7.1. The basin context: the Volta Basin Authority

The priorities for water use are not the same in Burkina Faso and Togo (irrigation) as in Ghana (hydropower). In order to implement an international cooperation for the sustainable management of the Volta basin water resources, and for better socioeconomic regional integration, the six countries meet within the regional Water Resources Coordination Centre of the Economic Community of West African States (ECOWAS- WRCC) and have recently created the Volta Basin Authority (VBA).

In the last decade, various activities and initiatives had taken place towards the establishment of the Volta Basin Authority. However, the current process started with creation of the Volta Basin Technical Committee (VBTC) in July, 2004. The mandate of VBTC was amongst others, to identify the issues and obstacles towards the establishment of a Volta basin organization. Within two years, July 2004 to July 2006, VBTC became the VBA.

While the Convention was signed by all the Heads of State on 19 January 2007, in 2009 the statutes have been ratified by the six countries.

The administrative organs of the Authority are as follows:

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

The Volta Basin Authority (VBA) may be identified as the main recipient of the outputs of the Volta BFP, with a mandate that has been defined as follows:

1. Promote permanent consultation tools among the parties for the development of the Basin;
2. Promote the implementation of IWRM and the equitable distribution of the benefits resulting from their various utilizations;
3. Authorize the development of infrastructure and projects planned by the stakeholders and which could have substantial impact on the water resources of the Basin;
4. Develop joint projects and works;
5. Contribute to poverty alleviation, the sustainable development of the Parties in the Volta basin, and for better socioeconomic integration in the sub-region.

In their meetings, both WRCC and VBA involve national water management experts who can transmit all needed information to the users (farmers associations, NGOs), decision makers, traditional chiefs, ministers and heads of states who also attend some meetings of these two assemblies. Although still a very young institution, VBA is the focus of strong attention by several funding agencies and as such can transfer the identified research needs to the donors. Time is needed to assess its efficiency for intra-basin developments.

7.2. Basin scale water management tools

The Akosombo/Kpong hydropower scheme is already making use of all the water available, with some critical periods of power failures. We have developed a simulation model of the inflows to Lake Volta that takes into account possible rainfall variations over the basin in the climate change context, and modifications in water abstraction in the basin for urban, industrial and agriculture uses, especially with the development of small reservoirs (de Condappa et al., 2008). In late 2008, joint work between BFP Volta and PAGEV led to a new version of the model. The model is intended to provide a concerted analysis at the basin scale of the impacts of different possible scenarios of water availability and uses. It should be further developed and used by the Volta Basin Authority and others.

In a first approach, the simulation model has shown that inter-annual variability may remain the main cause of uncertainty for water inflow to Lake Volta, but long term rainfall change (climate change as described above) may gain cumulative impact by 2025 or 2050.

Recent discharge data are needed to answer questions on the impact of small reservoirs development in the upper part of the basin. But a first analysis indicates that a very strong development of the small reservoirs (up to 7 times the present number) would decrease the inflow to Lake Volta, and hence hydropower generation, by only 3% in the present climatic conditions. This development may however have an impact on the other water demands in the upper sub-basins and notably on the large reservoirs of Bagré, Kompienga.

These results call for trade-off analysis between important improvement in livelihoods upstream in the Basin, through further development of small reservoirs, versus impacts on downstream hydropower schemes (de Condappa et al., 2008).

Although the various techniques available for improving water use in rain-fed agriculture may have some impact at the basin scale, via modification of run off and evapotranspiration, their development is more directly related to outcomes at the sub-basin and villages scale.

7.3. The national context of dual governance systems

In much of the Volta basin, two authority structures co-exist. These are the formal, national, legal structures, and the traditional structures of hierarchy. In many areas, the former have limited enforcement power and many decisions remain in the hands of the latter. Although decentralization has been implemented, the states in the basin have a limited ability to implement and enforce policies and reforms at the local level. Policy implementation necessarily takes place in a context of multiple power foci and multiple institutions (Lautze et al., 2006).

A specific example of the consequences of duality may be seen in the water reform in Ghana. In 1996, the Ghanaian government launched a water reform process, placing water resources under the control of a Water Resources Commission (WRC), which included representatives of water providers, statutory regulatory agencies, irrigation officials, NGOs, women and traditional authorities. This commission was assigned the task of ensuring the economically efficient, ecologically sustainable, socially equitable and gender sensitive development of the country’s water resources. It has, however, not been given the wherewithal to attain its goals.

The duality between the legal state and the traditional hierarchy impacts everyday life. Decisions regarding land tenure and access to land and water, for example, are often influenced by traditional authority structures. To the extent this reduces security of tenure in some areas, investments in land-improvement and resource-conserving technologies may be actively discouraged.

Although some authors (for example Bugri 2007 and de Zeeuw 1997) feel that customary land tenure is perceived by community members (if not by outsiders) to be well adapted, other reports state that duality in governance creates uncertainties in land tenure and discourages investment in land conservation (Lautze et al., 2006; report by PN47 of the CPWF, 2006). Land tenure is obviously in a transitional state in the basin countries, and the situation may vary according to the local ethnic rules.

7.4. Land tenure and access to water

The basin states have a limited ability to implement and enforce policies and reforms at the local level. Social control is highly fragmented and policy implementation takes place in a context of multiple foci of power and multiple institutions. In the Volta basin, the duality between the legal state and the traditional hierarchy impacts everyday life and a number of social determinants such as land tenure and access to water.

Legally, all land in Ghana and in Burkina Faso is vested in the state. The state has the power to appropriate land anywhere in the country for development purposes; however, compensation has to be paid to the traditional owners.

Channels of access to land include the family, spouses, sharecropping, lease, outright purchase, deed of gift and mortgages or pledges. Communal ownership is the major feature of land tenure in most parts of the Basin with family heads, chiefs (traditional rulers) and tindanas or tengsobas as the custodians of land on behalf of the people. Although some individual ownership does occur, this comprises a small fraction of the country's landmass (Fianu et al. 2001). After crop harvest, all members of the community have the right to graze their stock on farmlands, and grazing land (natural pasture) is generally communally owned.

Competition between local authorities and formal institutions, and a lack of local legitimacy and poor enforceability of official rules, make resource management prone to conflict and renegotiation in the allocation of land in irrigated schemes in Ghana. This compromised the efficiency, sustainability and equity of the irrigation sector as well as the prospects for the implementation of the water reform outlined above (Laube 2005).

"To avoid such outcomes as described above for irrigation management, reformers have to intensively study the local context and the ubiquitous traditional/legal duality in which implementation takes place. Institutional patterns, vested interests and their conflictive potential needs to be accounted for. This calls for information and communication processes which truly involve local water users instead of a rhetorical commitment to essentially flawed approaches of stakeholder participation. Only if sufficient political will exists to create mechanisms to involve local water users and to effectively mediate conflicting interests under the current institutional, administrative and political conditions water reforms will turn out to be a success and mirror the principles and objectives of IWRM" (Laube, 2005).

7.5. Access to markets for food crops

Ghana and Burkina Faso have invested for the development of cash crops, as they benefit the farmers, as well as the nations' hard currency income. In Burkina Faso, a strong political will has accompanied the development of cotton production, with several incentives offered to farmers. The result has been a spectacular increase in cotton production, the country ranking as a main producer in Africa (and the first in 2006). This example shows that when the political will exists, important development can be attained in agricultural production.

However, competitors on the world market often subsidize their own production (cereals in Europe, cereals and cotton in USA where support to national farmers largely exceeds development assistance to developing countries) so that the prices paid to the developing countries remain largely erratic and undervalued. As long as true trade liberalization has not been established, developing countries have little option but to protect their agriculture, and especially small producers of food crops.

Analysis of the national food market in Burkina Faso has shown that there is a strong possibility for development of national cereal markets, which would alleviate part of the cost of more than 200,000 tons per year of rice and wheat that are currently imported (Ducommun et al. 2005). At present, the total sales of food crops in Burkina Faso are estimated between 160 and 220 billion CFA (US$ 320 to 440 million), that is two to three times the cotton exports. The import of cereals amounts to about 40 billion CFA (US $80 million).

The development of national food-crop markets in Africa is especially needed with the recent world food crisis, and is strongly encouraged by UN Secretariat (2008). It must involve all the stakeholders, from small producers associations to the higher level state authorities.

In a context where the urbanized fraction of the Basin's population is rapidly increasing, a good organization of the national and regional food crops markets is essential and would contribute to alleviate rural poverty and food crises.

According to Ducommun et al (2005), an innovative and pro-poor approach is needed, involving several inputs:

- Credit supported by insurance to smaller farms, for equipment;
- Enhanced infrastructures for physical access to local markets;
- Development of small agro-industries to transform the local production for the national market in the first phase, and for export in the second phase;
- Organization of the national market with bottom prices; and
- Customs barriers (import tariffs or quotas) to protect local food productions from international dumping when needed.

8. The drivers for change: risks and opportunities

Like other benchmark basins, the Volta basin is affected by global, regional and national drivers of change. These include economic growth, population growth, technical change, land degradation, climate change, globalization, urban development, political change, and trade liberalization. In principle, these can profoundly influence future progress of increasing the resilience of the rural poor and of ecosystems at the river basin level in (1) maintaining growth in irrigated and rain fed agricultural production; (2) reversing the ongoing degradation of watersheds, and water-related ecosystems; (3) increasing incomes and enhancing and safeguarding the rights to domestic and irrigation water supplies for the poor, women, and socially-excluded groups, such as minorities and indigenous groups; and (4) managing conflicts over water use.

Two drivers are discussed in more detail: population growth and its consequences for food demand, and climate change and its consequences for food production (Lemoalle 2007).

Table 4. Global trends in the Volta basin and their consequences on rural activities.

Drivers	State variables	Secondary variables	Needed changes
Population change	Demand for food, Ratio urban/rural pop	Cultivated land area, Peri-urban production	Increase yields Small scale irrigation Increase meat production Increase fish production
Climate change	Rainfall distribution Temperature	Water allocation Water availability Length of growing season	

8.1. Population growth and food demand

While the limits of the Basin and its surface waters are exactly defined by the topography, there are no clear boundaries when social and economical aspects are considered, within the context of the component of national policy. In these instances, the basin limits are not fully operational. It is, for instance, difficult to estimate growth trends for population in the Basin itself or the local demand for agricultural products. We have thus applied the present share of the Basin population (24% of the total of the six states) to national data and trends in order to estimate global trends in the population for 2025 and 2050 (Table 5).

Table 5. Trends of demographic evolution in the Volta basin extrapolated from present population growth rates of the basin countries (population x1,000).

Year	Countries							Basin		
	Ghana	Burkina Faso	Togo	Benin	Côte-d'Ivoire	Mali	Total countrie s	Total	Rural	Urban
2005	22,535	13,933	6,239	8,490	18,585	11,611	81,393	19,500	13,650	5,850
2025	31,993	23,729	11,520	16,379	30,457	22,679	136,757	32,764	16,382	16,382
2050	41,881	37,503	25,550	38,794	60,911	58,447	263,086	63,030	22,060	40,969

Source for country data: Population Division of the Department of Economic and Social Affairs of the United Nations Secretariat, World Population Prospects: The 2008 Revision and World Urbanization Prospects: The 2005 Revision, constant fertility variant. http://esa.un.org/unpp,

Under these assumptions, the total basin population would increase from 17.2 million inhabitants in 2000 to **32 million in 2025**. It is however estimated that the increase rate in population may decrease in the future, and a population of **50 to 60 million inhabitants in 2050** in the basin seems a reasonable figure (United Nations population Division, 2008).

Together with this large increase, the ratio of rural to urban populations will change dramatically: if we compare 2025 with 2005, the rural population only increases slightly (x 1.2) but that rural population must provide food for a much increased urban population (16 million instead of 5.8 million in 2000). After 2025, the urban population will become much larger than the rural population with almost two urban dwellers for one rural in 2050.

If the climate remains constant, the greater production of food required cannot be achieved only by an increase in the area of cultivation, but large increases in productivity will be necessary as well. Moreover, the nature of the production will also have to change according to the changes in urban diet and the demand for rice, maize and animal proteins.

The main global scenarios, the Millennium Ecosystem Assessment and the Special Report on Emission Scenarios of the Intergovernmental Panel on Climate Change (SRES-IPCC) are pessimistic on the possibility for Africa south of the Sahara to be self-sufficient in food production. The identified risk is an increase in the population whose food needs would not be met by a sufficient increase in local food productivity.

The steep increase in food demand in all scenarios impacts the amount of both arable land and pasture land. Care will be needed to manage properly the competition for land and water, and to protect the natural pastures and water access to livestock for which the demand will increase strongly.

8.2. Climate change and food supply

The governments of the states in the Basin are well aware of the likely effect of climate change. They are all signatories of both the UN Framework Convention on Climate Change and its Kyoto Protocol and all have ratified both. Their First National Communications to the UNFCCC contain information on national circumstances, vulnerability assessment, financial resources and transfer of technology, and education, training and public awareness as well as on the present climate, on their contribution to greenhouse gases and on the possible future climate in their country, and impacts on their natural resources (see UN Framework Convention on Climate Change).

For Benin, the National communication estimates that the agricultural production of the country could decrease by 10 to 20 % by 2050.

For Togo, modeling climate change in 2025 and 2050 indicates a warming climate, but only minor associated change on the annual rainfall with a slight decrease in 2025 and an increase in 2050 in the northern part of the country that belongs to the Basin (République du Togo, 2001). As a result, the changes in agricultural and livestock production were presented as slight.

A detailed initial note was produced by Ghana, with studies on the water resources of the Volta basin (Republic of Ghana, 2001). Based on several models, rainfall is estimated to decrease by 2020 by 66 mm in the Upper East Region and by 25 mm in the Northern Region compared with the 1961-90 averages of 986 mm/yr and 1100 mm/yr respectively. The scenarios indicated flow reductions in the Nakambe of 16 and 36% respectively for 2020 and 2050. This anticipated change thus appears slightly larger than the changes in discharge observed around 1970. As a result of climate change and development, irrigation water demand could be affected considerably. It was considered that water management problems will arise by 2020 and 2050.

Burkina Faso has been using the same models as Ghana for its climate change estimates. The expected changes for two areas of the country (South West and Ouagadougou) are a 2.5 °C increase in mean temperature and a slight increase associated with a higher variability in rainfall for 2025. The mean rainfall in Ouagadougou would increase from the present 700 mm to 730 or 750 (with a standard error of ± 180 mm) with no change in potential evapotranspiration. In the most humid part of the country, it is expected that forest and cotton production may increase (Burkina Faso, 2001).

Overall, there is a great uncertainty on the climatic trends, with no major change on total rainfall, but increased variability and unreliability are a common feature of the models. Increased water productivity, drought mitigation in rain-fed cultivation with proper soil and water management techniques, and the development of irrigation are clear requirements to confront climate change.

9. Scenarios for the Volta basin and opportunities for implementation

The governments of the countries of the Volta basin are now well aware that the climate, and especially the rainfall regime, may change in the next 50 years. Policies and water management projects must take these changes into account, the difficulty being that there are some major uncertainties on the exact nature of the changes (Table 6).

Table 6. Constraints and opportunities for rural livelihood in the Volta basin.

Factor/ problem	Causes	Solutions	Constraints
Poor access to good quality domestic water	Inadequate investment in modern boreholes	Increase investment in modern boreholes and in water distribution systems	Geology, groundwater not available everywhere
Water related diseases	Various	Mosquito nets treated with repellent and insecticide, new medicines. Access to better water	Expensive for poor families
Low productivity of rain fed subsistence crop farming	Degraded soils, rainfall variability within and across rainy seasons, low labor productivity (disease), lack of tenure security	Soil and water conservation practices, organic and inorganic fertilizers, water harvesting, supplemental irrigation from reservoirs, improved health care, changes in land tenure arrangements	Social networks, national policies
Low productivity of rain fed cash crop farming	(Same as for subsistence crop farming), access to markets, market price instability	(Same as for subsistence crop farming), development of marketing systems	Same as for subsistence crop farming), international markets, quality requirements,
Low livestock enterprise productivity	Effect of previous droughts, livestock keeping as risk avoidance strategy	Develop good access to rangeland and water	Competition for water between herders and farmers.
Lack of irrigation infrastructures	Limited past investment, relatively few sources of water for irrigation	Increased investment, supplemental irrigation from small reservoirs	Groundwater resource not known and underused.

The past 50 years in West Africa may be divided into three rainfall periods: humid from 1950 to 1970, dry from 1971 to 1990 and intermediate after 1990. The difference between the three periods is approximately represented by a one-degree shift of the isohyets from the 1990-2000 means, northward in 1950-70 and southward in 1970-90.

We consider as an hypothesis that the rainfall may easily revert to a dry or to a wet period similar to those observed in the recent past, with plus or minus 1° latitudinal shift of the isohyets around the 1990-2000 situation. This hypothesis applies both for 2025 and 2050, and should be revised as soon as higher resolution and more consistent models are developed.

In the Volta basin, the distribution of the main food crops and the livelihood vulnerability of rural households reflects the rainfall distribution and its north-south gradient. The DSSAT model results also indicated a steep sensitivity of cereal yields to rainfall change in the range 500 to 1,000 mm rainfall per year. Changes in both the nature and quantity of the main staple foods, as well as rangeland productivity, may thus occur with climate change, especially in the northern half of the basin, mainly in Burkina Faso, where rainfall is already a limiting factor. In this region, it would be possible to increase the number of small reservoirs, and thus to develop a complement to the farmers' income by dry season cultivation.

Within these scenarios, we have identified three major means to alleviate poverty through better use of the available water.

9.1. A better access to good quality water

The governments of the countries in the Basin are well aware of the water quality-poverty nexus, and are drilling boreholes and modern wells to provide good-quality water for rural populations. This effort should be continued. Surveys indicate, however, that a significant proportion of the boreholes are not functioning properly because of lack of maintenance. A specific effort should be devoted to maintain the existing boreholes.

9.2. The development of small reservoirs

The storage of renewable water is a requisite for agriculture development (World Water Assessment Programme, 2009).
Analysis in the central part of the basin has indicated that, second to the lack of appropriate tools to improve the efficiency of the available work power, the possibility to cultivate during the dry season would avoid the need for short term migration. The construction of small reservoirs is an answer to this problem, and should be encouraged. It provides the possibility to produce out-of-season vegetables as cash crops, even for those who do not possess draught animals. The importance of small reservoirs as a tool for poverty alleviation has been documented by the Small Multi-Purpose Reservoir Project of the CPWF.

We have shown that, at the basin scale, the construction of small reservoirs in the upper basin has a negligible impact on the water flow into Lake Volta. Some further analysis is needed to check for possible impacts at the sub-basin scale, especially in the Bagré and Kompienga catchments where hydroelectric schemes have been constructed.

As a complement to small reservoirs, groundwater may be used for small-scale or complementary irrigation. Although recent research has shown that the resource is important at the basin scale, more research is needed to identify the resource distribution.

9.3. The use of fertilizers

Water harvesting and soil and water conservation techniques are available to improve the effective use of rain water use by crops, especially by increasing the water holding capacity of the soil especially through appropriate management of crop residues.

Most African soils are poor compared to other parts of the world. Insufficient use of fertilizer is one of the causes for environmental degradation in Africa, but conversely, an appropriate use of fertilizers may substantially increase the water productivity in rain-fed agriculture (Bationo et al., 1991, 2006). In the Volta basin, our DSSAT simulations have shown where the probability of yield increase is the best, as a function of soil quality and the latitudinal distribution of rainfall. More locally, the results of CPWF projects PN 5 and 6 on rainwater- and nutrient-use efficiency and strategic innovations in dry land farming have analyzed at the field scale the practical technology options for sustainable increases of crop yields.

The socio-economic acceptability of fertilizer use should now be tested for food crops, as it has been developed earlier for cotton production in both Burkina Faso and Ghana.

10. Knowledge management

The BFP Volta project has used a number of data, analyzed the important literature and produced a number of reports. All this material is compiled on DVD available for distribution. It is presently accessible on http://armspark.msem.univ-montp2.fr/bfpvolta and will be available on the IDIS/IWMI web site. Four of the BFP Volta reports are presented in Appendix 1.

The accessibility to these items is not uniform. The primary data used were not produced by the team, but were provided by a number of institutions to whom they belong. This is notably the case for hydrology, demographic surveys or some agricultural statistics. The addresses or links to the institutions that own the data are given in the data base. Some data are directly accessible (e.g. Agristat in Burkina Faso), others have to be obtained from the institutions (e.g. hydrologic data from Volta HYCOS).

The same caveats apply to reports and articles used during this study, and published by a variety of publishers. The references given in our data base provide a means for the reader to access the information and, when applicable, the link to the publication or report is given together with the reference.

Identification of, and links to all this material has been transferred to the IDIS website of CPWF and IWMI.

11. International public goods

A ready-to-use version of the WEAP water allocation software for the Volta basin has been presented to the Volta Basin Authority (VBA). This application is designed to help in analyzing the impacts of different water-allocation strategies at the basin and sub-basin scale as well as assess the possible impacts of climate change. This is the result of a collaborative effort by PAGEV, SEI and BFP Volta.

The *Project for Improving Water Governance in the Volta River Basin* (PAGEV) implemented by the *International Union for Conservation of Nature* (IUCN), and the BFP Volta have both developed an application for the Volta basin of the Water Evaluation and Planning (WEAP) software, each focusing on particular uses of the water. With the help of the *Stockholm Environment Institute* (SEI), developer of the WEAP software, a common improved application, benefiting of both approaches, has been produced.

Continued collaboration with PAGEV and SEI allowed the Volta BFP to hand over this tool and to provide training and capacity building in the use of WEAP to VBA focal organizations, and related institutions (VRA, Univ. Kumassi).

12. Conclusions

A major goal of the BFP program was to identify researchable questions or breakthrough implementation issues that promise major impact and change in the near future or in the longer term (2025 and 2050).

The research priorities identified during this study of the Volta Basin in cooperation with some Basin stakeholders are listed below, with a brief description of their rationale. A more extensive description of the present situation and of the research questions is given in the different BFP Volta reports (Béné, 2007; Béné and Russell, 2007; Clanet, 2008; Clanet and Ogilvie 2009; de Condappa et al., 2009; Terrasson et al., 2009).

These reports clearly indicate that although there are knowledge gaps on some issues at the basin scale, some knowledge exists locally in some regions of the Basin. This allows for development and implementation where the conditions are favorable. Examples are use of fertilisers in semi-arid areas, and irrigation with groundwater where there is sufficient proven resources available in sedimentary strata.

Opportunities exist in both advanced and applied research institutes for research to address knowledge gaps and innovative issues. Most of them involve a multidisciplinary approach with a strong social component: while technical or biophysical solutions already exist for many problems in agriculture, their implementation remains limited because of institutional, social, cultural and economic reasons.

The main research questions identified by the Volta BFP are as follows.

a) Water resources and management:

- A good knowledge on underground water resource is needed. It could contribute to the development of small scale irrigation and drought mitigation. The pro-poor institutional context for the development of this resource use needs to be examined.
- A transboundary, water-sharing, decision tool, based on the WEAP software, has been proposed during this study. It needs further development for the hydrologic impact of small reservoirs or the analysis of the impact of climate change.
- Small reservoirs: What are the hydrological constraints for their further development, and what institutional management is needed to prevent exclusion of the poorest from small-scale irrigation?
- International programs have been developed to understand the African monsoon system. How can the results be used, or the program improved, to develop a seasonal weather forecast for the Basin?

b) Rain fed cultivation

- The use of fertilizers in rain-fed agriculture can improve crop yields and water productivity. Research is needed on the socio-economic acceptability of fertilizer use and on the institutional environment needed to promote the technology (an extension of CPWF project PN 5).
- Which are the constraints to the extension of cultivated land in the Basin? Can general vs. local determinants be identified?

c) Irrigation

- Small reservoirs: Is the present use of phytosanitary products compatible with the sustainability of the vegetable production and the water quality (an extension of CPWF project PN 46)?
- Why is scale irrigation so under-developed in the Volta basin (and more generally in West Africa)?

- Peri-urban agriculture: Which water may be safely used for vegetable production (an extension of CPWF PN 38 and PN 51)?

d) Fisheries and livestock

- Closer monitoring of the fisheries is needed to provide the basis for sound management. Which cheap and efficient methods can be developed at the basin scale and also be used for large water bodies such as Lake Volta?
- A better use of bush and tree browse as fodder for livestock would improve water productivity and animal production. Applied research is here needed to select the plant species and practical methodologies for their use.

e) Institutions and socioeconomics

- What are the local or general determinants that favor or restrict the implementation of innovation in soil and water conservation (SWC) techniques in agriculture? Does the traditional/legal duality influence the ways in which implementation takes place?
- What migrations to and from the Volta basin will climate change cause?
- How do the present shifts in institutions (land tenure, water access for farmers and livestock) influence the distribution of rural poverty? How can water access for trandhumance livestock be assured in an equitable way?
- Pro-poor policies to assist small farmers: what lessons can be gained from the past experiences, what are the gaps and which conditions are needed to improve their efficiency?
- The services provided by the aquatic ecosystems are far from fully understood. There is a need for new methods for socio-economic appraisal in developing countries. But what are the priorities in terms of the services provided and the socio-economic characteristics selected across the range of aquatic systems?

These different research topics address directly the main issues considered in the Volta BFP: basin-scale water allocation, sustainability, alleviation of rural poverty through improved water productivity in irrigated or rain-fed agriculture or livestock herding and pro-poor water policies. The bio-physical constraints on the agriculture production in the Basin can be overcome (Table6). Answers to the research questions identified above would improve the possibilities of enhancing the overall agricultural production, especially food production. Political decisions are needed to put them in practice.

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1.5 Database

The BFP Volta project has used a number of data, analyzed an important literature and produced several reports. All this material is compiled on a **DVD** for distribution and has been sent to IDIS Colombo for implementation on the CPWF webpage.

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List of acronyms

BFP	Basin Focal Projects
CPWF	Challenge Program on Water and Food
CRU	Climate Research Unit, University of East Anglia
DSSAT	Decision Support System for Agrotechnology Transfer
EBCVM	Enquête sur le Conditions de Vie des ménages, Burkina Faso, 2003
ECOWAS / CEDEAO	Economic Community of West African States / Communauté Economique des Etats de l'Afrique de l'Ouest
FAO	Food and Agriculture Organization of the United Nations
GLOWA	Global Change and the Hydrological Cycle, Bonn University, Germany
GLSS 1998	Ghana Living Standard Survey in 1998-99
IWRM	Integrated Water Resources Management
MAHRH	Ministère de l'Agriculture, de l'Hydraulique et des Ressources Halieutiques, Burkina Faso
MDG	Millennium Development Goals
MOFA	Ministry Of Fisheries and Agriculture, Ghana
NEPAD	New Partnership for Africa's Development
PAGEV	Project for Improving Water Governance in the Volta River Basin, implemented by the International Union for Conservation of Nature
VBA / ABV	Volta basin Authority / Autorité du Bassin de la Volta
WEAP	Water Evaluation and Planning System, a model by Stockholm Environment Institute
WRCC / CCRE	Water Resources Coordination Centre / Centre de Concertation sur les Ressources en Eau
SIEREM	Système d'Informations Environnementales sur les Ressources en Eau et leur Modélisation
MARA/ARMA	Mapping Malaria Risk in Africa/Atlas du Risque de la Malaria en Afrique
CGIAR	Consultative Group on International Agricultural Research