

# GLOBAL TRENDS IN THE VOLTA BASIN



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## Executive summary

We need scenarios or trends for the Volta basin for 2025 and 2050 to analyze the usefulness or possible impact of recommended implementations. Based on available data, the selection of scenarios is presented here has been used as a common thread during the progress of the BFP Volta.

Considering the available literature, the overall situation that may be envisaged is summarized as follows :

- Uncertainties on rainfall lead to take into account three main scenarios : the first is that the present (1990-2002 or 2004) situation will continue, with its variability. The second and third are the two opposite hypotheses of a deviation of the yearly rainfall from the present distribution (1990-2002) by plus or minus 100 to 150 mm/y either in 2025 or in 2050. In the wet hypothesis, the situation that prevailed from 1950 to 1970 would be re-established.
- When the present national figures of growth rates of rural and urban populations are applied, the total basin population increases from 17 million inhabitants in 2000 to 32 million in 2025 and between 50 and 60 million in 2050. Together with this large increase, the ratio of rural to urban populations changes dramatically : from 2.3 in 2005, it decreases to 1.0 in 2025 and to 0.5 in 2050. From largely subsistence farming, the production has to shift toward developed national markets.
- The food demand per capita will probably increase, especially for proteins (meat and fish). If we consider this per capita demand constant, the total demand for the basin will be increased by 1.9 times in 2025, and by 3.7 in 2050 when compared with 2000. The ratio should be slightly lower for cereals and tubers, but higher for meat products.

These few and tentative figures set the scene of the BFP for the Volta basin. Objectives for each key issue has been analyzed within these trends. Productivity and yields per unit area, per unit water or per capita must be increased in high proportions, but also in ways that are both sustainable and acceptable by the rural societies.

The combination of increased population and climate change is the real challenge for the Volta BFP.

# Global trends in the Volta basin

## Introduction

The text below is a short review of the literature and available data useful to set the climate and demographic context in the Volta basin for the period 2000-2050. Such a framework is needed in order to test local scenarios for adaptation and development, taking into account the Millennium Development Goals.

The hypothesis is that political stability allows for a steady increase in population and in urban development in the basin, and that the local climate change is dependent on worldwide activities.

The combination of demography and climate change defines new pressures on the environment and water uses (Table 1). This sets the scene for an evolving and increasing food demand, and for the necessary adaptation of the agricultural production, productivity and water uses.

Table 1. Global trends in the Volta basin and their consequences on the rural activities.

Drivers	State variables	Secondary variables	Needed changes
Population change	demand for food, ratio urban/rural pop	cultivated land area, peri-urban production	Increased yields, Small scale irrigation,
Climate change	rainfall distribution temperature	water allocation, water availability, length of growing season	Meat production increased, Fish production increased

## The global change and scenarios

The interactions between the global climate change and the behaviour of our societies is such that some hypotheses have first to be drawn on the main political orientations. This is reviewed first, before zooming on West Africa and the Volta basin.

While the causes of the ongoing climate change on the earth may be attributed mostly to developed industrialized countries, their effects are widely distributed. They may change significantly the living of African populations South of the Sahara who have a small contribution to the greenhouse effect gases (mainly through enteric fermentation in cattle and small ruminants) but

are heavily dependent on climate for their natural resources and their rain fed agriculture.

Most climatic models agree on the global temperature trends, but they differ when applied to smaller regions, especially as far as rainfall is concerned. For Africa, the paucity of climate data is given as one reason for the lack of model applications to the continent.

### ***The Millennium Ecosystem Assessment scenarios***

The Millennium Ecosystem Assessment (2006) has considered the four different scenarios for the possible changes in our society for the next 50 years and their translation in terms of global ecosystem functioning and agricultural impacts (from Millennium Ecological Assessment, 2006). These scenarios are very similar to those proposed by the Special Report on Emissions Scenarios - SRES 2100 (Nakicénovic, 2000).

For each of the four scenarios, a set of plausible socioeconomic changes consistent with the contrasting approaches to ecosystem management has been analyzed.

- *Global Orchestration scenario (GO), (globalized, with emphasis on economic growth and public goods),*

GO relies heavily on global market forces, public and private investment in agricultural knowledge, science and technology (AKST) supporting rural infrastructure, and policy reform to govern global production and consumption activities.

With growing openness on all fronts including trade liberalization, markets and information technology, and technology transfer, the production structure of agriculture will tend to become more competitive. GO includes the highest level of investment in agricultural research and development, and agricultural extension, as well as the highest levels of investment in critical infrastructure.

- *TechnoGarden scenario (TG) globalized, with emphasis on green technology).*

This scenario targets an agricultural technology development, emphasizing high input in existing irrigated areas, and low input agriculture in rained areas, with a medium reliance on biotechnology.

It assumes medium population growth, medium to high income growth, medium and increasing levels of development in technology, irrigation efficiency and yield improvements, low growth in meat demand, low irrigated area expansion.

- *Adaptive Mosaic scenario (AM) (regionalized, with emphasis on local adaptation and flexible governance)*

In this scenario, there is an emphasis on organic and low input agriculture and crop management improvement through water harvesting, low tillage, and

soil fertility management. Assumptions include medium to low population growth, high investments in human, physical and natural capital, decline in irrigated area combined with high efficiency increases in water management.

Central to this scenario is the objective to develop a resilient food system.

- *Order from Strength scenario (OS) (regionalized, with emphasis on national security and economic growth),*

This scenario assumes high population growth, low to medium income growth, medium to low investments, low levels of development in technology, irrigation efficiency and yield improvements (particularly in developing countries), reliance on mining of natural assets such as forests, high meat demand growth in developed countries but relatively low in developing countries, high expansion in irrigated and total crop area, increased protectionism for agriculture and industry, and little control on environmental pollution. Agricultural and trade policies are geared towards food self-sufficiency within trading blocks. Production growth in poorer countries is achieved through expansion in crop-harvested area, as reduced investments in yield improvement are insufficient to keep up with demand levels. Also, crop area expansion follows goals defined by trade protection levels.

## **The climate change in Africa with a focus on West Africa and the Volta basin**

### ***The rainfall regime***

Different climates dominate over West Africa, with a series of latitudinal belts :

- The equatorial climate, characterized by a quasi continuous rainfall, is observed along the Gulf of Guinea, from Sierra Leone to Côte-d'Ivoire, but not along the coast of Ghana. It is thus not represented in the Volta basin.
- In the humid tropical climate, the rainfall is abundant, but it is divided by two dry seasons, the long dry season from December to April, and the short dry season in August-September. This climate is observed in the southern part of the basin.
- The dry tropical climate, characterized by the alternation of one dry and one wet season, covers most of the basin north of 9° latitude. It may be divided into several classes, from Guinean (>1100 mm/y), to Sudanian (900-1100 mm/y), sahelo-sudanian (500-900 mm/y) and Sahelian (<500 mm/y).

Two rainfall regimes are thus encountered in the basin. A unimodal rainy season in its northern part, and a bimodal distribution close to the Gulf of Guinea. The limit between the two regions is not clear-cut and covers a intermediary region.

## **Recent trends**

Based on historical records, a warming of approximately 0.7°C over most of the continent during the 20th century is reported in the IPCC TAR (2001). The linear updated trend of observational records for the last 50 years is 0.13 °C per decade (AR4, IPCC 2007). The six warmest years in the last century in Africa have occurred since 1987, with 1998 being the warmest.

The Sahel is a climatically sensitive region in which rainfall exhibits considerable variability on multiple timescales. Representing the transition zone between humid tropical Africa and the arid Sahara, it is particularly sensitive to changes in the position and intensity of the African Monsoon, which are both modulated by changes in solar irradiation and sea-surface temperatures. The Sahel has experienced numerous dry (and wet) episodes in the few last centuries.

The rainfall data for West Africa indicate a high year – to – year variability, but to the difference with the other African regions, wet or dry years often occur in series of consecutive years (Hulme et al. 2001). There has been a long wet period from 1950 to 1970, and a long dry period from 1971 to 2000 (L'Hôte et al., 2002) (Figures 1 and 2). The transition has not been a continuous progressive trend. It occurred quite abruptly around 1970 (see also Hoerling et al., 2005).

Comparing the two periods, 1951-69 and 1970-89, L'Hôte and Mahé (2003) have described a southward shift of the isohyets of approximately 150 km in West Africa, which roughly corresponds locally to a 150 mm decrease in total annual rainfall (Figure 1).

A change in the rain seasonality is associated with this shift. In the region where two rainfall seasons occur within the year, there has been a decrease in the total amount of the first season (usually the main rain season) relatively to the second season, and thus a change in “rainfall equilibrium” detrimental to the cycle of rain fed agriculture in the southern part of the Volta basin.



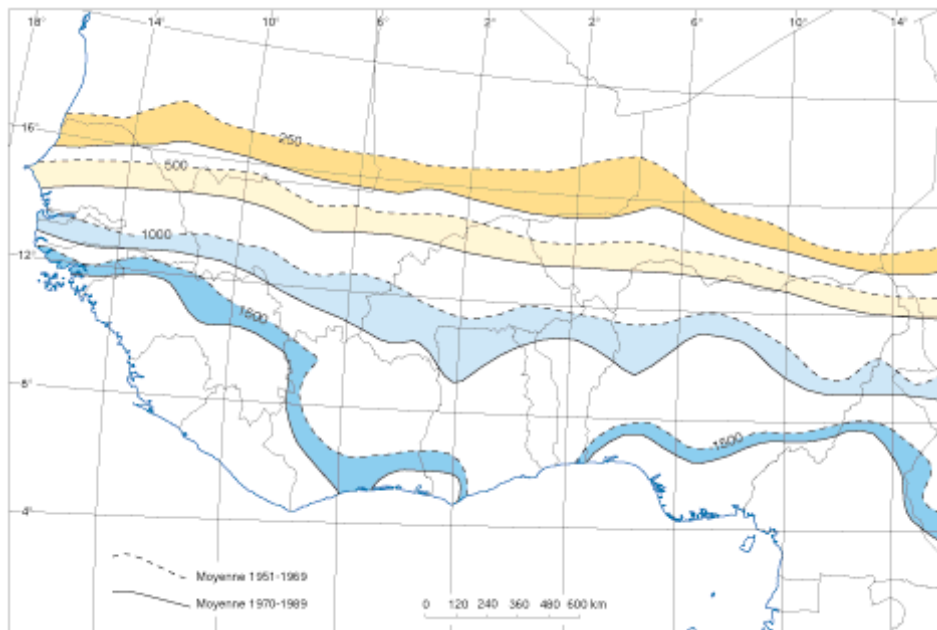


Figure 1. Mean annual rainfall distribution over West Africa for the periods 1951-69 and 1970-89 (from L'Hôte and Mahé, 1996).

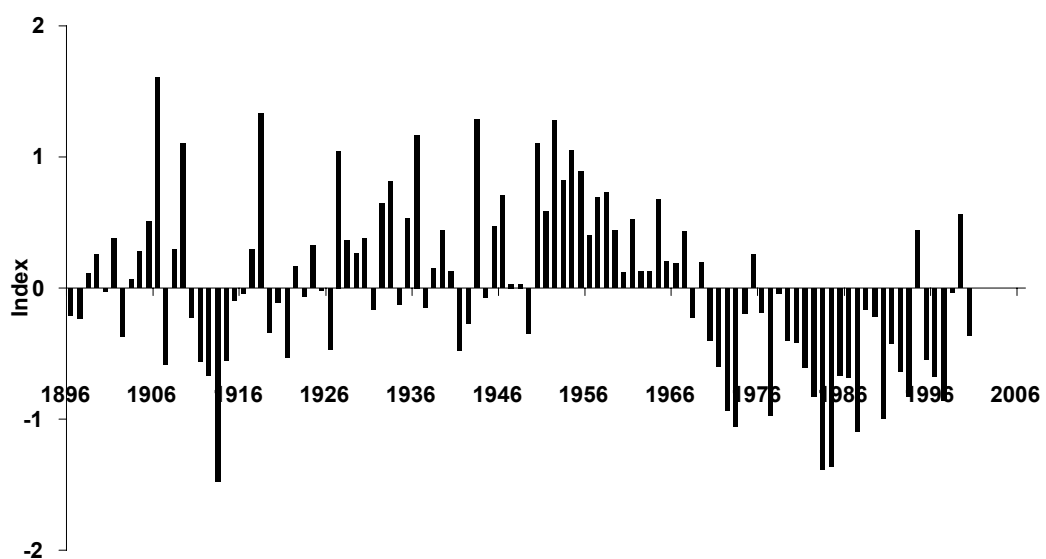


Figure 2. . Time series from 1896 to 2000 of a normalized rainfall anomaly index over the West African Sahel (mean value computed for 1921-2000). From L'Hôte et al., 2002.

## **Modelling African climate**

The modelling studies which have been most successful in reproducing the recent dry episode are those that are forced with the observed warming of the Indian Ocean since the 1950s, which may represent feedback processes between the atmosphere and the Sahelian land surface and vegetation cover. However, the negative impacts of human activities on the Sahelian land surface and these vegetation-atmosphere interactions in triggering the drought are questioned (Brooks, 2005).

The Fourth Assessment Report on climate change impacts from IPCC (AR4, 2007) states that by 2050, annual average river runoff and water availability are projected to increase by 10-40% at high latitudes and in some wet tropical areas, and decrease by 10-30% over some dry regions at mid-latitudes and in the dry tropics. Drought-affected areas will likely increase in extent. Heavy precipitation events, which are very likely to increase in frequency, will augment flood risk.

GCM-based climate change scenarios are generally consistent in predicting temperature rise across Africa, but show considerable uncertainty about both the magnitude and direction of changes in precipitation over the continent (ILRI, 2006). The increased temperature will have some adverse effects on evapotranspiration, on vegetation (and animal) distribution and productivity.

Global General Circulation models provide coarse climate prediction with low resolution. The task of developing reliable descriptions of future climate change in Africa is difficult because of the complexity of the African climate coupled with the lack of accurate baseline data on current climate (DFID, 2004). Two potentially important drivers of African climate variability, namely the El Niño/Southern Oscillation and land cover change are not well represented in the models (Hulme et al., 2001).

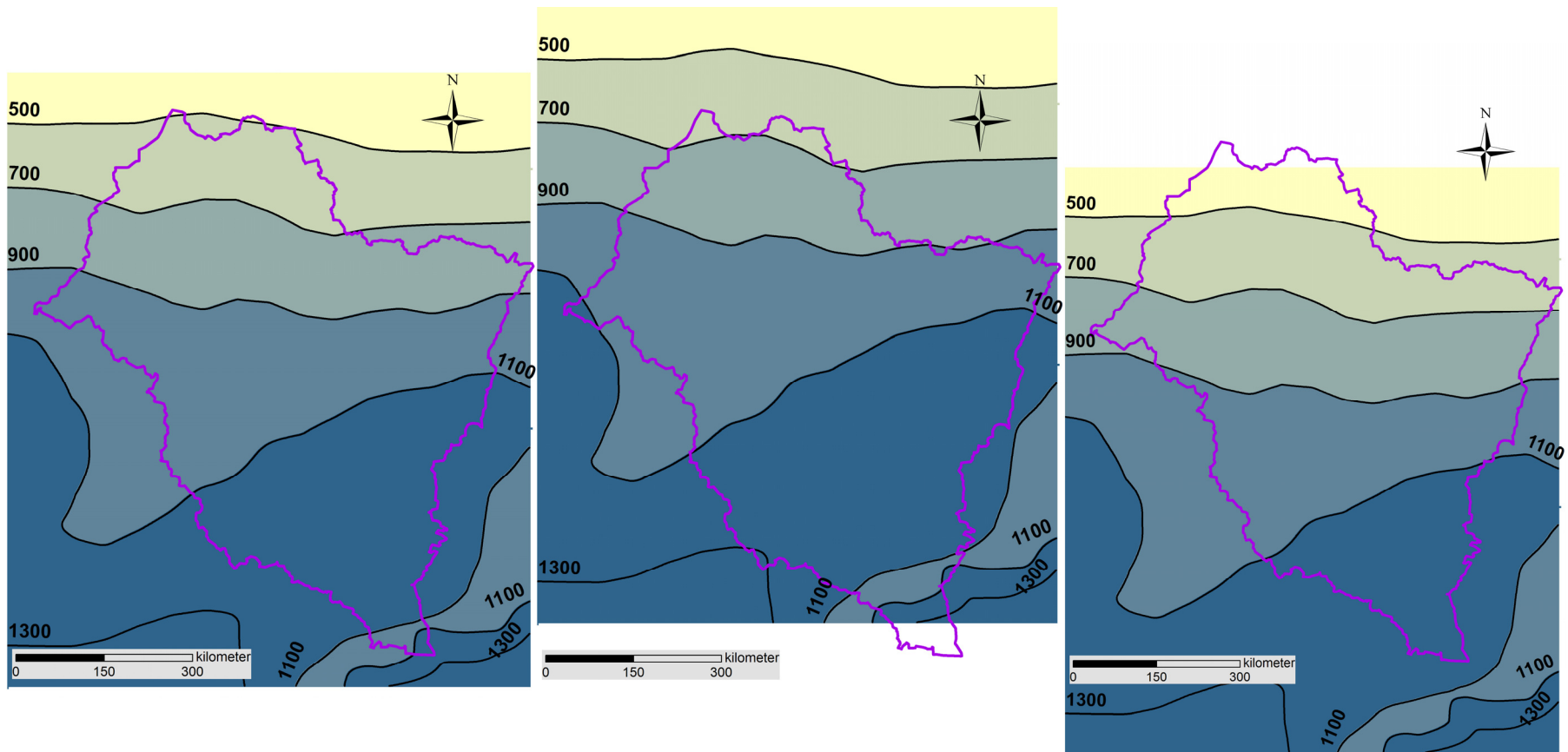


Figure 3. Three rainfall scenarios over the Volta basin : left, the situation that prevailed from 1980 to 2000, with the 500 mm/y (Sahel) isohyet at the northern limit of the basin (data from CRU); centre, a more humid climate, with isohyets shifted 1° North, which roughly represents the rainfall distribution in the 1950-70 period; and right, a drier situation, with the isohyets shifted 1° South compared to the 1990-2000 period, and the Sahel (< 500 mm/y) covering the northern part of the basin. The isohyets determine agroclimatic zones according to FAO : sahelian below 500 mm, sahelo-sudan between 500 and 900 mm, sudanian between 900 and 1100 mm, guinean above 1100 mm.

Under the B1 scenario, Hulme et al., (2001) found that relatively few regions in Africa will likely experience a significant change in their seasonal rainfall that exceeds the natural rainfall variability simulated by the HadCM2 model. With

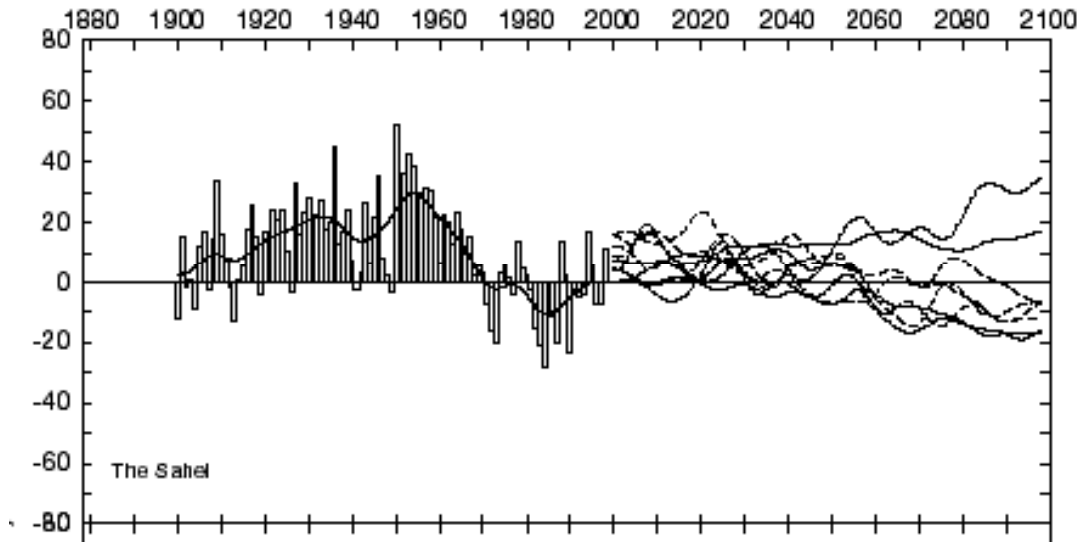


Figure 4. Observed annual rainfall anomalies for the African Sahel, 1900–98, and model-simulated anomalies for 2000–2099. Model anomalies are for 10 model simulations derived from 7 DDC GCM experiments and 4 HadCM2 simulations (dashed curves). From Hulme et al. 2001.

faster global warming (A2 scenario from SRES), West Africa could witness a significant decline in rainfall by 2100. Rainfall pattern over the Sahel is less certain (Figure 4). In some models, the Sahel is projected to be wetter (Hoerling et al.,2005), other models project that it will experience ‘significant’ rainfall decreases in rainy season under the B1- low scenario.

The mechanisms associated with the present prolonged dry episode in West Africa are consistent with anticipated and modelled scenarios of anthropogenically-driven global warming, although it is not possible to attribute the Sahelian drought to locally human-induced changes.

Modelling studies suggest that global warming may enhance the African summer monsoon, leading to an expansion of vegetation from the Sahel into the southern Sahara (Brooks, 2004). Wang and Eltahir (2002) even suggested that the recent amelioration (end of 1990s and beginning of 2000s) of the period of climatic desiccation in the Sahel could be the result of increased atmospheric CO<sub>2</sub> concentrations. A number of simulations indicate possible increases in West African and south Sahara rainfall with increased total atmospheric CO<sub>2</sub> (Liu et al., 2002 ; Maynard et al., 2002 ; Claussen et al., 2003 ; Brooks et al., 2005).

With similar hypotheses on CO<sub>2</sub>, but unknown global scenario, Thornton et al. (2006) produced a map of the changes of the length of growing season (LGP) in Africa indicating severe shift for West Africa, with a decrease of around 20 days in the central part of the Volta basin (Figure 5). Associated with this analysis, two short southward shifts for agriculture were identified in the Volta basin : for millet (60 days LGP) in the northern border, and for maize cultivation (120 days LGP) in the centre of the basin, around the Ghana – Burkina Faso border.

A number of possible temperature and rainfall changes with different global scenarios have been reviewed for the Volta basin in the ADAPT programme, together with their impact on the water resources (Andah et al. 2004).

The outputs of the AMMA programme on the functioning of the West African monsoon should include soon the results of the GCM based on AR4 and provide more confidence on the possible climate trends over the Volta basin in the next 50 years.

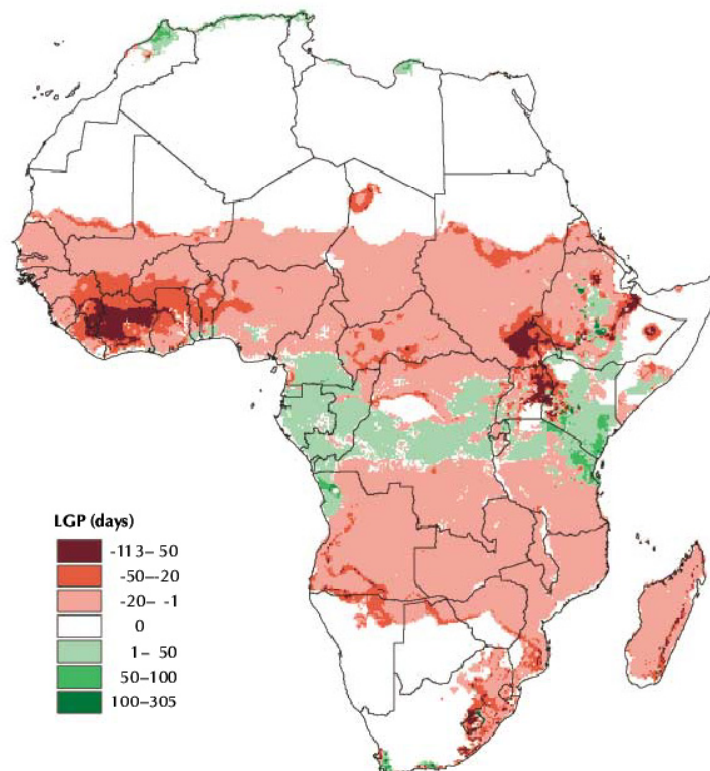


Figure 5. Change in length of the growing season between 2000 and 2050, indicating a severe shift in the Volta basin and Côte-d'Ivoire. The development scenario was not specified (source : Thornton et al., 2006).

### **National communications**

The governments of the states in the basin are well aware of the climate change. They have produced documents on the present climate, on their contribution to greenhouse gases and on the possible future climate in their country, with impacts on their natural resources (see UN Framework Convention on Climate Change).

For Benin, two stations have been particularly considered, Cotonou and Parakou which are outside the limits of the Volta basin. Using the same models as Togo, the study estimated that the agricultural production of the country could decrease by 10 to 20 % by 2050.

For Togo, modelling the climate change in 2025 and 2050 has indicated a global warming, 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, which 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 its three basins, among which the White Volta (Republic of Ghana, 2001). Based on three GCM models and a simple climate model (MAGICC), estimates for 2020 and 2050 have been carried out.

The main findings of the study included an observed increase of 1 °C, and reductions in rainfall and runoff of about 20 and 30 % respectively over the past 30 years. The estimated change on rainfall by 2020 is minus 66 mm to the average 1961-90 values of 986 mm/y in Navrongo (Upper East Region), and minus 25 mm to the 1100 mm/y in Tamale (Northern Region).

The scenarios indicated flow reductions in the White Volta of 16 and 36 % respectively for 2020 and 2050. This anticipated change thus appears much larger than would be expected considering past (1960-present) changes in rainfall and discharge. The reduction in groundwater recharge is similarly in the range of 5-22 % in 2020 and 30-40 % in 2050.

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  $\pm 180$ ) 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).

### **Scenarios for the Volta basin**

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 this change into account, the difficulty being that there is some major uncertainty on the exact nature of the change.

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 shift of the isohyets of plus or minus one degree from the 1990-2000 mean situation.

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, and schematically presented in Figure 3 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 will be developed.

### **Prospects for agriculture**

African countries whose economies heavily rely on agriculture for cash or subsistence crops are vulnerable to climate change. There is however no more consensus on the future of African agriculture than there is on climate scenarios.

Model results (Hadley Centre, CSIRO, Canadian Climate Centre, and NCAR) indicate that only 80,000 km<sup>2</sup> of agricultural land in Sub-Saharan Africa with currently severe environmental constraints (out of a total of more than 15.1 million km<sup>2</sup>) are expected to improve with climate change, whereas more than 600,000 km<sup>2</sup> currently classified as moderately constrained would migrate to the class of severe environmental limitations (Fischer *et al*, 2002).

Arnell *et al.* (2002) pointed out that, even with a stabilisation of the concentration of CO<sub>2</sub>, cereal crop yields in Africa will still decrease by 2.5 to 5 percent by 2080. Their results indicated a general decline of production in most of the subsistence crops, including maize in Ghana.

According to FAO (1999), general impacts of climate change on agriculture may result from a quick adaptation of pests to new spatial and temporal distribution of temperature and rainfall, while increasingly variable growing

season conditions (shifts in start of rainy seasons, length and quality of rains, etc) are disrupting subsistence agricultural production in many semi-arid regions of Africa (Elasha, 2006).

In the Volta basin, the distribution of the main food crops reflects the rainfall distribution and its north-south increasing gradient. 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 part of the basin where rain is a limiting factor.

## **Trends and figures: what do the scenarios imply for livelihoods in the Volta basin**

### ***Population trends***

The living conditions in the basin are not independent of the overall evolution in the world, which itself depends on the global scenario that will prevail. Furthermore, while the limits of the surface waters of the basin are exactly defined by the topography, there is no clear boundary when social and economical aspects are considered, with their national policy components. In these instances, the basin limits are not 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 3).

A figure of 17.2 million in 2000 has been given by the Comprehensive Assessment (unpublished), from which we assume a **population of 19.5 millions in 2005**. This figure is in agreement with the 19.3 million in 2005, which can be calculated for the basin from the UN adjusted population count grid in ArcGis format ( CIESIN et al. 2005).

If the present estimated trends (from UN Population Division, 2007, <http://esa.un.org/unpp/>) in the countries of the Volta basin are applied to estimate rural and urban populations in the basin in 2025 and 2050, the resulting figures are within the ranges that would be derived from the application of the four main scenarios to SSA (Table 2).

Under these assumptions, the total basin population would increase from 17.2 million inhabitants in 2000 to **32 million in 2025** and 63 million in 2050. 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.

Together with this large increase, the ratio of rural to urban populations changes dramatically: if we compare 2025 with 2005, the rural population has only slightly increased ( x 1.2) and must provide food not only for itself, but



also for an equivalent number of urbans (16 million instead of 5.8 million in 2000). After 2025, the urban population is larger than the rural with almost 2 urban dwellers for one rural in 2050.

The rural populations in the basin countries will grow at a much slower rate than total or urban populations, with the rural population almost stabilizing around 2015 at 12 million in Ghana and around 2050 at 20 million in Burkina Faso (Figure 6).

Table 2. Trends of demographic evolution in the Volta basin extrapolated from present population growth rates (population x1000)

Year	Ghana	Burkina F.	Togo	Benin	Côte-d'Iv.	Mali	Tot countries	Tot Basin	Rural bas.	Urban bas.
2005	22535	13933	6239	8490	18585	11611	81393	19500	13650	5850
2025	31993	23729	11520	16379	30457	22679	136757	32764	16382	16382
2050	41881	37503	25550	38794	60911	58447	263086	63030	22060	40969

Source for country data: Population Division of the Department of Economic and Social Affairs of the United Nations Secretariat, World Population Prospects: The 2006 Revision and World Urbanization Prospects: The 2005 Revision, constant fertility variant <http://esa.un.org/unpp>.

On a per capita basis, each rural inhabitant had to feed 0.4 urban dweller in 2005, and some complement had to be imported. In 2025, one rural will have to provide food for one urban, and this will increase to 1.9 urbans in 2050. The total production has to be multiplied by 2.1 between 2025 and 2050, that is multiplied by 3.7 between 2005 and 2050 with a large development of the national markets and periurban agriculture.

Climate being constant, this cannot be met only by an increase in cultivated area. Increases in productivity will be necessary as well. And the nature of the production will also have to change according to the changes in urban diet and demand.

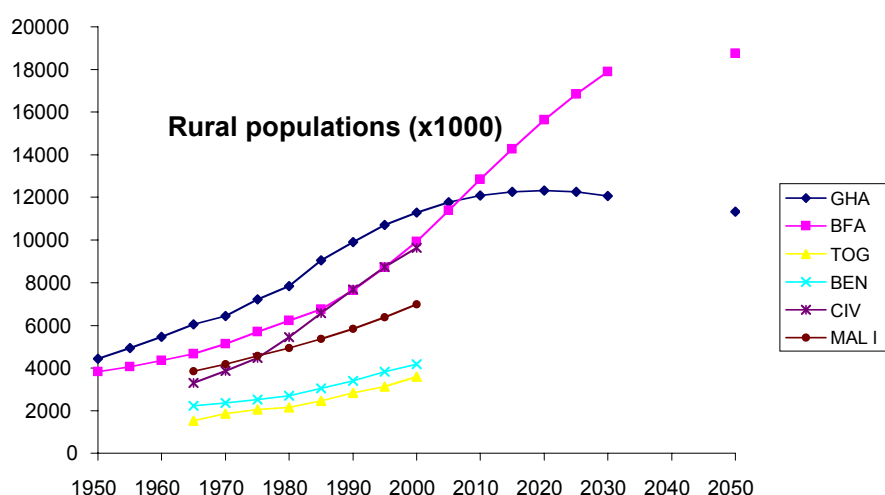


Figure 6. Trends in the increase in rural populations in the six countries of the basin ( from UN Population division).

The population in Africa South of Sahara (SSA) increases significantly in each global scenario , and shares the highest population growth rate with Central and West Asia and North Africa (Table 3). This may be related with the Per capita GDP, which remains the lowest in SSA compared to the other main regions of the world (Table 4).

Table 3. Total population and food consumption in SSA in 2050 according to the different scenarios (Millennium Ecosystem Assessment 2006).

SSA	2005	TG2050	GO2050	AM2050	OS2050
Population (Millions hab)	583	1245	1038	1399	1471
Per capita meat demand (kg/cap/yr)	12	22	30	18	17
Per capita cereal demand (kg/cap/yr)	120	180	230	140	120

Table 2. Per capita GDP (US\$) until 2050 in SSA according to the four different scenarios of the Millennium Ecosystem Assessment (2006).

SSA	2000	2005	2010	2020	2030	2040	2050
TG	718	746	800	960	1270	1874	2981
GO	718	749	818	1016	1374	2055	3296
AM	718	743	788	914	1120	1498	2167
OS	718	739	774	871	1027	1281	1668

## **Trends in food demand and production**

Although the mean production of starchy food in the Volta basin was estimated as 21 10<sup>12</sup> kilocalories (1992-2000), that is 20 % above the quantity needed if evenly distributed, some food was regularly imported in the basin (Volta BFP Report on rain fed agriculture, 2007).

The quantities needed for 2025 and 2050 are respectively 1.6 and 2.8 times the mean production for 1992-2000, with some shifts in the diet associated with the urbanization.

The global scenarios give indications on the possible changes in SSA as described below. However, care must be taken to identify specificities of the Volta basin, both as constraints and as opportunities.

Per capita meat demand will increase in SSA from a present 12 kg to 17-30 kg/person/y in 2050, these values being much lower than those for the other regions of the world. The present per capita cereal consumption is about 120 kg/cap/y, not taking into account the roots, tubers and plantain which are important items in the basin diet. This cereal consumption may change in 2050 to quite different values according to the global scenario : increase to 230 kg/cap/y in GO, or 180 in TG, but remain fairly stable in OS or increase slightly to 140 kg/cap/y in AM (Table 3).

In the different scenarios, production of livestock products increase much faster in SSA (3.6 %/y) than in other regions of the world albeit from a low 2000 level. The increase in cereal production is lower : 1.2 %/y.

The least developed regions, like SSA, show higher levels of productivity growth over the total period to 2050, compared with north western industrialized regions. The relatively lower level of productivity from which SSA region is starting explains much of this difference.

Increasing cereal and meat trade will be an important feature of all the four scenarios, but it is not projected that the demand in the SSA region will be matched by an increase in domestic production. SSA increases its reliance on food and feedstock imports. Africa will account for the majority of the total additional people at risk of hunger due to climate change by the 2080s (Parry et al., 1999, Fisher et al., 2002).

The projected global trends for production and consumption have implications for water uses.

Consumption of water for irrigation in SSA grows to 2050 for all scenarios, in contrast to other regions of the world. This contrast points out the differences in terms of irrigation technology improvement that are envisioned, combined with the growing need for food production from irrigation, needed to feed the growing populations. The increase rate is particularly high in SSA which

must supply the projected growth in consumption of livestock products with an increase of production of livestock, and a corresponding increase in stocking rates.

Table 4. Consumptive use of water across sectors, GO and AM scenarios in SSA (Millennium Ecosystem Assessment 2006). Units are km<sup>3</sup>.

SSA	2000	GO2050	AM2050
Domestic	3.3	12.8	17.9
Industrial	1.0	1.6	0.9
Irrigation	20.5	24.2	25.3
Livestock	4.0	17.7	9.1

The trends in Water Productivity have been evaluated for irrigated maize and rice in SSA. The increase in Water Prod. is generally lower for rice than for maize, and remains low for this region compared with the other parts of the world. The improvements are generally larger for the GO than the OS scenario given investments and yield improvements envisioned under GO compared to OS.

### **Impact on diseases**

Africa is already vulnerable to a number of climate-sensitive diseases (Guernier *et al.*, 2004). In the Volta basin water related diseases include: malaria, filariasis, trypanosomiasis, onchocercosis (WHO, 2003 ; Poda, 2007) Increased temperatures could also increase the levels and survival of cholera bacteria in tropical waters. Changes in rainfall will affect the transmission potential, and the presence and absence of vector- and water-borne pathogens (IPCC 2001).

Malaria is one of the world's most serious and complex public health problems and it has now been identified as the disease most likely to be affected by climate change (WHO/WMO/UNEP, 1996). The population of disease-carrying mosquitoes is expected to increase as a result of changes in temperature and precipitation (Lindsay and Martens, 1998). Environmental conditions are already so favourable for malaria transmission in some tropical African countries that climate change is unlikely to affect overall mortality and morbidity rates in hyper endemic lowland regions. In West Africa, the vulnerable areas are those where transmission is currently limited by a long dry season, as in the northern part of the Volta and Niger basins. A drier climate may also favour a southward invasion of dengue.

The boundary of human and animal trypanosomiasis, which crosses the basin, may also shift according to changes in rainfall distribution.

## **Other potential impacts**

Increasing frequency of droughts and floods associated with climate variability could have a negative impact on the ecosystems of some areas in Africa, including the water budget of lakes and reservoirs such as Lake Volta. This is dealt with in a report on surface hydrology (Volta BFP, in prep.).

Sea levels around Africa are projected to rise by 15-95 cm by the year 2100 (IPCC, 2001). This may become a major threat given the number of large cities located in coastal areas and more generally the high population densities along the coast line. Major changes may occur in the lower part of the Volta basin, which has already been deeply modified by the construction of the Akosombo dam more than forty years ago.

Climate change is not the only sector impacting the environment. Agriculture also impacts on the environmental system directly through changes in land use. Crop growth and animal husbandry are the most important determinants of land-use change in the agricultural system. The steep increase in food demand in all scenarios impacts the size of both arable land and pastureland. Arable land in SSA has to change drastically in all scenarios, as the increase in crop demand is not met by increase in yields, contrary to what happens in the other parts of the world. In the most developed countries, arable land is even decreasing since food demand is not increasing to a large extent, whereas crop yields continue to increase.

The size of arable land in SSA in the four scenarios changes from about 170 Mha in 2000 to 230 Mha in 2050. During the same period, pasture land projections are more variable and may increase from 820 Mha to 880 (TG) – 1350 (GO) Mha according to the scenario. The change in livestock is particularly important in SSA, from 200 Mheads in 2005 to 500-970 Mheads in 2050

## **Adaptation**

Increased pressure on resources strengthened tensions between nomads and agriculturalists in Niger during the 2005 crisis (OXFAM, 2006; Abdalla, 2006), and it was argued that increased competition over land was one of the triggers of the conflict in Darfur. Such conflicts may result from rapid climate changes in regions where increasing population densities would make adaptation more difficult than when the 1970 drought happened.

If the rainfall decreases in a region, the impact on farming could force people to leave their homelands. Although Africa's farmers have proved to be skilled at adapting to changing rainfall patterns over decades, global warming threatens to stretch coping mechanisms beyond breaking point (Nkomo et al, 2006).

An unusually persistent drought may increase vulnerability in the short term, but it may encourage adaptation in the medium to long term (Mortimore, 2000). This is particularly true for the drought prone area of the northern basin border which is subject to frequent climatic hazards.

The reverse hypothesis of a rainfall increase in some northern or southern border of the Sahel has not been much considered up to now, but should not be eliminated in the light of the present knowledge. In that case, an analysis of the behaviour and distribution of the populations before 1970, when the Sahel drought struck the region, would be most useful to evaluate the new natural resources.

Family farmers have been practicing coping strategies and tactics, especially in places where rainfall is both limiting and variable. They have developed their own ways of assessing the prospects for favourable seasonal food production (Downing et al., 1989). The rapid development of small reservoirs in Burkina Faso is an illustration of this capacity.

Home gardens and sheep fattening have greatly contributed to improve the adaptive capacity of small farmers. In many locations food crops have replaced cash crops, and more resilient crop varieties have been introduced (DFID, 2000). Seasonal migration for men appears also as a useful adaptation option for income diversification, but some day may reach its limits (Rain, 1999; DFID, 2000).

Sewell and Smith (2004) emphasized the need for building credibility of rainfall forecasts and improving their dissemination and use, especially by people in the drought prone areas of African Sahel. Improved seasonal forecasts and application of these results at the community level is a high priority to ensure communities transition smoothly to the changing climate. Roncoli et al (in press) have been studying how the information may be transmitted to the rural communities.

## **Conclusion**

The objective of this report was to identify the main trends in the Volta basin in order to figure out what are the needs for a rather close future, namely 2025 and 2050. The few and tentative figures which have been presented set the scene of the Challenge Programme Water and Food the BFP Volta basin. Objectives for each key issue should be analyzed within these trends. Productivity and yields per unit area, per unit water or per capita must be increased in high proportions, but also in ways that are sustainable and acceptable by the rural societies.

Trends in population are quite clear, although some differences appear between the different countries that share the basin. They indicate an urgent need for increased productivity.

The main uncertainty concerns rainfall : models for this region of Africa have not agreed yet, and both an increase and a decrease in annual rainfall have to be considered. It may also happen that each trend occurs in a different part of the basin. In any case, variability must be considered as a prime environmental driver, with its consequences on rained agriculture and livestock. The three scenarios for rainfall will be considered as presented in Figure 3, with the present rainfall (1990-2000), and a total amounting plus or minus 100 to 120 mm/y. The wet scenario is close to what prevailed between 1950 and 1970. The dry scenario is drier than what has been experienced in the 1980s.

The combination of increased population and climate change is the real challenge for the Volta BFP.

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