# 2. Impacts of climate change and variability on water, wetlands and desertification: current state of knowledge

This section succinctly analyses two issues: first, the cumulative impacts of climate change and variability as experienced in recent years; and second, the projected impacts over the coming years based on the most plausible climate change scenarios.

## 2.1 Impacts of climate change and variability observed in West Africa

In the northern half of West Africa, referred to as the Sahel (or area bordering the desert), climatic conditions, which have always been characterized by spatial and temporal variability, have become prone to disturbances of significant magnitude, particularly since the early 1970s. The series of droughts that affected the Sahel over the past three decades consisted of declining rainfall, great uncertainty about its distribution in time and space, a drop in river discharges, etc. This situation translated into the accelerated desertification process, major crises in cereal production, massive migration of rural populations to urban centres etc. The Permanent Interstate Committee for Drought Control in the Sahel (CILSS) was created in 1973 in response to this situation. The adoption of the United Nations Action Plan on Desertification in 1977 and the entry into force of the United Nations Convention on Desertification in 1996 resulted mainly from the Sahelian crisis.

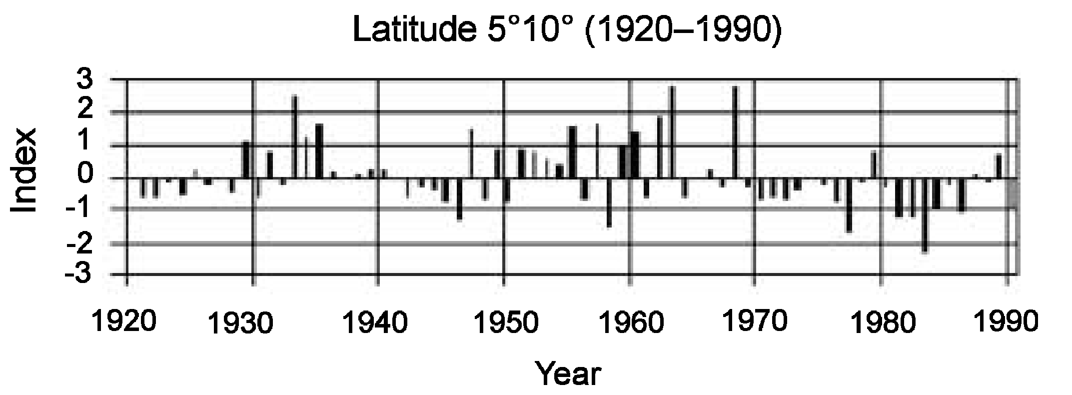
Thus, across the Sahel in particular and West Africa in general, climate change and variability are not only issues for the future. Whether they are referred to as climate variability and change or extreme climatic conditions, these new conditions have had an impact on all sectors.

### 2.1.1 Decline in rainfall

As already noted, West Africa has experienced a significant decline in rainfall in recent decades. A noticeable decline in rainfall series was observed around the years 1968–1972, with the year 1970 as a transitional year.

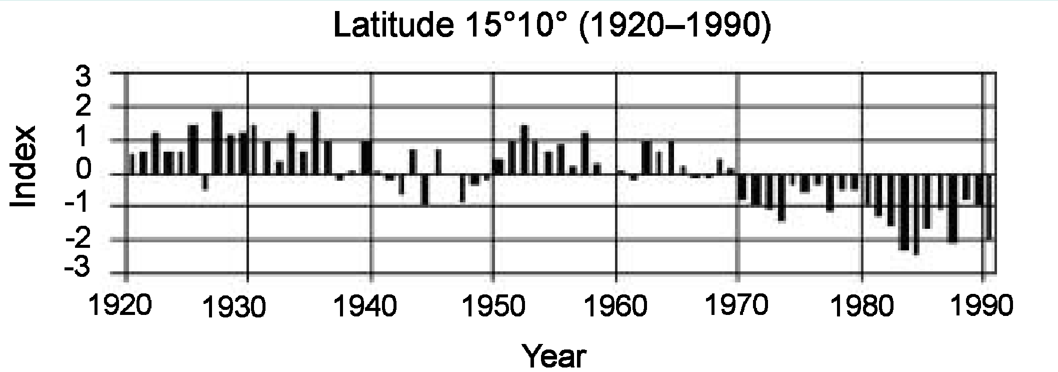
The drop in average rainfall, before and after 1970, ranges from 15% to over 30%, depending on the area. This situation has resulted in about 200km southward shift in isohyets. In the whole region, the decline in rainfall results from reduced number of rainy events. The causes of this anomaly (reduced number of rainy events) have yet to be clarified (Lebel *et al*., 1999).

**Fig. 2 Annual rainfall variation index for wet lower latitudes (West Africa)**




*Source*: Onibon, 2001.

**Fig. 3 Rainfall variation index for arid and semi-arid higher latitudes (West Africa)**




*Source*: Onibon, 2001.

### 2.1.2 Decline in the discharge of major watercourses

As in the case of the annual rainfall series, a significant variation in annual average discharge has been observed since the 1970s in most rivers. Across the region's major basins, the variation in discharge time is generally concomitant to that of rainfall. However, the decline in flow is more significant than that of rainfall: 40% to 60% average decline since the early 1970s against 15–30% for rainfall (Servat *et al.*, 1997 and Paturel *et al.*, 1997).[1] The table below shows around a 60% decline in the discharge of the Senegal and Gambia Rivers over the period 1971–1989 compared to the period 1951–1989 against a drop in the order of 25% in average annual rainfall across the same basin and for the same reference periods. With regard to the region's large drainage basins, the reduction in discharge ranges from 25–50% for the same periods. That is the case for the Niger River – the largest river in the region – where in addition to a drop in surface runoff, severe low flow conditions that resulted in the stoppage of flows were observed in 1983, 1984 and 1987 over the Bani tributary at Douna, Mali or in 1985 in Niamey. In 2002, the volume of water discharged at Koulikoro (upper reaches of the

[1] As will be seen later on, across some small basins the decline in rainfall did not necessarily result in a drop in discharge. Yet this does not contradict the general downward trend in the discharges of the region's watercourses.

river in Mali) was 29.7 billion cubic metres, that is, a 14% decrease in relation to the average for the period 1971–2001 consisting of a mean annual volume of 34.4 billion cubic metres. There is a 40% drop in the 2002 discharge compared to the average for the period before 1970 (over 49 billion cubic metres per annum).

**Table 3. Ten-year variations in precipitation and average discharge across the five largest drainage basins of West Africa: deviation from the average for the period 1951–1989 in %**

| Drainage basins | | 1951–60 | 1961–70 | 1971–80 | 1981–89 | Total 1971–89 |
|---|---|---|---|---|---|---|
| The Senegal, Gambia, Corubal and Konkouré rivers (Northern Guinea) | Rainfall | +23.0 | +13.0 | -8.5 | -16.5 | -25.0 |
| | Discharge | +32.6 | +23.6 | -24.1 | -35.7 | -59.8 |
| Rivers of Southern Guinea, Sierra Leone and Liberia | Rainfall | +10.3 | +5.2 | -3.5 | -13.3 | -26.8 |
| | Discharge | +19.6 | +15.7 | -9.3 | -28.8 | -38.1 |
| Lower reaches of the Niger River Delta (Onitsha, Benué) | Rainfall | +11.3 | +3.1 | -4.2 | -11.2 | -15.4 |
| | Discharge | +14.8 | +13.4 | -8.7 | -21.5 | -30.2 |
| Rivers of Côte d'Ivoire, Ghana, Togo, Benin | Rainfall | +9.3 | +4.6 | -5.5 | -9.4 | -14.9 |
| | Discharge | +23.4 | +21.8 | -18.4 | -29.9 | -48.3 |
| Coastal rivers of Nigeria and Central Cameroon: Wouri, Mungo, Sanaga | Rainfall | +3.1 | +7.4 | -1.4 | -9.6 | -11.0 |
| | Discharge | +10.5 | +12.6 | -9.3 | -15.3 | -24.6 |

*Source*: Mahé and Olivry, 1995.

### 2.1.3 Threatened continental wetlands

The decrease in discharge recorded in the region's largest watercourses since the early 1970s gave rise to a significant reduction in the area of major natural wetlands. The shrinkage in the average area of the Hadéjia Nguru Floodplain (on the Komadugu Yobe river system in northern Nigeria) ranges from 2,350km$^2$ in 1969 to less than 1,000km$^2$ in 1995. A similar trend was observed over the Niger River Inland Delta, which is the second largest wetland of the continent after the Okavango floodplain in Southern Africa.

The maximum area flooded in the Inland Delta has decreased significantly from 37,000km$^2$ in the early 50's, down to about 15,000km$^2$ since 1990. The area flooded for at least four months in the year (an important biological parameter) declined from 23,000km$^2$ to less than 2,000km$^2$ during the same period. The area of Lake Chad estimated at more than 20,000km$^2$ during wet years before 1970, shrunk to less than 7,000km$^2$ in the 1990s. A consequence of this situation is the splitting of the Lake into two parts (northern and southern basins). Today, only the

**Drying out of a watercourse (eastern Burkina Faso),** ***Mahé/IRD***

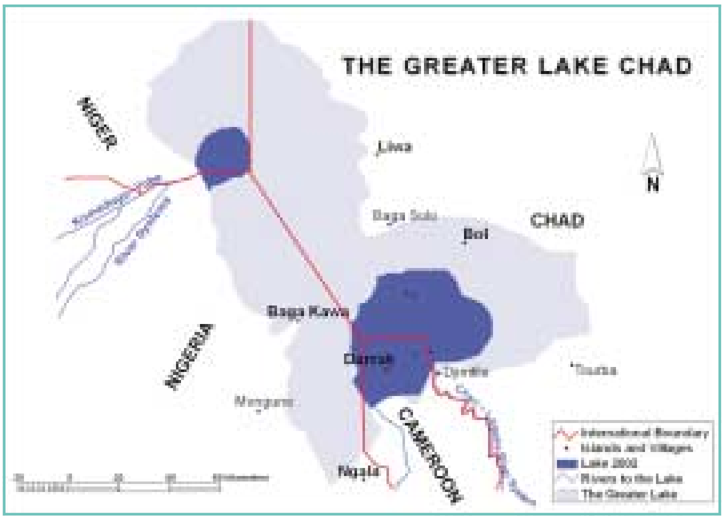
southern part contains water permanently. Over the past decade, a slight regeneration of the lake has been observed due to improved rainfall conditions.

### 2.1.4 Degradation of water quality

One of the consequences of the general deterioration of climatic conditions in the subregion is the proliferation of invasive weeds (water lettuce, water hyacinth, *Typha* etc.). Favourable conditions for invading weeds are created by the decline in flows, warming and eutrophication, which reduces the velocity of flood propagation and sometimes causes the virtual stagnation of water in some places. Floating weeds hinder fishing, navigation, the functioning of irrigation schemes and hydroelectric developments. In addition, they create an environment conducive to the multiplication of vectors of waterborne disease such as malaria. These invading weeds choke several water bodies of the region, including wetlands whose biological diversity is recognised as being of global importance. In recent years, the water hyacinth has been proliferating on the Otti subcatchment across the Volta and the *Typha* has been significantly expanding over the Komadugu Yobe Basin (Northern Nigeria), including Lake Nguru classified as a Ramsar site. Upstream of the Diama Dam at the mouth of the Senegal River, on the edges of the Djoudj and Diawling Ramsar sites, the expansion of *Typha* was compared to a giant carpet spread over the river.

The disposal of untreated wastewater from big urban areas into the river and increased use of agricultural inputs contribute dangerously to degrading water quality and spreading waterborne diseases.

**Fig. 4 Shrinking and splitting of the Lake Chad**




*Source*: Based on map by LCBC Remote Sensing Unit; May 2002

### 2.1.5 Decline in groundwater recharge level

The recharge of the area’s aquifers has significantly decreased and often because of the decline in rainfall and surface runoffs. In arid and semi-arid zones, aquifers are often present in large sedimentary basins in fossil form. In some areas such as the subcatchment of Bani – upper reaches of the Niger River in Mali – water tables reached their lowest level in 1987. The decrease in the water table has noticeable consequences on depletion coefficients, which as a result reduces the input of groundwater into major watercourses (Olivry, 1997). In humid and sub-humid areas, groundwater reserves are often limited in quantity in the Precambrian formations, in the form of fault waters, fissure waters or merely arenaceous waters. They are fed through direct infiltration in alteration layers and fluctuate according to seasonal rhythms. Consequently, they are directly affected by the decline in rainfall.

### 2.1.6 Threats to ecosystems, housing and infrastructure in coastal areas

Very sensitive to erosion, beaches and dune ridges along Africa's coastal area tend to retreat at variable rates: from 1–2 metres to more than 20–30 metres per annum in Senegal and along the Gulf of Guinea respectively (UNEP/UNESCO/UN-DAESI, 1985). Likewise, in Senegal, an accelerated retreat of coasts was observed between 1987 and 1991, which resulted in the splitting of dune ridges of which Sangomar Point (Pointe de Sangomar) is the most well known. This coastal erosion or sea advance often leads to degraded coastal ecosystems such as mangrove populations (which still cover an area of 28,000km$^2$ in West Africa). For example, there have been many changes in the layout of the Cotonou-Lomé road in the region of Grand-Popo, Benin; and hotel facilities and houses in the residential area of Akpakpa in Cotonou have been destroyed. The town of Rufisque (suburbs of Dakar) has also witnessed repeated destruction of houses along the seashore in recent years.

### 2.1.7 Climate change and variability as driving forces of desertification

The recurrent drought resulting from climate change and variability accelerates desertification and deforestation, which contributes to the persistence of drought. For instance, the overgrazing prevailing in the event of poor rainfall, which entails low fodder production, strips the soil bare and consequently increases the albedo.[2] This situation results in exacerbated and expanded atmospheric subsidence over the Sahara, which in turn, prevents rain from falling over the Sahel and therefore accelerates the disappearance of the vegetation. This feedback loop is likely to play a part in increased desert encroachment (Charney *et al.*, 1977). The increase in discharge observed over some small catchment areas such as some tributaries of the right bank of the Niger River as well as some portions of the Nakambé[3] – which is in contradiction to the general situation observed, particularly in the region's watercourses – can be explained by increased runoff coefficient during the dry period as a result of the degradation of the vegetative cover and the soil. Changes in land cover, hence the desertification process, seem to have a great impact on the hydrological cycle and rainfall-runoff relations. The Niger River whose bed tends to silt up is an illustration of this accelerated erosion.

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[2] The ratio or fraction of the incident sunlight that is reflected by a given surface.

[3] Mahé *et al.,* 2002; Amani *et al*., 2002.

**Banjul beach (The Gambia) showing coastal erosion, *Ibrahim Thiaw***

### 2.1.8 Climate variability: a determining factor and barometer of the performance of the regional economy

In West Africa, perhaps more than elsewhere, the climate plays a central role in the economy, and its vagaries (intra- and inter-annual variability of rainfall and flows in watercourses) often have immediate consequences on the economy of the various countries of the region. The relation between inter-annual rainfall variability and economic growth and the socio-economic impacts due to deficient replenishment of dam reservoirs testify to it.

#### Rainfall variability, agriculture and economic growth

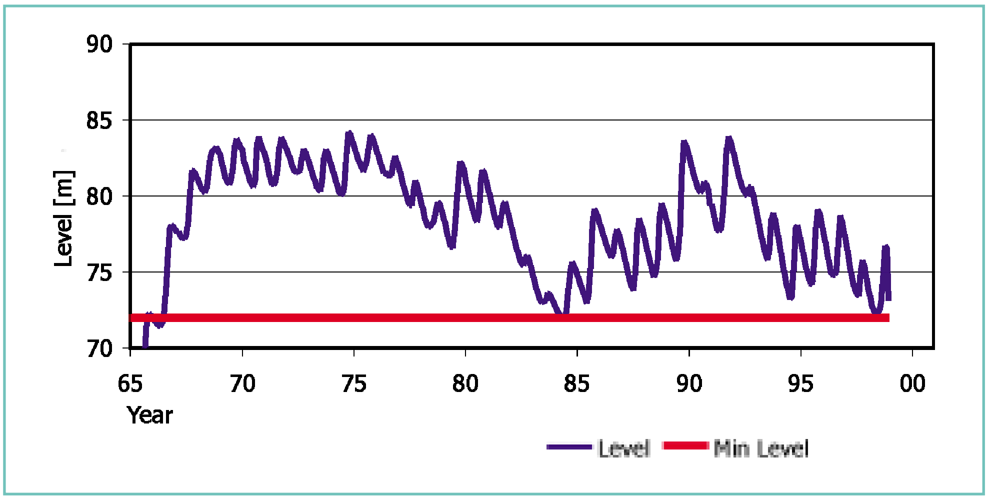
Climate variability directly affects the national economies of African countries. As an illustration of this situation, in Zimbabwe for example, a significant correlation was observed between annual rainfall performance and the economic growth rate (Gray, 2002). This situation is all the more striking since Zimbabwe ranks second after South Africa, in terms of number of large dams. Most of the 250 large dams in this country are intended for irrigation (as a reminder there are 110 dams altogether in West Africa). In West Africa in general and in the Sahel in particular, the great weight of annual rainfall in economic growth can be explained by two main factors. The first one concerns the key role of agriculture, which accounts for 29% and 66% of the regional GDP and working population respectively (see Table 1). The second factor relates to poor water control. The case of Senegal eloquently testifies to the decisive role of the climate in the performance of West African national economies. Senegal's economic growth rate dropped from 2001 (5.7%) to 2002 (-1.1%) before increasing again in 2003 (6.3%). The 2002 situation mainly resulted from the much reduced primary sector activities mostly due to the vagaries of the climate, and particularly the bad weather, which affected some areas of the northern part of the country.[4]

### From climate change to deficient replenishment of water reservoirs

The drop in the flow of the large rivers in the region mentioned earlier has had direct consequences on the replenishment of most dam reservoirs in West Africa. Built mainly in the 1960s and 1970s, these dams were in general designed according to the prevailing hydrological standards of the previous decades, which were relatively wet. As mentioned above already, the area has been subject to recurrent rainfall and hydrometric deficits since the beginning of the 1970s. The frequent poor replenishment of reservoirs had serious socio-economic impacts. Among those, one can note the reduction in the level of urban water supply: the town of Ouagadougou for example, which is primarily supplied from surface water reservoirs, had to face serious water supply shortage, particularly in 2002 and 2003.

In other cases, widespread flooding brought about disruptions in the operation of hydroelectric dams: such was the case of the Kainji dam in Nigeria, in September 1999. In February 1988, Ghana faced a severe energy crisis following the fall in the water level of Lake Volta, to below the threshold level needed to feed the turbines of the Akosombo dam (red line in Figure 5 below). This dam (of 912MW built capacity) together with the Kpong Dam (160MW) located downstream provide 95% of the electricity consumption in Ghana and part of the electricity consumed in Togo and Benin. The resulting power cuts seriously affected the economic activity, with the most affected sectors being industry and mining.

**Fig. 5 Fluctuation in the water level of the Akosombo dam reservoir**




*Source*: GLOWA Volta Project.

[4] *Jeune Afrique l'Intelligent*. L'Etat de l'Afrique. 2004. Hors-Série N° 6. p.185.

**Water shortage in Ouagadougou in 2003, *National daily newspaper* Sidwaya**

### 2.1.9 Social and economic costs of extreme climate events

Extreme events (devastating floods, droughts, sharp temperature changes) punctuate climate variability and climate change and seem to have become more frequent in West Africa. Their environmental and socio-economic costs are often high. In September 1999, torrential rains in the Niger-Nigerian and Benin sections of the Niger River led Nigerian authorities to open the floodgates of the Kainji, Jebba and Shiriro dams (approximately 300km north of Lagos). This resulted in enormous losses: 60 villages were destroyed, tens of recorded deaths, nearly 80,000 homeless people, 100,000 hectares of destroyed millet, rice and maize fields.[5] During the same period, strong and sharp increases in the flow of the White Volta (Nakambé) led, according to certain sources, the managers of the Bagré dam in Burkina Faso to open the floodgates of the dam in order to lower the pressure on the dam. This resulted in catastrophic floods in the Ghanaian part of the river. According to information released at the time, forty villages were affected and nearly 50 people died (Pearce, op.cit.).

Following the experience of devastating floods, which displaced several hundred thousand people in 1998, Northern Nigeria was again under the waters of the Hadéjia and Jama'are tributaries in September 2001. The floodgates of the Tiga and Challawa dams had to be opened, causing a heavy death toll: nearly 200 people died (25 in Kano State and 180 in Jigawa State) according to some sources; more than 35,000 displaced people, as well as material losses.[6]

**A village under the floods: Inner delta of the Niger River (Mali), *Mahé***

5 Pearce, 2001; BBC,1999.

6 Johnson, 2001. Asaju, 2001.

More recently, in January 2002, torrential rains accompanied by an unprecedented cold wave fell on northern Senegal and southern Mauritania. In northern Senegal, more than 50,000 head of cattle and 500,000 small ruminants were killed. More than 20,000 houses were destroyed, in one of the three affected districts alone. More than 30 people died instantly, notwithstanding subsequent cases of suicides.[7]

Such examples (many more could be given) are part of the normal behaviour of the West African climate. In spite of their greater frequency, they still take decision makers and the general public by surprise. Each disaster is managed in great confusion, thus increasing their social and economic impacts.

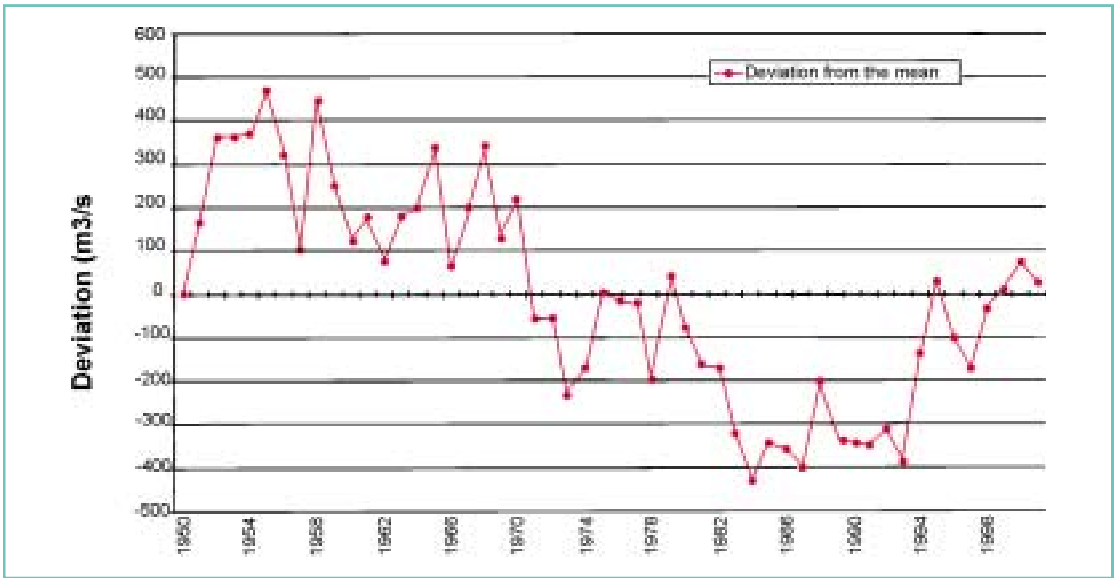
### 2.1.10 Risks of multiple conflicts over water

Climate variability and change often result in the decrease of water availability or in the degradation of its quality. These consequences often lead to the exacerbation of the competition for access to water.

In the middle and lower valleys of the Komadugu Yobe (Northern Nigeria), reduction of water availability due to climate variability and change, but also to construction of dams upstream, created strong tensions among riparian populations. In order to secure water supply for their flooded crop fields, several village communities had to dig channels in order to divert water to their advantage. Today, these various initiatives have deeply disorganized the natural drainage network of the basin.

At the international level, the high degree of interdependence of the West African countries with regard to water, combined with the low levels of awareness amongst decision makers and the general public on the impacts of climate, create a favourable ground for tension and even inter-state conflicts over water resources. For example, Nigeria, which has invested heavily in irrigation schemes and hydro-electric development in the downstream part of the river Niger (Kainji and Jebba dams, 1.6 million hectares of irrigated land, river transport installations, and urban water supply), fears

**Fig. 6 The Niger River's annual discharge in Niamey: deviation compared to the average for the period 1950–2001**




[7] UN, 2002.

today that the realization of dam projects upstream (Kandadji in Niger and Taoussa in Mali) will lead to a fall in the flow of the river in its Nigerian part. Thus, on several occasions the Nigerian authorities have expressed their concern over any hydroelectric project on the Niger River, which would involve a reduction of more than 10% in the annual volume of water received in Nigeria.[8] Considering what happened in the recent past, (drops of 20–50% in average flows) and the predicted climate, one can wonder whether climate variability and change are not going to "withdraw" more water from the Niger river than downstream countries such as Nigeria would consider acceptable (see above). One would even fear the occurrence of misunderstanding that could lead to upstream irrigation schemes being blamed for changes due to climate variations.

The energy crisis experienced by Ghana in 1998 (see Box 1) illustrates the serious implications that ignorance of climate change and variability as increasingly significant factors in the management of water resources could bring about.

**Box 1. Energy crisis in Ghana in 1998: acknowledging climate as a "user" of water to avoid conflicts between riparian countries**

At the time of the energy crisis which hit Ghana in 1998, following the water shortfall in the Volta Lake (a lake which is also the reservoir of Akosombo hydroelectric dam), some part of the general public and even some of the leaders of the country suspected Burkina Faso of being at the root of the problem. Some indeed thought that the drop in the water level of Lake Volta was the result of increased pumping of water by Burkina Faso from the upstream sections of the White Volta and the Black Volta – these two tributaries contributing 56% to the water supply in an average hydrological year. This thesis seemed all the more plausible since between the end of 1960 and the mid 1990s, Burkina Faso had built 1,500 small water reservoirs, three major dams and had increased its irrigated surfaces from 2,000ha to 25,000ha in the upper basin of the Volta. But analyses showed that the total water storage capacity of all the small and large dams of Burkina Faso (even including three other dam projects) represented only 1.49 billion cubic metres, i.e. less than 5% of the normal volume of Lake Volta. Thus, there was obviously another more credible cause to explain the water deficits in Lake Volta: climate (Andreini *et al*., 2000; van de Giesen *et al*., 2001).

Other consequences of climate variability and change – devastating floods (the Ghanaian part of the White Volta in 1999), migrations of floating plants along the water courses, the degradation of water quality, etc – are likely to contribute to the deterioration of relations between neighbouring States, especially because of the great interdependence of West African countries in relation to fresh water.

### 2.1.11 Conclusion

Climate perils in West Africa are thus serious. The impacts already recorded are significant. One could thus expect the worst if climate variations observed over the last decades were to remain the same or worsen.

[8] ABN, 2002. See Annex 7 in particular: "Position du Nigéria sur les projets de barrages de Taoussa (Mali) and Kandadji (Niger)".

## 2.2 Future impacts of climate variability and change in West Africa

### 2.2.1 Climate change scenarios used in West Africa

The Third Assessment Report (TAR) of the Intergovernmental Panel on Climate Change (IPCC) provides new forecasts on the expected concentrations of greenhouse gases (GHG), on the profiles of changes in the world, the rate of variations in temperature, precipitation, sea level, and the modification of the frequencies and amplitudes of extreme climate events. It also examines the risks of abrupt and irreversible changes and evaluates the biophysical effects and socio-economic climate changes.

At the regional level, the TAR confirms that Africa is very vulnerable to climate change. The impacts identified on this continent relate to water resources, food production, human health, desertification and coastal areas, particularly in relation to extreme events. However, it is worth noting that water resources are an increasingly fragile key sector in Africa because of the increasing needs of households, agriculture, livestock, industry, energy, etc. The evaluation of this vulnerability is, however, plagued by uncertainties due to the diversity of the climate and the great variability of precipitation. Added to this the observation networks are often poorly maintained, rendering climate change forecasts inaccurate at the regional and local levels.

Most recent impact studies carried out in the region (particularly within the framework of the national communications) are conducted on the basis of scenarios using General Circulation Models (GCMs). Regional evaluations are generally obtained from GCMs rough resolution outputs. Up to now, the most widely used GHG emission scenarios are the first generation developed by IPCC.[9] The most recent national communications, such as that of Mauritania, considered the second generation of scenarios, the SRES. Almost all the studies on vulnerability and adaptation made at national level in the region used pre-existing climate change scenarios. The horizons of selected time frames vary from the years 2020 to 2100, most scenarios being focused, however, on 2025 and 2050 in terms of time horizon. This undoubtedly translates the concern of getting closer to nearer futures and of taking into account the concerns of the decision makers and the national forecasts made by economists/planners.

The majority of the coastal countries also considered one or more assessment scenarios of sea level. The results obtained show the vulnerability of the coastal areas and the ecosystems.

### 2.2.2 Impacts on fresh waters and continental wetlands

#### Rainfall

Even if model simulations are not consistent from one model to the other, with regard to West Africa, it is to be noted that the evolutions in future rainfall by the majority of GCMs are relatively modest, at least compared to the variability of current rainfall. Most climate change scenarios consider a reduction in precipitation, which varies from 0.5–40% with an average of 10–20% for the horizons 2025. In Senegal for example, the study done in the framework of the national communication, expects a reduction of the annual rainfall from 7–24%, compared to the average annual rainfall of 1961–1990. In

[9] The IS92 scenarios are the first generation of emission scenarios of greenhouse gases of IPCC, the last generation being those of SRES. The IS92a scenario is based on hypotheses corresponding to the maintaining of current emission trends.

Mauritania, rainfall would drop according to the latitude and will be 1% in the north and 30% in the south. Togo considers very limited variations of precipitation (lower than 1%). In addition, some countries took into account a hypothesis of precipitation increase (Mali, Burkina Faso).

### Surface and ground waters

Although the forecasts, with regard to streamflow and ground water recharge, vary at the regional level according to the envisaged changes in precipitation, the majority of climate change scenarios report a decrease in flow and recharge of ground water tables in the arid and semi-arid countries of the region. In general, river flow is expected to decrease in proportions varying between five and 34% according to the time horizon and the country. Furthermore, there will be a fall in the ground water level following the reduction in their recharge as well as a reduction in the number and size of ponds and watering points. As an increase in the demand for human consumption and irrigation is expected (five times by 2025, according to the West African Water Vision), some countries such as Burkina Faso, Cape Verde and Niger could experience water shortage.

### Extreme events

There is lack of information to confirm or invalidate the common assumption that a fall in the magnitude of floods in much of the region and their localized increase in the Sahelian areas are subject to man-made activities. However, the major droughts and a certain number of recent floods of unusual magnitude in the Sahel and in other regions cause many specialists to expect exacerbated climate extremes in some parts of West Africa. Seasonal low flows could drop in many areas because of lower groundwater levels and greater evaporation.

### Socio-economic impacts

In the agricultural sector, a reduction in the yield of the major crops is expected (maize, early and late millet, sorghum, rice, cowpea), and therefore a reduction in cereal production in particular. The Gambia, however, anticipates a 15–47% increase in the production of groundnut because that crop adapts better to land degradation and to decreasing rainfall resulting from the expected climate change.

In the livestock sector, countries like Cape Verde and The Gambia simulated fodder production. Thus, deficient fodder productions are expected (with some uncertainties about time horizons) and livestock health problems, while in Niger, the models predict a reduction in the livestock. The amplitude of livestock transhumance movements is expected to increase.

The shrinking of continental wetlands (Niger River Inland Delta, floodplain of the Senegal River Valley, Lake Chad) is expected to continue and, combined with the decline in the rate of river flow, will consequently lead to the modification of the ecological niches and the life cycles of aquatic animal species, fish in particular. In the case of Lake Chad, it is already observed that fish catches dropped from 100,000 tonnes per annum in the 1970s to less than 60,000 tonnes today. With regard to forests, Burkina Faso and Côte d'Ivoire have not recorded any effects of climate changes, whereas other countries, located further north (Niger) anticipate the disappearance of some natural forests. The Gambia estimates that by 2075 the country will be covered by dry and very dry tropical forests.

The energy sector (hydroelectric power generation) could be affected, as in the case of Ghana mentioned earlier in this document. The reduction in river flow will also affect hydroelectric power generation in countries such as Côte d'Ivoire, Togo and Benin.

Climate change could also seriously affect the health sector, even if few countries (Niger and Togo for example) have tackled this issue systematically. Niger and Togo anticipate the resurgence of malaria, an upsurge in the epidemics of meningitis and measles as well as respiratory diseases.

### 2.2.3 Impacts on coastal areas according to climate change scenarios

In the first global analysis of vulnerability to the impacts of sea level rise (IPCC/RSWG, 1990), eight out of the 50 countries classified as the most vulnerable in the world, are located in West Africa: Guinea Bissau (6th most vulnerable country), Liberia (16th), The Gambia (17th), Sierra Leone (23rd), Togo (36th), Benin (39th), Senegal (45th) and Ghana (46th).

The tables below show the results of simulations of some impacts of climate change on the coastal zones of West Africa.

**Table 4a. Effects of climate change on the coastal zones of some West African countries: scenario of rise in sea level of 0.5m by the year 2100**

| | Land lost by erosion ($km^2$) | Areas to be flooded ($km^2$) | Population at risk (thousands) | Value of properties affected (millions of US$) |
|---|---|---|---|---|
| Senegal | 28–44 | 1,650 | 69–104 | 345–464 |
| Côte d'Ivoire | n.a. | (281.3) 471 | 1,475 | 4,710[10] |
| Benin | 22.5 | 17.5 | | |
| Nigeria | 78–145 | 8,864 | 1,600 | 9,003.3 |

**Table 4b. Effects of climate change on the coastal zones of some West African countries: scenario of rise in sea level of 1m by the year 2100**

| | Land lost by erosion ($km^2$) | Areas to be flooded ($km^2$) | Population at risk (thousands) | Value of properties affected (millions of US$) |
|---|---|---|---|---|
| Senegal | 55–86 | 5,987 | 112–183 | 499–707 |
| Côte d'Ivoire | n.a.[11] | (562.5) 924 | 2,455 | 9,240 |
| Ghana | | 1,110 | 132.2 | |
| Benin | 145 | 85 | | |
| Nigeria | 156–428 | 17,968 | 3,180 | 18,134.1 |

*Sources*: Senegal: Denis *et al*., (1995); Côte d'Ivoire: Jallow *et al*., (1999) and Initial National Communications (the values in brackets relate to the Abidjan area alone); Ghana: Initial National Communication: Benin: Adam (1994); Nigeria: French *et al*., (1995).

[10] This value was equivalent to Cote d'Ivoire's budget!

[11] Only the retreat of the coast has been evaluated (between 35 and 62m) (Jallow *et al*., 1999).

One of the most immediate major impacts of the rise in sea level will be the flooding of the lowest coastal zones (the deltas and estuaries in particular). This will result in the loss of significant housing areas and industrial and communication facilities, as well as cultural sites in and close to large cities like Banjul, Abidjan, Lomé, Cotonou, Lagos, Port Harcourt, etc.

Significant areas of mangroves and coastal wetlands will also disappear. In countries such as Senegal, The Gambia and Nigeria, some studies estimate that all the mangrove areas will be decimated in the event of a rise in sea level of one centimetre per annum (i.e., one metre in a century) (Nicholls *et al*., 1995). In Senegal, it is estimated that 37% of the surface areas of mangroves would be lost, in the event of a rise in sea level of 0,5cm, by the year 2100 (Dennis *et al*., 1995). The loss of the coastal wetlands and the mangroves, among other things, will affect the local economy which depends on them (for example, oyster fishing) and will disturb the migration cycle of millions of migratory birds. Sea encroachment will also result in the increase in salinization of soils, ground water and surface water in the coastal countries of the region. This concern was mentioned in the national communications and adaptation strategy documents of countries such as Cape Verde, Ghana, Togo, Benin, The Gambia and Senegal. In the latter country, a recent study shows that salt water intrusion will further affect the aquifer of Dakar (Faye *et al*., 2001).

In addition to infrastructure and housing, the most plausible scenarios of climate change and their expected rate of the rise in sea level will seriously affect sensitive sectors of the economies of the coastal countries in the region: agriculture (with the loss of cultivated lands or land salinization), tourism (whose infrastructures are located essentially along the coast), fishing and marine transport.

### 2.2.4 Conclusion

Significant uncertainties surround the science of the future climate. Most climate change scenarios predict a decline in precipitation in the range of 0.5–40% with an average of 10–20% by 2025. Many of these scenarios portray a generally more pronounced downtrend in flow regimes and the replenishment of groundwater. As a result of the major droughts and a number of recent floods with unusual magnitudes, specialists expect exacerbated extreme climate events in some parts of West Africa. Most coastal countries also considered scenarios of increase in sea level (0.5.–1m over a century), with more or less significant losses in housing zones and economic infrastructures and the disappearance of significant areas of mangrove and coastal wetlands. However, it is important to point out that the climate change scenarios used do not consist of definite predictions but rather present plausible future climates. Considering the many possible future scenarios, what matters is the ability to manage the uncertainty. This includes reducing current vulnerability to climate variability and change as well as keeping management options open to deal with the worst-case scenarios and to take advantage of opportunities that may arise.