CHAPTER 2

Climate of Central Africa: past, present and future

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1. Introduction

Albeit some improvements, climates and paleoclimates in Central Africa are still unsufficiently known. This uncomplete knowledge results from the lack of local data, the disperse networks of past and current measuring and the very few pieces of scientific work on climate in this region. Consequently, some uncertainty still prevails on how these climates may evolve in response to current climate warming. In order to understand changes that might affect these climates, it is necessary to get some solid knowledge about their current functionning, more specifically the way they fit into the global climate system and to what extent they affect climate variability and changes in the tropical zone (Camberlin, 2007). Few existing studies show that the Region presents some mild interannual rainfall variability when contrasted to other regions with similar annual rainfalls. The spatial coherence is also particularly weak. These two elements reflect some small sensitivity to interannual major forcing of tropical climate, notably to sea surface temperatures. One also may predict an increase in extreme events, disruptions in the frequency of meteorological catastrophic events, hence hazards. Consequently, it is necessary to understand how countries in the region get organized with regard to climate change challenges.

Photo 2.1: Deforestation causes climate changes at the local level, promoting the loss of water available through rising temperatures, evaporation and runoff

2. General climate context

Due to its geographic situation, Central Africa confers a variety of climate types which can be grouped into two broad types: equatorial and tropical (Figure 2.1). Some areas of limited extent are subjected to montane climate, such as the Albertine Rift (towards the East of DRC) and the Cameroon volcanic line.

Equatorial climate with four seasons stretches up to southern Cameroon and CAR, the centre of DRC, in Congo, in Gabon, in Equatorial Guinea and in Sao Tomé and Principe (Mpounza and Samba-Kimbata, 1990). Mean annual rainfall is about 1,500 to 1,800 mm with some extremes as high as 10,000 mm in Debundsha, in south-west of Mount Cameroon, and south of Bioko Island in Equatorial Guinea. The climate is warm and humid with temperatures ranging between 22°C and 30°C.

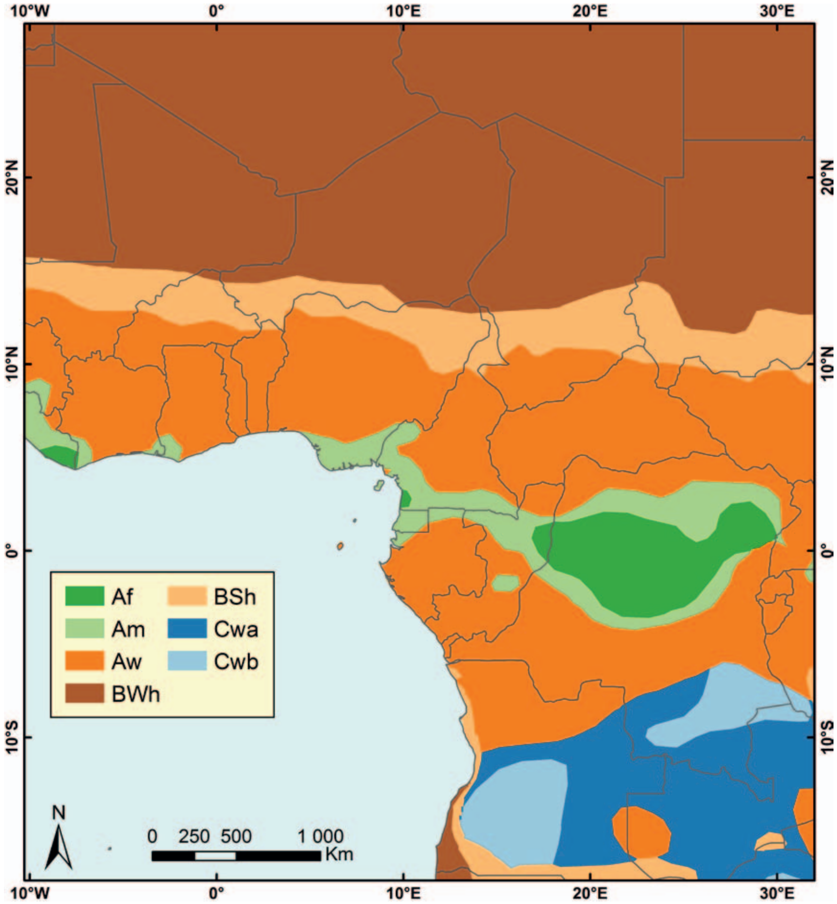


Figure 2.1 : Climate classification of West and Central Africa using the Köppen-Geiger system[15] (Peel et al., 2007). Af = equatorial/humid, Am = tropical/monsoon, Aw = tropical/dry winter, BSh = semi-arid/dry, hot, BWh = arid/ hot, Cwa = hot temperate/dry winter/hot summer, and Cwb = hot temperate/dry winter/warm summer.

Tropical climate, with two seasons, presents several sub-types : Sudanese, Sahelian and Saharan. Sudanese, sudanese-sahelian and sahelian sub-types are found in North Cameroon, the south of Chad, the centre and north of CAR. The southern DRC has a more temperate climate due to an average altitude higher than other areas. Mean annual rainfall ranges from 300 mm to 1,500 mm. Shahelo-Saharan and Saharan subtypes only include north of Chad where the mean annual rainfall is below 300 mm and where maxima temperatures may reach 50°C (Godard and Tabeaud, 2009).

The equatorial and tropical climates of the Northern hemisphere are characterized by a dry and sunny main dry season (December to February), while those in the Southern hemisphere, especially to the Atlantic coast, have a cloudy dry season cover preserving very high levels of humidity (June to August). These climatic differences, on both sides of the climatic hinge separating the northern and southern climates, impact on the vegetation and their importance is too often unrecognized regarding future climate changes (Gonmadje *et al.*, 2012 ; Monteil *et al.*, in prep.).

3. General functionning and characteristics of present climates

3.1 Dynamic of the atmosphere

Two circulation modes – the Hadley circulation and the Walker circulation – control the movements of air masses and climate in Central Africa.

3.1.1 The circulation of Hadley

The circulation named after Hadley (Figure 2.2), between the equator and the tropical latitudes (30°), commands weather types and climates in Central Africa.

The high temperatures in the equator lead to significant evapotranspiration and the formation of clouds causing heavy rainfall. While rising in the atmosphere, the air becomes progressively drier towards higher altitudes. It then moves north and south and, when cool enough, descends to the lower layers of the atmosphere (Figure 2.2). Strong updrafts winds at the equator make the effect of a pump which then attracts surface winds of tropical latitudes towards the equator. The south and north trade winds meet along a surface of discontinuity called Inter-Tropical Convergence Zone (ITCZ) or Inter-Tropical Front (ITF). The ITCZ migrates north from January to July and allows the southern trade winds, that change direction and load oceanic moisture, to dump heavy rains on the African continent. At its migration peak towards

15 Note : This map is a very general outline that reflects only partially the variability of climates in Central Africa. In particular, most of Gabon and Congo benefits from equatorial to subequatorial climates, intermediate between the climates Af, Am and Aw.

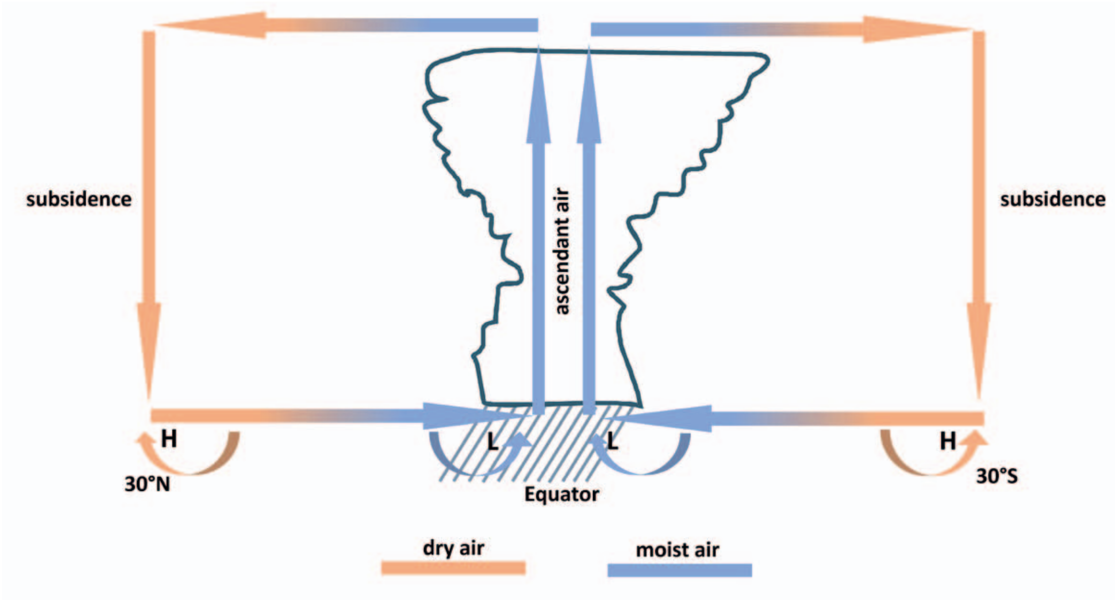


Figure 2.2: Section of Hadley cells on both sides of the equator (adapted from Demangeot, 1992)

north, the southern trade wind is very close to the continent and causes the dry season from July to August in areas located in the southern part of the region. Starting in July, the trade winds from the north-east, also called Harmattan, deploy itself to the South thanks to the retreat of the ITCZ. It reaches its southernmost position in January, providing dry weather corresponding to the dry season in northern Central Africa.

Figure 2.3 shows the ITCZ average positions and the Interoceanic Convergence (IOC) on Africa during the year. The IOC is materializing the confluence of winds from the Atlantic and the Indian oceans. Although the impact of the IOC movements during the year is far from negligible, particularly in the east of the area we are concerned with, the migrations of ITCZ are of the utmost importance to countries impacted by them since they allow to understand the patterns of seasons and their variations among years. These migrations are influenced by the earth rotation and the rotation around the sun as well as ocean surface temperatures. Man, through his activities (afforestation, deforestation, bush fires, air pollution, etc.), may make the composition of the air masses more complex and impacts on their movements and raining capacity.

Photo 2.2: Small mountains along the Atlantic coast benefit from a high atmospheric moisture from the ocean which favor the development of dense evergreen forests

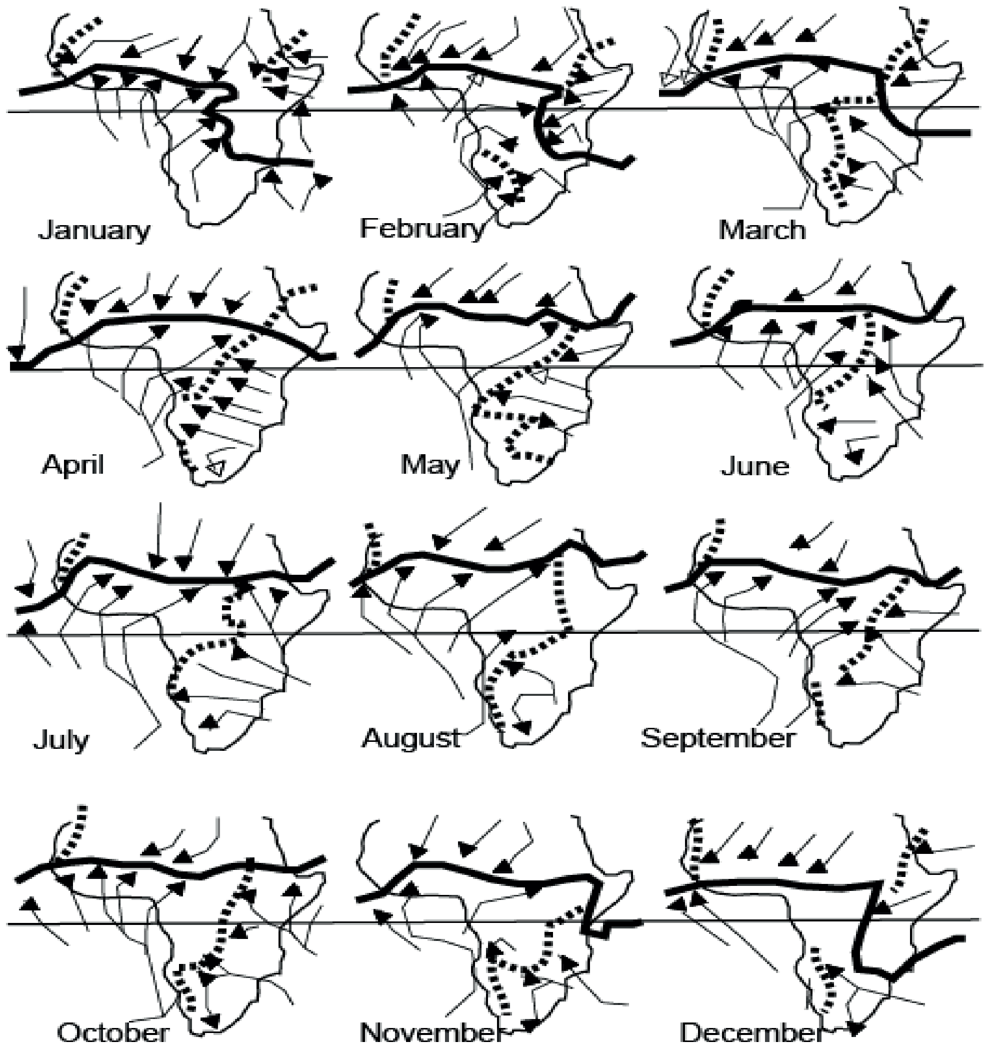


Figure 2.3 : Mean monthly position of the ITCZ (plain line) and the Inter-Oceanic Confluence (dash) across Africa (Samba-Kimbata, 1991 ; Bigot, 1997).

3.1.2 The Walker circulation

Central Africa is also subject to a cell circulation linking the climates of the entire tropical belt. Seasonnal anomalies in regions located East and West of the Congo Basin originate from this so called "Walker circulation" (Figure 2.4).

Walker and Hadley circulations combine themselves to impact seasonnal and annual climatic parameters.

3.2. Impact of the ocean circulation

The ENSO phenomenon (El Niño Southern Oscillation) seems to partly impact climates in Central Africa as well as Sea Surface Temperatures (SST). Rainfall variability seems to be linked to ENSO and the western Indian Ocean in the first months of the year, and to the Atlantic during the June-August period ; the Indian Ocean becoming again important later on (Balas *et al.*, 2007). Precipitations in Central Africa are promptly and seasonnaly impacted by the behaviour of sea surface temperatures, especialy in the Atlantic Ocean, in relation with the dynamics of the ITCZ. Years during which the Southern Atlantic Ocean is warmer than usual show a lack of rainfalls during July-September period north to 10°N latitude, and in October-December south of Cameroon then Gabon. Conversely, on the southern fringe of the

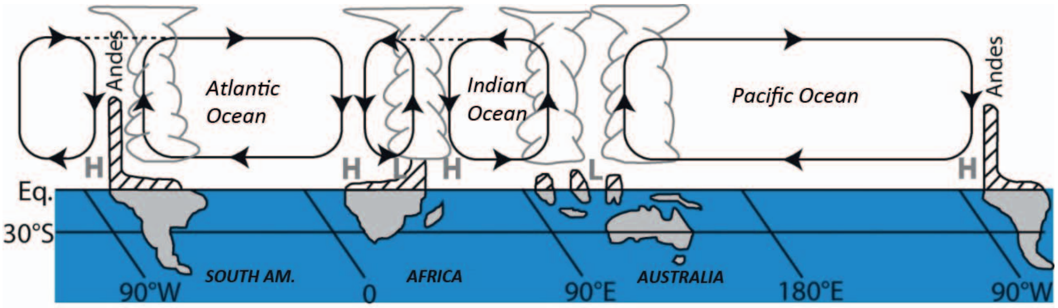


Figure 2.4 : Walker circulation

Source : Dhonneur, 1985

ITCZ, a warm central Atlantic Ocean goes with some excess of rainfalls, at least close to the ocean.

3.2.1 Space and time variability of rainfalls at a regional scale

3.2.1.1 Mean annual rainfalls

Figure 2.5 shows the variations in rainfall between the early twentieth and the early twenty-first centuries (Djoufack, 2011; Djoufack and Tsalefac, 2014). All in all, one observes two areas of high precipitations (P>2,500 mm) : the one above and below the equator (equator stripe) and the coastal area of the Gulf of Guinea. Elsewhere, total annual rainfalls do not exceed 1,500 mm. North of 15th parallel, Saharan and Sahelian areas get less than 500 mm per annum.

The bottom of the Gulf of Guinea and, in general, the Atlantic Central Africa is under the influence of the African monsoon and experience heavy rainfall. This ocean influence combines with other influences (relief, vegetation, etc.) to create the diversity of local climates. Therefore the high pluviometry on the coastal area from Cameroon to Gabon is directly or indirectly related to the presence of highlands such as Mount

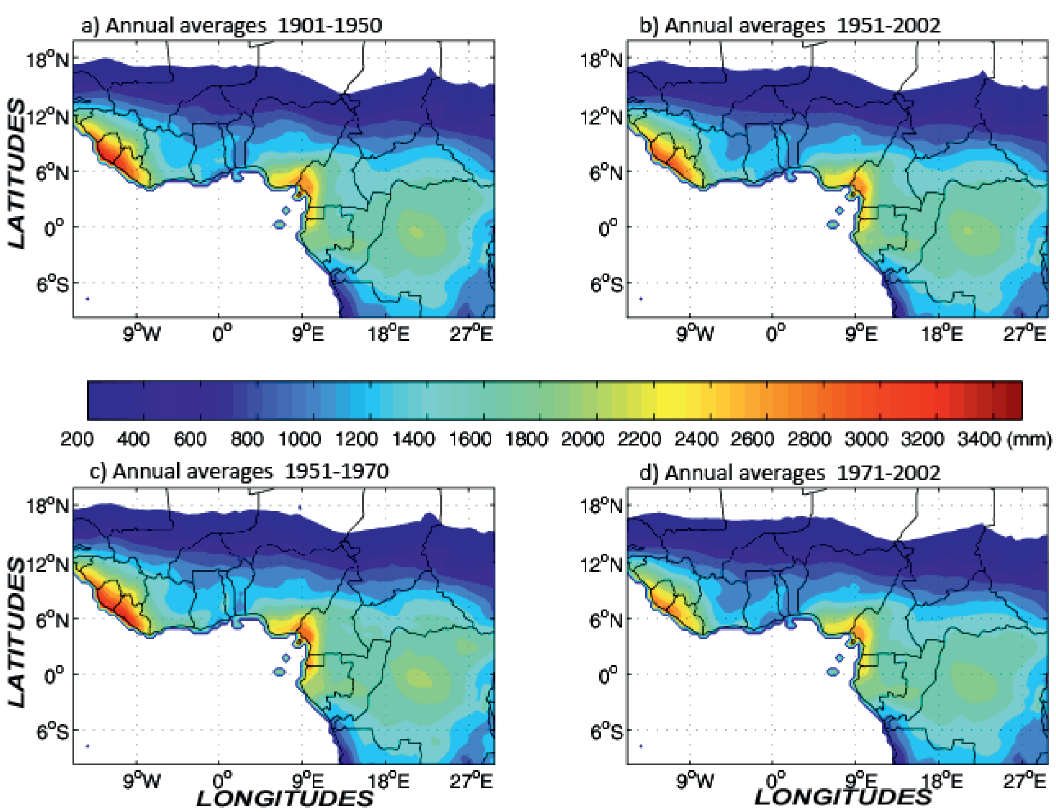


Figure 2.5 : : Changes in annual rainfall (mm) between 1900 and 2000 at the regional level; a) average 1901-1950 ; b) average 1951-2002 ; c) average 1951-1970, d) average 1971-2002.

Photo 2.3: If the climate dries up, rare ecosystems of high ecological value such as the swampy clearings could disappear

Cameroon or the small mountains bordering this atlantic coast.

The Congo Basin also has its heavy rainfall, less from the influence of the ocean than from the evapotranspiration of its forest and marshy cover (Bigot, 1997).

3.2.1.2 Precipitation trends

Figure 2.6 suggests that rainfalls remained relatively abundant during the last century, although they seem to have decreased since the 1950s and especially since the 1970s. Thus, one has noticed a downward trend of total precipitations of 31 mm/decade between 1955 and 2006 (Aguilar *et al.*, 2009). The biggest fall of precipitation levels were seen during the decade 1968 – 1980 (Mahé, 1993) and were not of even intensity across the region. In the south of Cameroon and in Congo, the fall in precipitation has occurred until 1990. Besides, in Gabon and CAR, one has observed a rise after 1980 and 1985 respectively (Mahé, 1993).

Some discrepancies were also noticed at a local scale (Tsalefac *et al.*, 2007 ; Tsalefac, 2013). While the pluviometry in the north of the Republic of Congo is marked by a fall, it remains stable in the south of the country (Samba-Kimbata, 1991). Similarly, one has noticed a decrease in the number of rainy days with precipitations >1 mm, as well as a decrease of the number of days with precipitations >10 mm (Aguilar *et al.*, 2009).

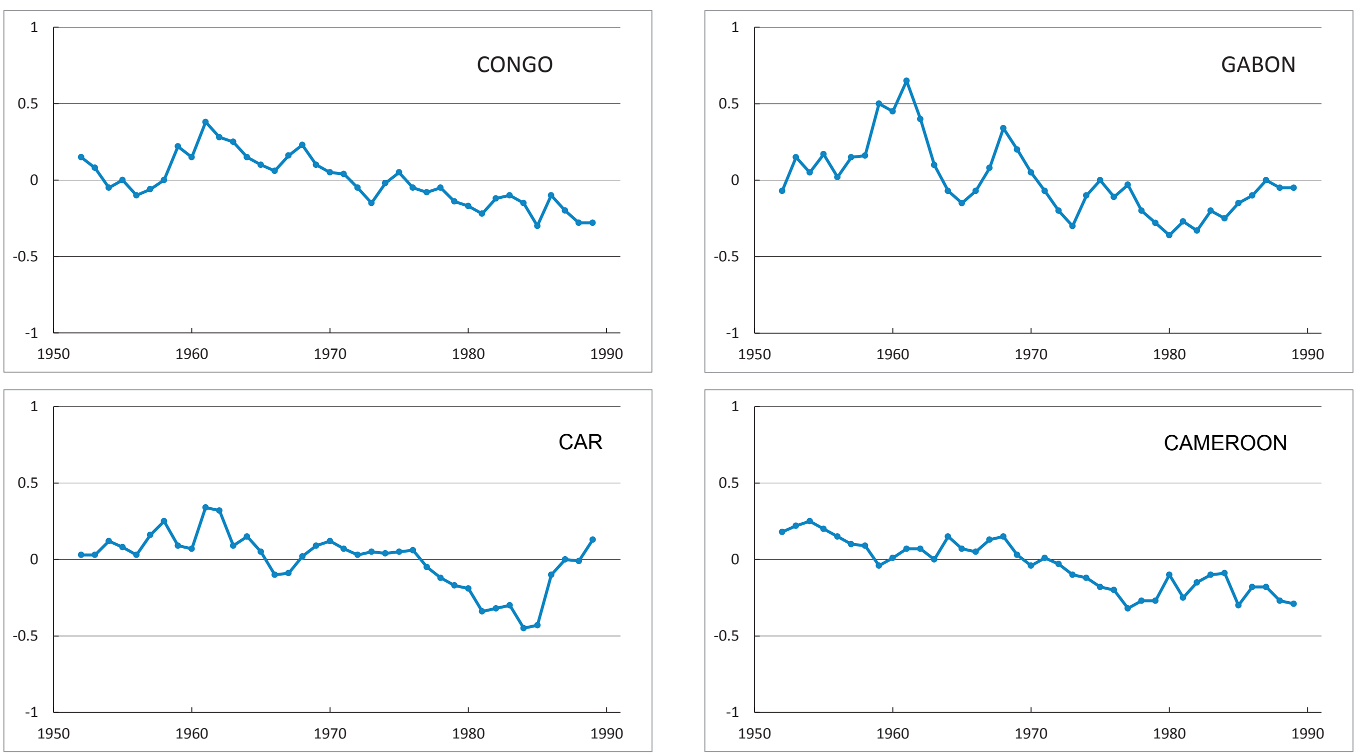


Figure 2.6: Evolution of annual precipitations since 1950 in different regions of Central Africa (Mahé, 1993)

3.2.1.3 Trend in temperatures

Conversely, temperatures show an upward trend. In the Republic of Congo, over a period of time from 1950 until 1998, temperatures have increased by 0.5°C up to 1°C during the decades 1980s and 1990s (Samba-Kimbata, 1991). Regarding changes of temperature in the long run observed in the region, data available from local weather stations, although limited, tend to show some warming at a statistically significant level (GIEC, 2007). This trend is accompanied by an increase in extreme temperatures (for example, the temperature of the hottest day seems to increase by 0.25°C every new decade) while period of time with cooler weather have become less frequent (Aguilar *et al.*, 2009). Nevertheless, given the scarcity of data from field stations, it seems very difficult to draw definitive conclusions on the evolution of current climates.

4. Past climate of Central Africa

Paleoclimates in Central Africa are relatively well known over the period of time spreading over the Upper Pleistocene and Holocene for which the chronology of climatic events has considerably evolved, mainly due to C^{14} dating. Palynology and sedimentology studies in lakeside and sea sediments allow a relatively coherent scheme of paleo-climates (Table 2.1).

Around 4,000 years BP, the sea surface temperature decreased and precipitation lowered. At that time, erosion and alluvial deposits, however, remained moderate. This phase of relative drying changed suddenly around 2,500 years BP with a change in the seasonal distribution of rainfall. Despite higher sea surface temperatures and rainfall probably more sustained than previously, the length of the dry season seemed to increase, causing negative effects on forest cover. At that time, erosion and alluvial deposits intensified, showing the existence of a more tropical climate with contrasting seasons.

From 2,000 years BP, a wet phase resettles to the current days, interspersed with drier periods such as the one that took place between 500 and 200 years BP (from the XV^th^ to the XVIII^th^ century), corresponding to the small Ice Age in Europe.

Photo 2.4: Mangroves will undoubtedly suffer from future sea level changes

Table 2.1: *Overall evolution of past climates in Central Africa according to palynological and sedimentological data*

Chronology	Climate	Indicators
-22,000 à -16,000 years BP(*) (Kanemian)	Cool and dry climate	Presence of aeolian sediments and dunes along the banks
-16,000 to -8,000-7,000 years BP (Bossumian, Pleistocene transition)	Humid phase	Sealing of fairways and mangrove development; development of rainforests
-7,000 to -4,000 years BP	Persistence and peak of the humid phase	Maximum development of forests towards -6,000 years BP and then beginning of fragmentation on the forest margins
-3,000 to -2,000 years BP	Sudden dry phase	Sudden shrinkage and opening of forests, deepening of fairways, strengthening of Benguela Current (Giresse, 1984)
-2,000 to -1,800 years BP	Sudden come back of humid phase	Expansion of forests on land not used by men

(*) BP = before present.

5. Predicted climate of Central Africa

5.1. Global and regional assessments of climate changes

Assessments on how precipitation and near surface temperature, the most important climate parameters, might change over the course of the 21st century have been made by several COMIFAC countries in the framework of their national communications to the UNFCCC. These assessments were based on projections of Global Circulation Models (GCM) and display a limited accuracy due to their coarse spatial resolution (up to 500 km). As Appendix 1 shows, their projections differ substantially between the countries.

At regional level, climate projection studies are available that cover the Congo Basin completely or at least to a large portion, even though the region was not always the focus of these studies (Sonwa *et al.*, 2014). Most of these studies go only up to the middle of the 21st century and use the input of only one GCM run for one specific scenario. But recently, a comprehensive regional climate change assessment was conducted over the Congo Basin region from 2010 to 2012 (CSC, 2013). In this assessment, 77 existing and additionally compiled global and regional climate change projections were analyzed for high and low GHG emission scenarios respectively. This study allowed not only to estimate the potential magnitudes of projected climate change signals but also enabled to judge on the reliability of the projected changes. Furthermore, a representative subset of the climate change projections has been used as input for subsequent impact assessments and the formulation of adaptation options.

5.2 Near surface air temperature

The aforementioned Climate Change Scenarios study (CSC, 2013) revealed that for near surface air temperature all models, independent from season and emission scenario, show a warming of at least 1°C towards the end of the 21st century. The frequency of cold/hot days and nights, will decrease/increase respectively, again independently from season and emission scenario (Table 2.2). Since all models are projecting changes in the same direction, the likelihood of these changes to occur is very high. However, the full range of possible changes is large and mainly caused by a few outlier model projections.

Therefore a sub range (the central 66 % of projections) defining changes being likely to occur was defined. For near surface annual mean temperature the likely changes towards the end of the century, are between +3.5°C and +6°C for a high emission scenario and between +1.5°C and +3°C for a low emission scenario (Haensler *et al.*, 2013). In general, projected temperature increase is slightly above average in the northern parts of the region, North of the climatic hinge, and slightly below average in the central parts.

Table 2.2 : *"Likely range" (centered on the median) of projected changes (in %) for the frequency of cold/hot days/nights averaged over the entire Congo Basin region.*

Projected Changes	Low emission scenario		High emission scenario	
	2036 – 2065	2071 – 2100	2036 – 2065	2071 – 2100
Cold nights (in %)	-9 to -7	-10 to -7	-9 to -8	-10
Cold days (in %)	-8 to -5	-9 to -6	-9 to -6	-10 to -9
Hot nights (in %)	+27 to +43	+29 to +56	+38 to +53	+64 to +75
Hot days (in %)	+12 to +21	+13 to +29	+16 to +28	+31 to +54

Source : Haensler et al. (2013).

5.3 Total precipitation

According to Haensler *et al.* (2013), for total precipitation, the results of the different projections are not as robust as for near surface air temperature. Some models project an increase of annual total precipitation in most parts of the Congo Basin region, whereas other models project a decrease over the same areas. However, the same authors are projecting towards the end of the 21st century a general tendency for a slight increase in future annual total precipitation for most parts of the Basin. Largest increase in annual total precipitation is projected over the generally dryer northern part, which is mainly related to the northward expansion of the ITCZ and to the fact that total precipitation amounts are rather small over this region. The range likely to occur for changes in total annual precipitation is between -10 to +10 % in the more humid zone and between -15 to +30 % in the more arid zone. It thus seems rather unlikely that drastic changes in annual total rainfall will occur in the future.

In contrast, the rainfall characteristics are projected to undergo some substantial changes. The intensity of heavy rainfall events is likely to increase in the future (likely range for most parts positive, up to +30 %). Also the frequency of dry spells during the rainy season is for most parts of the domain projected to substantially increase in the future, indicating a more sporadic rainfall distribution.

Photo 2.5: Transport of logs floating on the Mfimi river (Bandundu -DRC)

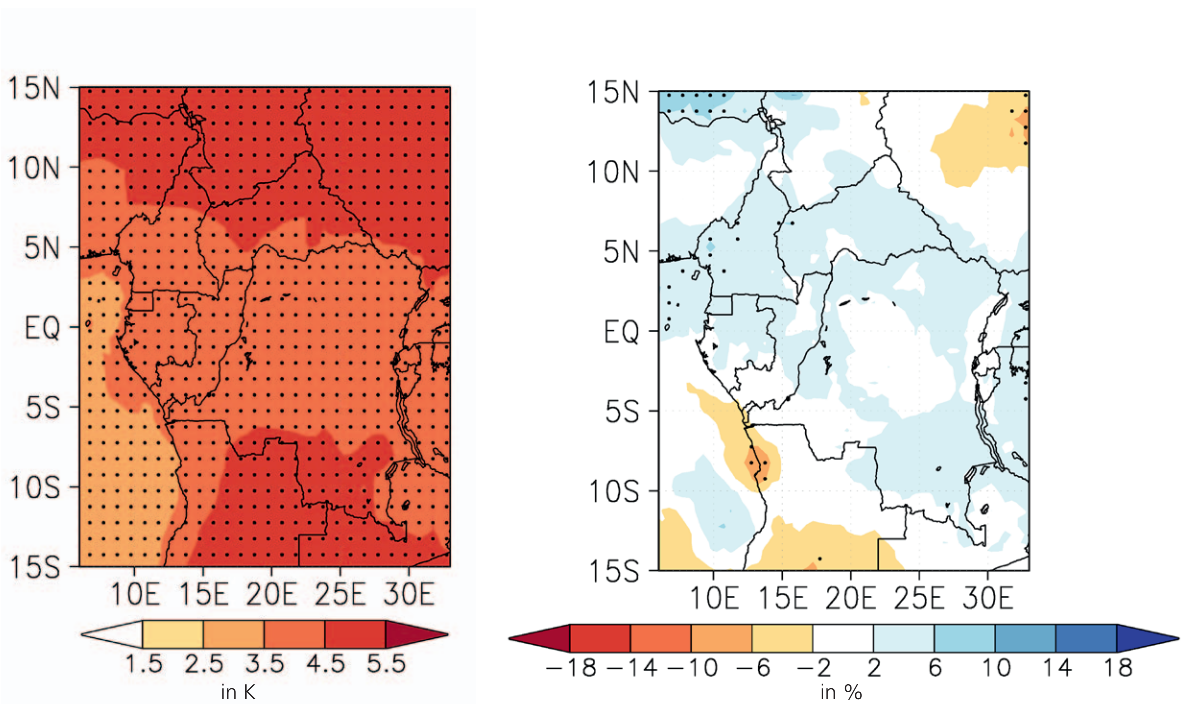


Figure 2.7: Projected change in annual mean temperature (left) and annual total precipitation (right) until the end of the 21st century (2071 to 2100) for a high emission scenario.

Source: CSC (2013)

The depicted change in figure 2.7 is the median change from a set of 31 different climate change projections from global and regional climate models. The black stipples highlight regions where the majority of the models agree in the direction of change. Changes in these regions are therefore more robust than over regions without stipples.

6. Current climatic delineation and water regime trends

Abrupt climate change occurred over Africa several decades ago with different impacts on river regimes (Laraque *et al.*, 2001 ; Mahé *et al.*, 2013). These changes on river regimes are related both to climate change and to human activities. Central Africa seems much less impacted by human activities as it is the case in other African areas, due to less population density and less agricultural development.

In Central Africa, hydrologists have studied the hydrological regime of many rivers for decades since the 1950s. Data are gathered in the SIEREM information system (Boyer *et al.*, 2006); (http ://www.hydrosciences.org/sierem/) and in the Hybam observatory for the Congo catchment (http ://www.ore-hybam.org). These data are used to study the variability of the river regimes, which can be linked to rainfall changes.

6.1 Global trends of hydrological regimes of large watershed in Central Africa

Long time series of annual discharges standard values for several large river basins of West and Central Africa have been studied within large regions (Mahé *et al.*, 2013). They show differences in the interannual variability according to the region. Common periods of low flows and high flows can be observed (during the 1910's, 40's, 60's, 70's). But some periods show discrepancies in the evolution (50's and 80's). Equatorial rivers do not show any interannual trend, while tropical rivers follow a decrease since the 70's, and Sahelian river discharges increase since the 80's.

6.2 Case study of the impacts of climate change on the hydrological regime of the Congo River watershed

Beyene *et al.* (2013) made an assessment of impact of projected climate change on the hydrologic regime and climate extremes of the Congo River basin. This specific river basin, despite its huge importance and implications to the regional hydrological cycle, has the least number of climate change impact studies in Africa to date. Land surface hydrologic modeling, used bias-corrected and spatially downscaled climate data from three GCMs (CNCM3, IPSL, and ECHAM5) and two emissions scenarios (A2-High and B1-Low), to simulate historical and future hydrologic regimes. The reference historical observations from the newly available global WATCH (http ://www.waterandclimatechange.eu/) and the forcing dataset (henceforth referred to as WFD ; Haddeland *et al.*, 2011) were used to simulate the current

Photo 2.6 : Herd of cattle entering the Faro National Park in the dry season (Cameroon)

status of the hydrologic regime of the Congo River basin. The current and future hydrologic regime change in the Congo River basin was simulated using the Variable Infiltration Capacity model (VIC), and then assessed (Beyene *et al.*, 2013). The following results were found on key hydrological parameters.

6.2.1 Evaporation

According to Beyene *et al* (2013) the model simulation outcomes indicated that climate change will result in increased evaporation throughout the basin. The change is quite evenly distributed throughout the basin but the increase in evaporation will be slightly higher towards the edges compared to the central Congo Basin. On average, the increase in evaporation by the end of the century will be about 10 % for the A2 emission scenario and 8 % for the B1 scenario (Table 2.3). The different climate models gave similar results and for all six scenarios the evaporation increased.

Increased evaporation as a result of climate change is reported in many other studies, especially if the rainfall is increasing (Beyene *et al.*, 2013). It is important to note here that the Variable Infiltration Capacity (VIC) modeling framework used for this assessment does not include the direct impact of CO_2 enrichment on plant transpiration. Higher CO_2 concentrations reduce plant transpiration because the leaf stomata, through which transpiration takes place, have to open less in order to take up the same amount of CO_2 for photosynthesis (Lambers *et al.*, 1998). It is thus possible that VIC over estimates the impact of climate change on total evapotranspiration.

Table 2.3 : *Summary of changes in precipitation, evapotranspiration and runoff across the Congo River basin using climate change scenarios (30-year average changes not weighted) for the 2050s and 2080s, for SRES A2 (high) and B1 (low) emissions scenarios expressed as percentage change of the historical base simulation (1960 – 2000)*

GCM	Precipitation				Evapotranspiration				Runoff			
	A2		B1		A2		B1		A2		B1	
	2050	2080	2050	2080	2050	2080	2050	2080	2050	2080	2050	2080
CNCM3	+8	+12	+10	+6	+8	+11	+8	+9	+12	+15	+10	+9
ECHAM5	+6	+21	+8	+15	+13	+17	+3	+5	+16	+60	+24	+42
IPSL4	+11	+9	+5	+13	+9	+12	+9	+11	+19	+6	-3	+20
Multi-model average	+8	+14	+8	+11	+10	+10	+7	+8	+15	+27	+10	+23

Source : Beyene et al. (2013).

Box 2.1 : *Runoff and discharge*

Runoff, in hydrology, is the quantity of water discharged in surface streams. Runoff includes not only the waters that travel over the land surface and through channels to reach a stream but also interflow, the water that infiltrates the soil surface and travels by means of gravity toward a stream channel (always above the main groundwater level) and eventually empties into the channel. Runoff also includes groundwater that is discharged into a stream ; streamflow that is composed entirely of groundwater is termed base flow, or fair-weather runoff, and it occurs where a stream channel intersects the water table (from Encyclopaedia Britannica).

Discharge, in hydrology, is the volume rate of water flow, including any suspended solids (e.g. sediment), dissolved chemicals (e.g. $CaCO_{3(aq)}$), or biologic material (e.g. diatoms), which is transported through a given cross-sectional area (from Wikipedia).

Photo 2.7 : The erosion settles gradually on the abandoned logging roads

6.2.2 Runoff

Beyene *et al.* (2013) found that in most scenarios the runoff is increasing (Table 2.3). The increase in runoff is not evenly distributed throughout the Basin. Runoff is especially increasing in central and western DRC and in the Republic of Congo. Also the Cameroon and part of the Congo Basin shows a relatively high increase in runoff. On the Northern, Southern and Western edges of the Basin, the results are considerably different. Here the increases are marginal and sometimes the runoff decreases. On average, over the whole Congo Basin, runoff is projected to increase by 15 % by mid-century for the A2 scenario and 10 % for the B1 scenario (Table 2.3). By the end of the century, runoff is projected to increase with 27 % for the A2 scenario and 23 % for the B1 scenario.

The changes in runoff also depend on the season. For all three climate models the difference in runoff between dry and wet season are increasing indicating a more variable future hydrologic regime. Also on spatial scale the variability is increasing. Especially in the wetter central and western part of the Basin, the runoff is increasing while at the drier edges the runoff is slightly increasing in some scenarios and decreasing in others. Other previous studies on the impact of climate change on hydrologic characteristics of the Congo River basin show diverse results (Beyene *et al.*, 2013). Arnell (2003) showed a possible decrease in average changes in runoff over the Congo River basin by 2050, using a different set of climate models. Aerts *et al.* (2006) documented an increase in runoff of 12 % in the Congo River basin by 2050 compared to the historical simulations.

Table 2.4 : *Projected relative changes in annual average Congo river flow at Kinshasa for two future periods expressed as percent change compared to the historical time period (1960-2000). Three different climate models were used in combination with a high emission scenario (A2) and a low emission scenario (B1).*

Climate Model	2036-2065		2071-2100	
	A2	B1	A2	B1
CNCM3	20 %	5 %	27 %	17 %
ECHAM5	23 %	28 %	73 %	46 %
IPSL4	8 %	1 %	14 %	18 %
Multi-model average	17 %	11 %	38 %	27 %

Source : Beyene *et al.* (2013).

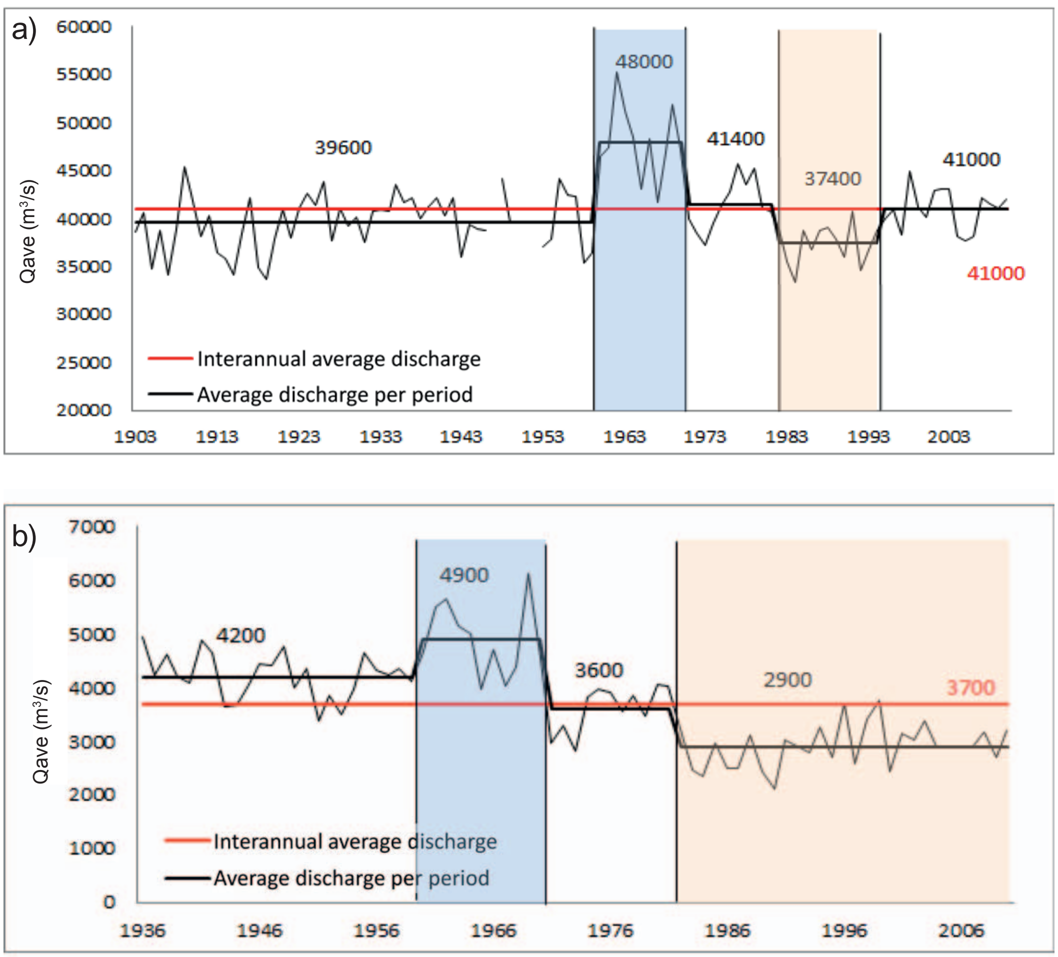
6.2.3 Discharges

Consistent with projected runoff changes, Beyene *et al.* (2013) found that multi-model average annual flows at Kinshasa gauging station were projected to increase between 11 and 17 % by 2050 depending on the emission scenario and by 27 to 38 % by 2080, compared to the historical period (1960-2000 ; Table 2.4). There was a large difference between the climate models in projected changes in discharge.

Increased changes in discharge are especially observed in the wet season. In October, November and December all analyzed scenarios show an increase in discharge. In the dry season, however, both the CNCM3 and IPSL4 models indicate a reduction in discharge for the 21st century. Especially, the IPSL4 model shows a significant reduction in discharge from June until October. These results indicate that during the wet season river flows are likely to increase. During the dry season however results are more uncertain and flows could both increase and decrease. So while total water availability is likely to increase in the future this does not mean that droughts or low flow frequency will reduce in the future. For all scenarios the difference in discharge between the dry and wet season are increasing, indicating that both wet and dry extremes could increase in the future, towards a more seasonal and tropical type climate.

Based on field measurements, Mahé *et al.* (1990), Lienou *et al.* (2008) and Laraque *et al.* (2001, 2013) presented recent changes of river regimes of Central African rivers. According to these studies, the annual discharge time series of these rivers do not show any long term trend like in West Africa. However, a significant drop in the interannual Congo and Oubangui discharges was reported in relation to the average of century's recordings (Laraque *et al.*, 2013). These authors also mentioned that since 1995 discharges of the Congo have been returning to normal, whereas those of the Oubangui and Sangha, despite some recovery, remained drastically below normal levels (Figure 2.8). In 2010 and 2011, the lowest levels in 65 years were observed in Brazzaville, and the Oubangui reached its lowest level in one hundred years in 2012. According to the authors, these changes seem to highlight climatic disturbances that affect more specifically northern regions of the Congo Basin (Oubangui and Sangha basins), north of the climatic hinge, already marked by climatic deterioration.

Photo 2.8: The Ogooué river in the dry season at Okanda (Gabon)



Blue = humid period; Orange = dry period; White = normal period
Figure 2.8.: Sequencing of annual discharges of a) the Congo river in Brazzaville from 1903 to 2010 and b) the Oubangui river in Bangui from 1936 to 2010

Source: Laraque et al. (2013).

In addition, significant changes in seasonal discharges have been noticed (Figure 2.9). For the Ogooué and the Kouilou rivers, and part of the South Cameroonian rivers, the March-June flood decreased steadily over the 1970s and the 80s, when the October-December flood showed no change or a slight increase. Even for the huge Congo River, spring flood is also severely reduced compared to the autumn flood. The flood peak is also observed in April during the recent observation period (years 2001 to 2007), rather than in May before, which is, despite its size, along the same trend than for the Ogooué.

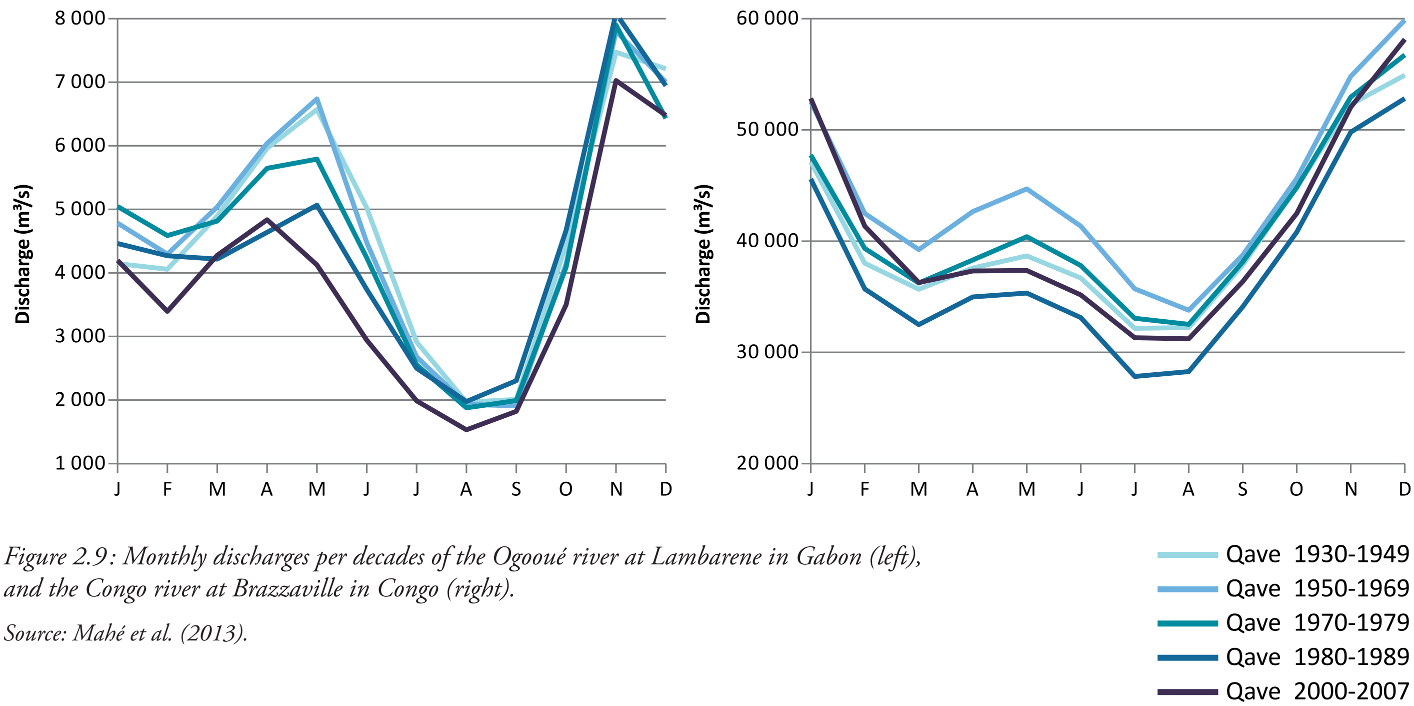


Figure 2.9 : Monthly discharges per decades of the Ogooué river at Lambarene in Gabon (left), and the Congo river at Brazzaville in Congo (right).

Source: Mahé et al. (2013).

7. Issues on climate evolution monitoring in Central Africa

7.1 Climate observation in Central Africa

In 2000, the Global Climate Observing System (GCOS), the World Meteorological Organization (WMO) and the national hydrological and meteorological services made several assessments of the climate observation systems in different parts of the world. The result of this assessment showed that the density and quality of meteorological stations of Africa are the weakest of the world. From 2001 and 2005 regional consultations were then undertaken to develop regional action plans for Africa. Especially, the AU-NEPAD action plan for environment and regional strategy on hazards reduction have underlined the need to improve the availability and the use of climatic data as mean to enhance economic development of Africa. But so far nothing has effectively been done to improve the situation.

Sonwa *et al.* (2014) reported that there are 419 meteorological stations and 230 hydrological stations in the ten COMIFAC countries. Some stations have produced data for well over a century. Regular climate measurements began in 1885 and 1889 at the Douala and Yaoundé stations in Cameroon (Nicholson *et al.*, 2012). According to these authors, the majority of the stations, however, only began their observations in the 1950s and 1960s. Since the 1980s, several stations have unfortunately stopped functioning regularly, and time series are often interrupted, limiting the number of stations with reliable and complete time series data.

To compensate for the lack of field observed climate data, the use of estimates derived from geostationary satellite is becoming widespread. Recent satellite-based studies have been conducted to test some calibration methods (Munzimi *et al.*, 2015 ; Washington *et al.,* 2013). These studies have tended to adopt proxies such as streamflow to represent rainfall quantities or satellite altimetry to evaluate water resources and climate.

7.2 Strategies developed by countries and regional bodies to improve availability of climate data

7.2.1 Climate for development program (ClimDev-Afrique)

ClimDev-Afrique is a common initiative between the African Development Bank (AfDB), the African Union and the African Economic Community (BAD, 2009). Its aim is to facilitate the involvement of climate data producers, especially meteorological and hydrological services and research organizations in development projects in order to create direct links between climatic services and development priorities. ClimDev will enable a continuous flow of climatic data between data producers and users. The AfDB has been mandated to host and manage a special fund for the program, namely the Africa ClimDev Special Fund (FSCD).

Photo 2.9: In many parts of Central Africa, river transport remains of great importance - Kindu beach, DRC

7.2.2 Regional Meteorological Telecommunication Network (RMTN) in West and Central Africa

Central Africa countries are members of the Regional Meteorological Telecommunication Network (RMTN) and ASECNA (*Agence pour la Sécurité de la Navigation Aérienne en Afrique et à Madagascar*). ASECNA is actually coordinating the satellite telecommunication network called SATCOM, which covers Western and Central Africa including Madagascar, and provides communications for civil aviation programs. The SATCOM network has sufficient capacity to also ensure the improved GTS (Global Telecommunication Systems of the WMO) links, which are being implemented for ASECNA members. The SATCOM network offers a unique opportunity to modernize the RMTN in West and Central Africa. Discussions among member countries have been conducted on operational modalities of the SATCOM network to improve the RMTN in ASECNA countries.

Photo 2.10: During particularly pronounced dry seasons, some small rivers may dry completely