Chapitre 4 : Changement climatique et adaptation en Afrique Centrale

Passé, scenarii et options pour le futur

Chapter 4. Climate Change and adaptation in the Congo Basin

Past, scenarios and options for the future

1. Introduction

Evidence for human induced climate change and its impacts on various sectors is steadily increasing and it isdoubtful, whether limiting rising global average temperature to 2 °C above pre-industrial levels is still a realistic goal. According to the 4th Assessment Report (IPCC AR4) of the Intergovernmental Panel on Climate Change (IPCC, 2007), the African continent has an elevated susceptibility towards the stress caused by climate change combined with relatively low adaptation capacities. Sectors identified as the most vulnerable are agriculture and food security, water supply as well as ecosystems. A science policy dialogue in Yaoundé in 2008 stressed that sectors related to forest that were more sensible to climate change included food security, water, energy and health (Sonwa et al. 2012). The vulnerability of these sectors requires that the concepts of sustainable management and the development strategies take climate change aspects into account and be adjusted if needed. Combatting climate change involves two different levels: reducing the rising CO2 concentration in the atmosphere (mitigation) and preparing to live with the inevitable consequences of climate change (adaptation). Forests have played a crucial role regarding mitigation in the international negotiations on climate change since the concept of REDD arose in 2000. Forests store and build in carbon: avoided deforestation and reforestation may have a positive effect on the CO2 concentration in the atmosphere. The role of forests in contributing to mitigation receives increasingly interest in the region, reported in previous editions of the State of the Forest of the Congo Basin (Nasi et al. 2009; Kasulu et al. 2009; Tadoum et al. 2012). COMIFAC and its member countries have put a lot of effort in the international negotiations (common positions on REDD during UNFCCC) and in the implication of the REDD+-concept (regional World Bank REDD+-project and FAO project on MRV).

Forests and adaptation on the other hand, have gained little attention so far. In the tropical forests of Latin America ideas have been developed on how mitigation and adaptation are linked in the forest sector. A panel of African scientists met in 2009 in the framework of the IUFRO Special Program for Developing Countries (IUFRO-SPDC) in collaboration with the thematic group "Forest and climate change" of the Forestry Research Network for Sub-Saharan Africa (FORNESSA) to propose / develop ? a policy brief on "Making African Forests Fit for Climate Change" (ADD REFERENCE). The policy brief aims at the facilitation of adaptation in Africa. More recently efforts have gradually been put on how to use forest resources to cope with climate change in EBA (Ecosystem Base Adaptation), such as mangrove areas that illustrate how forest management complements coastal engineering works (dikes) to reduce vulnerabilities. Also in Central Africa, responses to climate change generally emphasize mitigation measures without prioritizing adaptation (Bele et al 2011). Climate change adaptation in the COMIFAC region has mostly been focused on the agricultural sector but it should be kept in mind that Non Timber Forest Products (NTFP) play a crucial role for food security whereas timber is a major factor for national economies in the region. While the forest adaptation option of reduced impact logging to maintain ecosystem integrity appears to be of some importance in the region, increased silvicultural variability during reforestation seems to be of limited potential in the vast Congo Basin Rainforests, since even certified forest concessions have encountered only limited success in reforestation. Options to optimize tropical forest management with regard to climate change adaptation need to be further explored. Aiming to fill this gap of knowledge, several studies have started to look into climate change scenarios and impacts (GIZ/BMU project “Climate Change Scenarios for the Congo Basin) and into forest adaptation options in the Congo region (CIFOR projects “COBAM” and “CoFCCA” etc.). The CoForchange project of CIRAD also tried to understand the linkage between forests and climate change/variability.

This chapter aims to summarize the current state of knowledge of climate change and adaptation related to forests in the COMIFAC region. This synthesis may assist the Congo Basin countries to develop adequate adaptation options and policies for forests and the local communities living in forest landscapes. For this chapter we rely on information from IPCC 2007 and other published literature as well as unpublished information from the few implemented projects in the region (GIZ, Cofcca, COBAM, CoForchange). This chapter is built around the vulnerability framework [V= f (E,S,AC) that considers vulnerability as a function of exposition, sensitivity and adaptation. The function can also be applied in the forest sector (Locatelli et al. 2008, see Fig.1) and its principles are underlying important parts of this chapter. The sensibility is broadly captured by the review on why forests and adaptation to climate change is needed in Central Africa. Exposure to climate change will be presented in the form of available information concerning climate change observed in the past and projections of climate change in the future, based on the parameters *precipitation* and *near surface air temperature*. The influence of these changes on different sectors and thus on local communities, observed in the past and projected in the future, will be presented in the impact section. Possible responses to these impacts of climate change will then be provided in the adaptation section. As adaptation actions are not happening in a vacuum and joining efforts with previous initiatives can help, we will explore the synergies with others activities. At the end, a conclusion will summarize the main findings of the chapter.

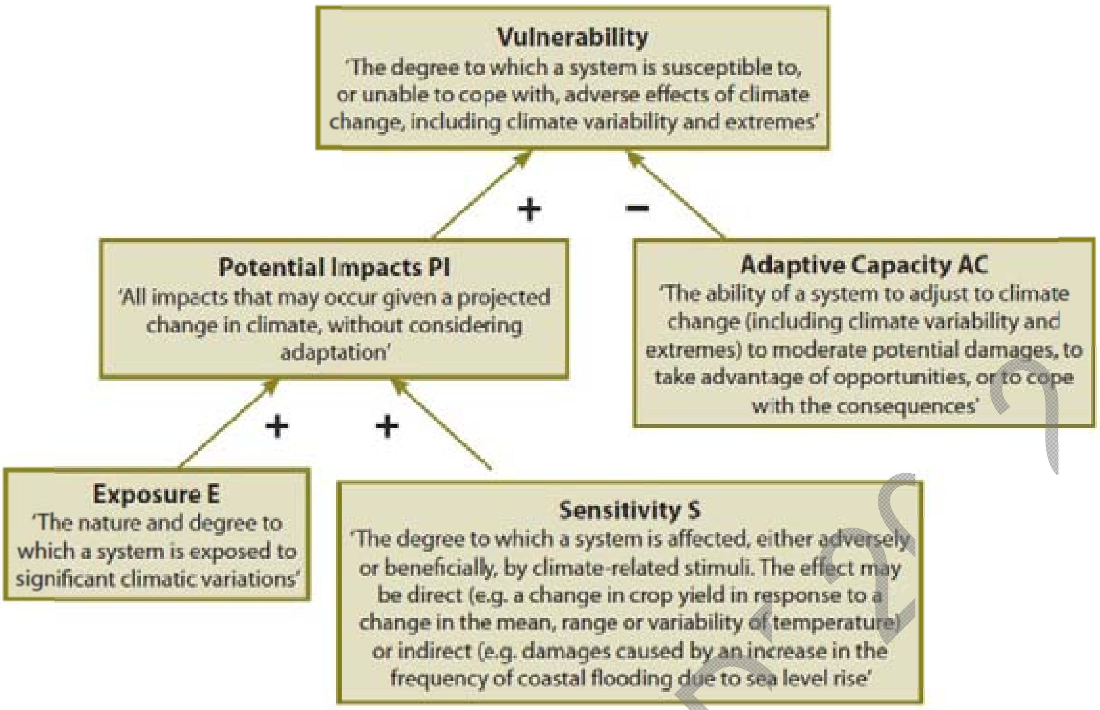

Figure 7. The components of vulnerability (definitions are from IPCC: McCarthy *et al.* 2001). The signs under the arrows mean that high exposure, high sensitivity and low adaptive capacity induce high vulnerability.

Figure 1. from Locatelli et al 2008

2. **Why ‘forests and adaptation’ in Central Africa?**

While the importance of the forestry sector with its environmental, economic and social benefits for the COMIFAC countries is widely accepted, the question of how to adapt to climate change remains largely unanswered. Vast forest concessions in the Congo Basin make it difficult to adapt to climate change through a shift towards more resistant timber species, like it is often done in temperate regions where small, often family owned, concessions allow for effective implication and close survey of such activities.

Il existe une grande complémentarité entre adaptation aux changements climatique dans le secteur forestier et les autres secteurs de développement. Le dialogue science politique en Afrique centrale a permis de montrer qu’il y avait un lien entre le foret et les secteurs comme l’eau, la santé, la sécurité alimentaire et l’énergie (Sonwa et al. 2012). Ces secteurs sont importants dans le développement des pays de l’Afrique Centrale. De plus en plus dans les réponses aux changements climatiques, il est pensé que la nature peut jouer un rôle important pour faire face aux perturbations climatiques.

On parle de plus en plus de ‘Ecosystem Based Adaptation’ (EBA). Dans le cas de l’Afrique Centrale, il pourrait s’agir d’utiliser les ressources forestières pour planifier l’adaptation aux changements climatiques. Dans le domaine de l’hydrologie par exemple, utiliser les forêts dans la zone côtière pour faire face aux vagues peut être classé comme EBA. Les pratiques agroforestières pour diversifier les cultures dans une perspective de vulnérabilité climatique font aussi parti de l’EBA. Avoir des plantations forestières avec des ressources génétiques différentes pouvant avoir des réponses différentes faces au stress climatique fait aussi parti de l’EBA. Gérer les basins versant pour permettre d’avoir constamment de l’eau et de l’énergie hydro-électrique peut faire partir d’EBA. D’après Collset al (2009), les EBA pour réussir doivent prendre en compte la réduction des stress non-climatiques, impliquer les communications locales, intégrer plusieurs acteurs, s’appuyer sur des bonnes pratiques de gestion des ressources naturelles, avoir une approche adaptative, s’intégrer dans une stratégie globale d’adaptation qui dans certains cas peuvent nécessaire une complémentarité avec des réponses qui prennent en compte d’autres solutions. Les succès doivent faire l’objet de beaucoup de communication. Les ressources forestières peuvent donc faire partir des réponses d'adaptation dans différents secteurs de développement. Mais ceci n'est pas toujours connu des acteurs qui travaillent en Afrique Centrale.

While such actions can help the forest sector to adapt to climate change, the sectors putting direct or indirect pressure on the forests, such as agriculture, mining and urban settlements, will play an important role in adapting to climate change in the greater Congo Basin region. Only if the land occupied by these activities will be used in an efficient and sustainable manner, it will allow to keep production and conservation forests in a vital competition with these other forms of land-use. Forest adaptation goes thus far beyond the forest sector itself, but incorporates rather all forms of competing land-use.

3. Climate parameters in the past and projected in the future

3.1 Climat passé en Afrique Centrale

Une enquête récente (GIZ/BMU 2011) a dénombre 419 stations météorologiques et 230 stations hydrologiques dans les dix pays de la COMIFAC. Pour certaines stations la première année de prise régulière de données remonte à 1889 (Yaoundé au Cameroun; Nicholson et al 2012) voir 1885 (Douala au Cameroun; Nicholson et al 2012). Mais en majorité elle débute pendant les décennies 1950s et 1960s (GIZ/BMU 2011). En plus de la détérioration de plusieurs de ces stations au cours des années, on note des discontinuités dans les séries temporelles. Ceci réduit de manière significative le nombre de stations ayant des séries temporelles fiables (Aguilar et al 2009).

Plusieurs analyses sur ces données montrent que le climat de l'Afrique Centrale est associé au cycle annuel de la Zone de Convergence Inter Tropicale, qui est associé à la migration, dans la direction nord-sud, de la zone des précipitations. En Janvier, la zone de précipitation est localisée dans l'extrémité sud du bassin du Congo. Au cours de ce mois, de très faibles quantités de pluies sont enregistrés dans le nord. Après Janvier, la zone de précipitation migre vers le nord, traverse le centre du bassin en Avril, et est localisé dans le nord en Juillet. Les précipitations dans le sud sont minimales cette période (Hirst et Hasternrath 1983). Comme conséquence, le cycle annuel des précipitations dans la sous-région est bimodal. La moyenne des précipitations à travers la région est maximale pendant les périodes allant d'Octobre à Décembre (160 mm/mois) et de Mars à Mai (146 mm/mois). Les minima de précipitations sont enregistrés de Juillet à Septembre (73 mm/mois) et de Décembre à Février (123 mm/mois) (Todd and Washington 2004). En plus de cette variabilité nord-sud, les caractéristiques climatiques varient aussi de l'ouest vers l'est. Dans les zones situées à l'est du Bassin du Congo (est de la République Démocratique du Congo), le maximum de précipitation est enregistré entre Mars et Mai. Sur la zone côtière dans l'ouest, les précipitations sont plus abondantes entre Septembre et Novembre (Nicholson et Dezfuly 2013). En plus de cette variation spatiale du cycle annuel, les précipitations enregistrent aussi une hétérogénéité des caractéristiques saisonnières. Les dates de début et fin des saisons de pluies, ainsi que les longueurs des saisons sont aussi variables (Guenang et Mkankam 2012).

Cette forte hétérogénéité spatio-temporelle traduit la complexité du climat dans la Bassin du Congo, et la multitude des facteurs qui l'influence (Balas et al 2007; Jackson et al 2009; Nicholson et Dezfuli 2013; Dezfuli et Nicholson 2013). Parmi ces facteurs, le flux de vapeur dans la basse troposphère venant de l'océan Atlantic (Hirst et Hasternrath 1983; McCollum 2000; Matsuyama et al 2004). Ce flux de vapeur d'eau influence autant le cycle annuel que la variabilité interannuel du cycle de l'eau dans la sous-région (Pokam et al 2012). Des courants jets atmosphériques à moyenne et haute altitude à travers le continent Africain impactent aussi sur le climat dans la sous-région (Nicholson et Grist 2003). Ces courants jets favorisent l'approvisionnement en vapeur d'eau de la sous-région (Pokam et al 2012), ainsi que les mouvements ascendants des masses d'air (Jackson et al 2009). La topographie du Bassin du Congo contribue aussi à ces mouvements ascendants (Vondou et al 2009, Jackson et al 2009) et contribuent aux fortes précipitations dans la région ouest du Cameroun et l'est de la RDC (Nicholson and Dezfuli 2013). Les températures de surface des mers à travers l'océan Atlantic, l'océan Pacific et l'océan Indien influencent la variabilité interannuelle des précipitations annuelles (Balas et al 2006) et saisonnières (Nicholson et Dezfuli 2013) dans le bassin du Congo.

Depuis les années 50s, on a observé une tendance à la baisse des précipitations totales de 31 mm/décennie entre 1955 et 2006 (Aguilar et al 2009). Cette baisse des précipitations est associée à une diminution de 0.67 mm/jour par décennie des quantités de précipitations des événements extrêmes. Les plus fortes baisses des hauteurs de précipitation ont été observées pendant la décennie 1968-1980 (Olivry et al 1993). Ces diminutions des précipitations n'ont pas la même intensité à travers la région. Dans le sud du Cameroun et au Congo, la baisse des précipitations a persisté jusqu'en 1990. Par ailleurs, au Gabon et en Centrafrique, on a observé une hausse respectivement après 1980 et 1985 (Olivry et al 1993). Des disparités ont aussi été notées à l'échelle locale. Tandis que dans le nord de la République du Congo la tendance est marquée par une baisse de la pluviométrie, dans le sud du pays elle est stable (Samba et al 2008). Le nombre de jours consécutifs humides ainsi que le nombre de jours très humides ont été moins fréquent et ont respectivement baissé de 0.35 jour par décennie et 12.19 mm par décennie entre 1955 et 2006 (Aguilar et al 2009).

Les températures ont montré une tendance à la hausse. On a observé dans un passé récent un durcissement des conditions chaudes. Les jours et les nuits très chauds ont montré une hausse respective de 0.25^0C et 0.21^0C par décennie entre 1955 et 2006 (Aguilar et al 2009). La fréquence des journées chaudes a connu une augmentation de 2.87% de jour en une année par décennie entre 1955 et 2006. La même tendance a été observée pour la fréquence des nuits chaudes, avec une hausse de 3.24% de jour en une année par décennie. Il est important de noté que ces hausses sont environ deux fois plus important que les statistiques moyennes globales sur la même période. Par ailleurs, la fréquence des nuits froides a baissé d'environ 1.17% de jour en une année sur la période 1955-2006. La tendance a été la même pour les jours froids qui ont connu une diminution de 1.22% de jour en une année (Aguilar et al 2009). Tout comme pour les précipitations, on a noté des différences d'amplitudes des tendances à travers la région. Dans la République du Congo, sur la période allant de 1950 à 1998, les températures ont augmenté de $0,5^0$ à 1^0C pendant les décennies 1980s et 1990s (Samba et al 2008). A l'échelle locale, les températures ont connu une hausse de 0.3^0 à 0.5^0C dans le nord du pays, tandis que dans le sud elles sont restées stables. Sanga-Ngoie et Fukuyama (1996) ont montré une hausse des températures d'environ 1^0C à Kinshasa, en République Démocratique du Congo sur le période 1960-1990, avec des valeurs allant de 0,6 à $1,6^0$C à travers le reste du pays.

3.2 Projected Future Climate

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 from Global Climate Models (GCM) and display a limited accuracy due to their coarse spatial resolution (up to 500 km). As Table 1 shows, their projections differ substantially between the countries.

Tableau 1 : Overview of GCM-projections used in the National Communications to the UNFCCC for seven COMIFAC countries (adapted from GIZ/BMU 2011)

Pays	**Nombre de communications à la CCNUCC**	**Paramètres simulés**	**Période de référence**	**Horizons de simulation**	**Résultats**
Burundi	2	Précipitation température	1975-1990	2010,2020, 2030,2040, 2050	- précipitations : positif 2010-2030 ; négatif 2030-2040, puis positif à partir de 2050 - températures : augmentation de 1° à 3°C de 2010-2050
CMR	1 (la 2ième est en voie de finalisation)	Précipitation température niveau marin	1961-1990	2025,2050, 2075,2100	- précipitations : augmentation générale avec une forte variabilité en région soudano-sahélienne à l'horizon 2100 -températures : augmentation +3°C -hausse du niveau marin
Congo	1	Précipitation température	1961-1990	2050,2100	-précipitations : +4 à 24% en 2050 ; +6 à 27% en 2100 -températures : +0,6 à 1,1°C en 2050 ; +2 à 3°C en 2100

Gabon	1	Précipitation température	1961-1990	2050,2100	-précipitations : +5 à 6% en 2050 ; +3 à 18,5% en 2100 -températures : +0,9°C en 2050 ; +2°C en 2100
RDC	2	Précipitation température et pression atmosph.	1961-1990	2010,2025, 2050,2100	-précipitations : de +0,3% en 2010 à +11,4% en 2100 -températures : de +0,46°C en 2010 à +3,22°C en 2100 -pression atmosphérique : de 0,52 hPa en 2010 à -0,47 hPa en 2100
Sao Tomé et Principe	1	Précipitation température niveau marin	19961	2100	- Précipitations à la baisse - Températures à la hausse - hausse du niveau de la mer
Tchad	1	Précipitation température	1961-1990	2023	-précipitations : +50 à 60 % en 2023 -températures : +0,6 à 1,7 °C

At a regional level, some 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. An example for these studies are downscaling activities for the whole African continent (Mariotti, 2011), or a large portion of Africa (e.g. Paeth et al., 2009 for northern Africa and the tropics; e.g. Hudson and Jones, 2002; Engelbrecht et al., 2009 for subequatorial Africa). 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. Therefore they can be classified as case studies rather than comprehensive climate change projections. However, at least for temperature, these studies agree on a basin wide increase. For precipitation however, results differ. While some studies project a decrease in rainfall over large parts of the basin by the middle (following the A1B scenario; Paeth et al., 2009) and the end of the century (following the A2 scenario, Engelbrecht et al., 2009), respectively, others project constant rainfall amounts until the end of this century (following the A1B scenario; Mariotti, 2011).

A first experience of regional climate modeling in the region has been recently conducted through the CoFCCA-project (Pokam et al., 2011). The projections have been made with the regional model PRECIS. Based on the high emission scenario, with a reference period spanning from 1961 – 1990, changes were projected for the period from 2071 – 2100 for the climate parameters near surface air temperature and precipitation. While the eastern part of the COMIFAC region is projected to experience a decrease in precipitation of about 1mm/day, the western parts might experience an increase between 1 and 2 mm/day. Concerning near surface air temperature the model predicts an overall increase of 4°C for the whole region compared to the reference period.

In 2010-2012, through the BMU funded project "Climate change scenarios in the Congo Basin", for the first time a comprehensive regional climate change assessment has been conducted over the greater Congo Basin region. In this assessment a very large set of existing and additionally compiled global and regional climate change projections has been analyzed for high and low emission scenarios respectively. This analysis allowed to not only estimate for the potential magnitudes of projected climate change signals but also enabled to judge on the reliability of the projected changes. Furthermore within this project, a representative subset of the climate change projections has been used as input for subsequent impact assessments and the formulation of adaptation options (GIZ-BMU). The key findings are described below.

Climate Change Scenarios

The BMU study 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 21th century. Temperature extremes like the frequency of cold/hot days and nights will decrease/increase respectively, again independent from season and emission scenario. 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 subrange (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. In general, projected temperature increase is slightly above average in the northern parts of the region and slightly below average in the central parts.

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 greater Congo basin region, whereas other models project a decrease over the same areas. However, towards the end of the 21st century a general tendency for a slight increase in future annual total precipitation is projected 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 tropical convection zone 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 % (-10 to +30 % in the north) and between -5 to +10 % (-10 to +15 % in the north) for the high and low emission scenarios respectively. 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 in the future.

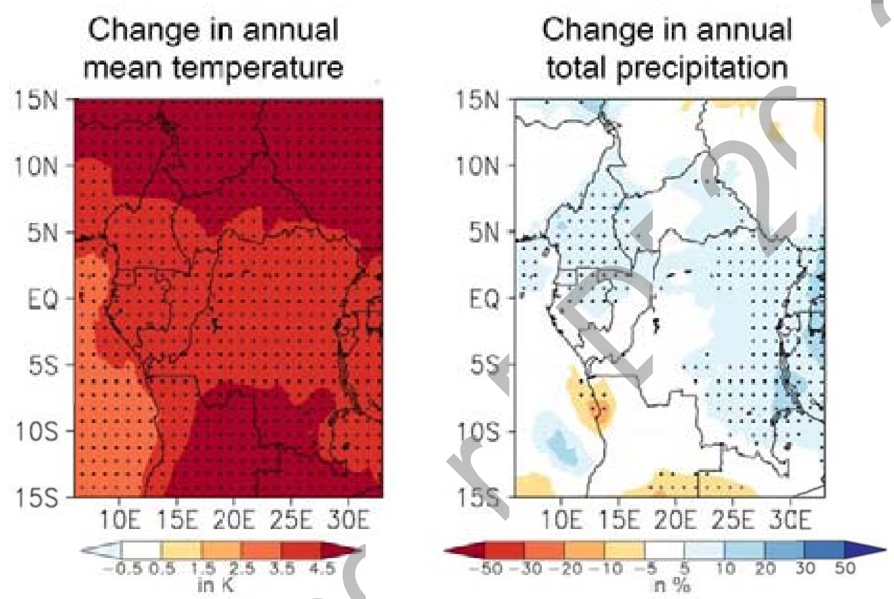

Figure 1: Projected change in annual mean temperature (left) and annual total precipitation (right) until the end of the 21st century (2071 to 2100) compared to the period 1961 to 1990 for a high emission scenario. The depicted change is the median change from a set of 31 different climate change projections 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.

In general, it seems that projected rainfall changes will not lead to a general water shortage in the region. Some prolonged and more frequent dry periods might nevertheless become more likely in the future. While this finding is rather independent of the underlying emission scenario, near surface air temperature is projected to increase substantially larger under the high emission scenario.

4. **Climate Change Impacts**

a. **Past Impacts**

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b. **Future Impacts**

Impacts on Hydrology and Energy

Some studies dealing with future impacts of potential climate change on the water resources in the region have been compiled within the region. An older study (Kamga et al., 2001) showed a future change in annual river flow from -3 to +18 % for the upper Benue River located in the semi-arid parts of northern Cameroon. A study on a more regional level was recently conducted (Tshimanga & Hughes, 2011), and assessed the impact of climate change on the hydrology of the Oubangui and Sangha sub basins of the Congo basin. A decrease in total runoff in the order of 10% is projected for the future, mainly caused by an increase in evapotranspiration, whereas rainfall was found not to change.

The above mentioned BMU study showed that projected changes in rainfall and temperature will result in substantial changes in the hydrology of the Congo Basin. Rising temperatures potentially lead to increased evaporation rates. In the subset of available climate change projections used to analyse potential impacts of climate change, the rainfall increase exceeds the increase in evaporation and as a result the run-off increased up to 50% in some parts of the Basin. Run-off and stream flow will especially increase in the wet season, suggesting a significant increase in t flood risks in the future, in especially in the central and western parts of the Congo basin. During the dry season the scenarios show conflicting results: some scenarios indicate a drier dry season while others show higher flows during the dry season. What is clear from all model results is that the difference between wet and dry season will become larger compared to the current climate. Especially the wet extremes will become more frequent and more intense, which is also related to the higher frequency of heavy rainfall events.

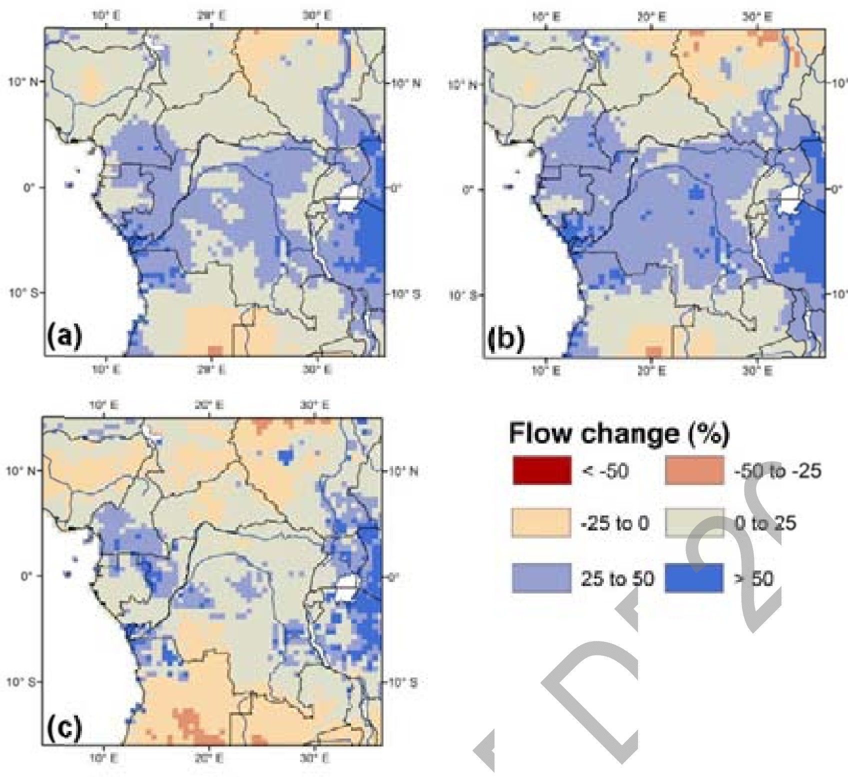

Figure 2: Maps show the projected mean of changes in mean flow (a), high flow (Q95) (b) and low flow (Q10) (c) for 2071-2100 relative to 1971-2000 for a high emission scenario. Flows are calculated using the VIC model in combination with three different climate models.

In general, the analyses showed that more water will be available for hydropower in the future. So on average, climate change will have a positive impact on potential electricity production. However, the rainfall variability also is also projected to increase, which means that in some years power production will be much lower compared to other years. Countries should therefore ensure that they have enough other sources of electricity to cover the reduced hydropower production during dry periods.

Impacts on Forests

Climate change will have a range of different impacts on forest ecosystems. The higher atmospheric CO2 concentrations might increase forest growth and carbon capture. Higher temperatures however will have negative impacts on forest growth and reduce the amount of carbon in the forests. The impact analyses show that as a result of climate change, the Congo basin is unlikely to see a decline in forest growth such as sometimes predicted for the Amazon basin. Instead, there could be a moderate increase in ecosystem carbon. Depending on how the climate will change there could be a shift in land cover of the different ecosystems. Based on the analyses a moderate expansion to the North and South of Evergreen forests into savannas and grasslands is the most likely future scenario. The model assessments show a large uncertainty range, highlighting the fact that collecting new data on, e.g., biomass in the central Congo basin and responses of forests to changing climate and CO2 concentrations are essential to further narrow down prediction ranges.

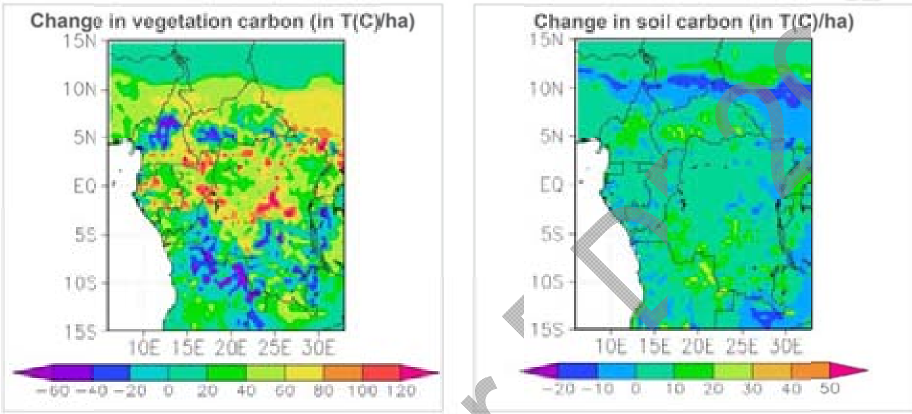

Figure 3: Maps show the projection of change towards the end of this century (mean of the period 2071-2100 compared to the mean of the period 1961-1990) under a high emission scenario. In the left panel, changes in potential vegetation carbon are shown and in the right panel, changes in potential soil carbon. Changes in total ecosystem carbon equal the sum of these two. Changes in potential vegetation and soil carbon are calculated using the LPJ-ml model in combination with a single climate model (ECHAM5).

Impacts on Agriculture

In general, climatic conditions are currently not limiting agricultural production in the Congo basin region. Only on the (drier) edges of the region water limitation is sometimes reducing the potential agricultural productions. In the tropical climates too much rainfall and high humidity limits agricultural production through nutrient leaching and fungal growth. The impact of future climate change on agricultural production will therefore be limited in the region. In most of the area the water stress will increase slightly in the future. However the agriculture will not suffer from structural water shortages. Only the agriculture in the savanna regions surrounding the Congo basin could potentially face water shortages in the future. In the southern savanna region analyses indicate that more frequent droughts will affect agriculture production and water stress.

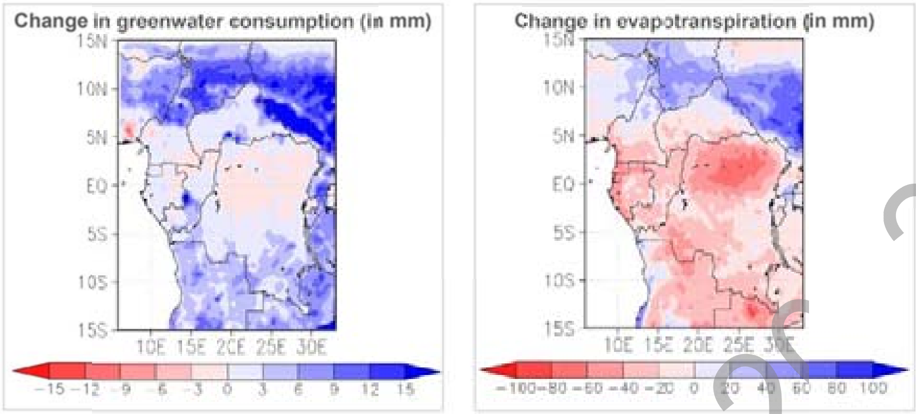

Figure 4: Maps show the projection of change towards the end of this century (mean of the period 2071-2100 compared to the mean of the period 1961-1990) under a high emission scenario. In the left panel, changes in greenwater consumption are shown and in the right panel, changes in evapotranspiration. Greenwater consumption and evapotranspiration are calculated using the LPJ-ml model in combination with a single climate model (ECHAM5).

Impacts on Economic Growth

In several of the COMIFAC countries there is a clear correlation between annual rainfall and GDP growth. GDP and Agricultural GDP growth rates tend to be higher in years with above-average rainfall than in the dry years. The impact of climate variability on GDP growth is most pronounced during dry years. During below-average rainfall years growth is sometimes severely reduced and generally the drier the lower the GDP growth rate. All above-average rainfall years tend to have relatively similar economic growth rates. The correlation between rainfall and GDP growth rates is stronger in countries with lower and more variable rainfall. In most countries, agricultural GDP growth rates are affected stronger by climate variability than the total GDP growth rates. For example in the Democratic Republic of Congo during dry years the growth was negative while during average and above average rainfall years the economic output of the agricultural sector is growing. In Chad, the situation is even more dramatic with large reductions in agricultural productivity during dry years and rapid growth especially during the years with near average rainfall.

In terms of future climate change impacts on economic development our analysis shows that COMIFAC countries are especially vulnerable to a reduction in rainfall and a significant increase in interannual rainfall variability. Our results show that at a continental scale, climate change is likely to have a negative impact on development in Africa. However the economies of central African countries are likely to be less affected by climate change compared to countries in West, East and Southern Africa. Also at macro scale the climate scenarios seem to be more favourable in the central African part compared to the rest of Africa. However some climate change scenarios show large increases in climate variability and this could have a negative impact on development.

In conclusion the region needs to prepare for a more variable climate and a more variable hydrological regime. Also the difference between seasons and between different years is likely to become larger in the future. The region needs to prepare for more intensive rainfall and probably more floods during the wet season. The dry season could become both wetter and drier. It is also clear that temperatures will increase in the future. Climate change adaptation should therefore focus on reducing the impacts of increased rainfall variability and higher temperatures.

5. Possible responses

To be effective Climate change adaptation should be performed at a well-balanced mixture at the local, national and regional level.

Au niveau local dans les communautés forestières subissent les effets des changements climatiques. En l'absence de cadres politiques et institutionnelle sur l'adaptation bien planifiée, les populations semblent désarmées face aux variations climatiques. Les études dans le cadre de Cofcca montrent que sans appuis les communautés ne peuvent pas faire face efficacement aux changements climatiques (Bele et al ADD YEAR). Le projet a en utilisant la PAR initie des réponses pilotes dans les zones locales en RDC, RCA et Cameroun. Ces actions concernent l'apport des variétés de cultures (Manioc, Plantain) qui résistent aux stress climatiques, la plantation d'arbres et autres PFNL et le développement de l'apiculture pour diversifier les sources de revenus. Dans le cadre de

COBAM, des projets pilotes seront aussi mis en place en prenant en compte la synergie adaptation et atténuation. Since adaptation to climate change is highly local, institutions, particularly in rural areas, have been shown to be the fundamental mediating mechanism to translate the impact of external interventions (Agrawal, 2008, 2010). A study in forest area of Cameroon showed that diverse institutions, both formal and informal, exist within villages; primarily informal savings and loan groups, forest or agriculture groups, and forest or agriculture product marketing groups. Group members usually came from the same ethnic group but this differed between provinces, representing the cultural make up of an area. While groups sometimes were gender specific, this was not most often the case. Villagers are often members of several groups which may present opportunities for social learning to occur. Social learning occurs when people engage with one another, sharing perspectives and experiences in order to address changing circumstances (Brown, 2011)

Au niveau national, les travaux de Cofcca donnent une illustration des réponses institutionnelles nationales aux changements climatiques (Brown et al. For Cameroon, DRC & RCA). The adaptive capacity or capability of all three countries to adjust to and limit risk in the face of climate change is low, due to the lack of key determinants of adaptive capacity, such as economic wealth, technology, information, skills and infrastructure. Vulnerability is exacerbated, particularly in CAR and DRC, as a result of recent civil conflict and on-going insecurity in some parts of both countries (Brown, 2010; Brown et al., 2010; Brown et al., 2013). . L'analyse des politiques et institutions en RCA, Congo et Guinée Equatoriale montre une absence de coordination entre les administrations (Nguema & Pavageau, 2012 ; Gapia & Bele 2012 ; Pongui & Kenfack 2012) dont une faible cohérence et complémentarité intra-sectorielle et multi-niveau dans la planification et la mise en place de l'adaptation est pourtant nécessaire. Les acteurs dans les pays sont bien au courant des menaces des changements climatiques mais ceci ne se traduit pas forcement par une traduction de cela dans la genèse des institutions qui permettent de faire face aux changements climatiques. Quelques pays comme la RCA et la RDC ont développé des PANA. La RDC a eu son PANA financé dans le domaine de la sécurité alimentaire. Le Cameroun a pour le moment la première communication nationale sur les changements climatiques et est en train de travailler pour développer un plan national d'adaptation. L'analyse de ces PANA et autres documents montrent une faible/non prise en compte des ressources forestières dans l'adaptation aux changements climatiques (Bele et al. 2011). While NAPA documents stated the need for a gender sensitive approach to climate change adaptation, it did not appear that there had been broad participation in the development of the documents with only vague strategies to address gender concerns.

At a **regional level**, both political will and institutions for responses to climate change exist and thus regional adaptation options are manifold in Central Africa. The mandate of COMIFAC is to coordinate and harmonize forest and environmental policies in its ten member countries and includes regional adaptation options in these sectors.

L'on s'attend à ce que la COMIFAC, qui jusque-là a été la plateforme fédératrice des réponses aux changements climatiques, intègre les initiatives scientifiques et opérationnelles de l'adaptation au changement climatique. Une étude faite par Ecoseruties montre que la région ne s'est pas bien mobilisée pour décrocher les fonds sur l'adaptation. En Afrique Centrale, l'action sur la vulnérabilité et les réponses éventuelles ont généralement porté sur la réduction des eaux du lac Tchad et le besoins d'analyser les eaux du Bassin du Congo afin de l'alimenter.

La COMIFAC a par la suite été associée à cette étude, dont la restitution a permis de dégager des pistes pour des activités futures. Toutes ces initiatives sont principalement venues des structures de recherche avec des dialogues science politiques à l'une ou autre phase des projets (Sonwa et al. 2012). Les prises de positions des Ministres de la COMIFAC au sujet de l'adaptation n'ont pas donné autant d'emphase en comparaison à l'énergie déployée sur la REDD+. Il en est de même des partenaires internationaux travaillant dans la région dans le cadre du CBFP, des acteurs de conservation et de la société civile, qui n'ont pas encore donné une réponse d'envergure régionale ciblant la vulnérabilité des populations/communautés et des ressources forestières aux changements climatiques. La CEEAC-COMIFAC a mis en place un groupe des experts sur le Climat pour qu'il soit la déclinaison du GIEC au niveau de l'Afrique Centrale. Mais la structure tarde encore à décoller effectivement.

Besides COMIFAC, there are other regional organisations which widen the possibilities of regional adaptation options significantly. The economic drawbacks of not considering adaptation in national development strategies are obvious and clearly imply the ECCAS. In the hydrology sector there are specialized regional organisations like CICOS and CBLT which can take action concerning watershed management and thus anticipated on changes with impact on hydropower and flooding.

There is a need to improve preparedness for extreme weather events such as droughts and floods because such events will occur more often in future. In addition, in the agricultural and energy sector there should be risk spreading by diversification. Farmers should grow different crops and also different varieties to reduce the impact of climate variability. Countries should be careful not to become fully dependent on hydropower because this makes them too vulnerable to droughts. Other sustainable energy sources such as solar and biofuel could also be promoted. To prevent forest degeneration and erosion there should be more attention on reforestation and agroforestry. Programs on food and water security should develop strategies to manage climate variability so they are prepared for both dry and wet periods. The knowledge of climate change impacts and adaptation is still very limited in the region and there is need for more capacity building and awareness raising.

Most of the COMIFAC member countries have large development challenges, with general income tending to be low and still high poverty rates. These immediate development needs may overall be more important than climate change adaptation. However future development also creates opportunities for adaptation. To avoid wrong investments and to reduce future cost of adaptation, climate change adaptation should therefore be integrated in future development plans.

An important indirect impact of climate change on the Congo Basin countries might arise from neighbouring countries in the north and south which are expected to be severely affected by climate change. Climate change related increased variability in agricultural production might lead to increased migration from these countries into the

Congo Basin. Adaptation options to such impacts need a response foremost on the social and political level.

5 Synergies with other initiatives

Les ressources forestières et les communautés rurales ciblées dans les initiatives d'adaptation font déjà l'objet d'attention dans les initiatives de conservation de la biodiversité et d'atténuation des changements climatiques.

En matière de réponse aux changements climatiques, le premier réflexe a été de voir comment le **REDD+** et l'adaptation peuvent être mis en synergie. La complémentarité entre REDD+ et Adaptation dans le domaine de la foresterie a déjà été mentionnée (Guariguata et al 2008 ; Locatelli et al. 2010). Les activités de la REDD+ doivent intégrer les préoccupations d'adaptation aux changements climatiques. Dans le cas contraire un problème de durabilité peut se poser dans la mesure où les réponses peuvent être vulnérables aux changements climatiques. Certaines activités initiées dans le cadre de la REDD+ peuvent aussi permettre aux communautés rurales de faire face aux changements climatiques. elles peuvent donc en même temps servir l'atténuation et l'adaptation. A titre d'exemple, la restauration des mangroves contribue à capter le CO_2 pendant la croissance des arbres, rendus adultes, ils pourront alors réduire l'intensité des vagues dont les effets néfastes sont de nature à s'amplifier avec les changements climatiques. Sur terre ferme une plantation d'arbres contribue à stocker le Carbone. Ces arbres peuvent aussi permettre une adaptation, par exemple si ils sont plus résistants aux perturbations climatiques que les autres sources de livelihood du ménage, et/ou en servant de brise vent, et/ou en diversifiant les sources de revenus des ménages. Mais pour qu'une activité puisse être utile à l'atténuation et à l'adaptation, il faut intégrer la synergie dans sa planification et son exécution. C'est les potentialités et les opportunités de cette synergie que recherche le projet COBAM en explorant les politiques et les stratégies régionaux, nationaux et locaux de changement climatique dans le Bassin du Congo. . Le projet est en train d'initier des activités pilotes de synergie adaptation et atténuation dans 5 des 12 paysages de conservation de la biodiversité de l'Afrique Centrale. Les études préliminaires au niveau national en Guinée équatoriale, RCA et au Congo (Nguema & Pavageau, 2012 ; Gapia & Bele 2012 ; Pongui & Kenfack 2012) ne montrent pas que les politiques actuelles encouragent cette synergie. Le climat influence plusieurs secteurs de l'économie nationale et rurale et les réponses doivent être intégrées et multi-institutionnelles.

La COMIFAC et la CICOS regroupent les états de la région respectivement autour des Foret et de l'Hydrologie, cependant pour le moment, ces deux initiatives n'ont pas encore d'actions communes pour répondre aux perturbations climatiques. Dans un contexte de changement climatique, le lien entre les deux secteurs au niveau de bassins versants est bien établi. Une diminution des pluies entraine une diminution de l'offre énergétique. La coupe du bois vient combler les déficits d'énergie. Il s'en suit l'érosion des sols et l'engorgement des barrages conduisant à la réduction de l'offre énergétique. La solution est à trouver dans une concertation institutionnelle à l'échelle des bassins versants. Celles-ci doit aussi se penser au niveau sous régionale avec une bonne coordination entre la COMIFAC et la CICCOS. Cette dernière qui gère par ailleurs l'un des secteurs les plus sensibles aux changements climatiques n'a pas encore reçu le même degré d'attention que la COMIFAC. Le partenariat populations, ressources forestières est tout à construire en Afrique Centrale (Sonwa et al. 2012).

Dans le secteur forestier, Parmi les synergies les plus en vue, il y a celles avec le REDD+ qui pourraient permettre d'avoir une réponse plus intégrée du secteur des forêts aux changements climatiques. La synergie avec le secteur hydraulique permettrait à la CICOS et la COMIFAC de bien cordonner les initiatives et éventuellement de développer des mécanismes de PES dans l'électricité et l'eau, qui pourrait d'ailleurs faire intervenir le secteur privé (eau & Energie) dans l'adaptation aux changements climatiques. Intégrer l'adaptation au changement climatique dans les autres initiatives visera à rendre le développement et la gestion des ressources naturelles de la région plus résilients aux perturbations climatiques. Intégrer l'adaptation au changement climatique dans la conservation de la biodiversité, la REDD+ et gestion des eaux permettrait de rendre des initiatives plus résilientes. L'adaptation basée sur les écosystèmes (EBA) permettrait encore plus d'utiliser la gestion des ressources forestières pour contribuer à l'adaptation aux changements climatiques dans les secteurs de développement.

Conclusions

(TO BE COMPLETED WHEN ALL PARTS ARE AVAILABLE)

In conclusion the Congo Basin region needs to prepare for a more variable climate and a more variable hydrological regime. Also the difference between seasons and between different years is likely to become larger in the future. The region needs to prepare for more intensive rainfall and probably more floods during the wet season. The dry season could become both wetter and drier. It is also clear that temperatures will increase in the future. Climate change adaptation should therefore focus on reducing the impacts of increased rainfall variability and higher temperatures.

References.

(Nguema & Pavageau, 2012 ; Gapia & Bele 2012 ; Pongui & Kenfack 2012)

Nguema J., Pavageau C. 2012. Adaptation et atténuation au changement climatique en Guinée Equatoriale : acteurs et processus politiques. Document de travail. CIFOR Bogor, Indonésie.

Gapia M., Bele Y 2012. Adaptation et atténuation au changement climatique en République

Pongui B., Kenfack C. 2012. Adaptation et atténuation au changement climatique en république du Congo : acteurs et processus politiques. Document de travail. CIFOR Bogor, Indonésie [Published]

Hannah, L., Dave, R., Lowry, P.P., Andelman, S., Andrianarisata, M., Andriamaro, L., Cameron, A., Hijmans.
R., Kremen, C., MacKinnon, J. *et al*. 2008 Climate change adaptation for conservation in Madagascar. Biology
Letters, 4(5):590-594.

AMCEN, 2011: Addressing Climate Change Challenges in Africa; A Practical Guide Towards Sustainable
Development.

A. Colls, N. Ash, and N. Ikkala (2009). *Ecosystem-based Adaptation: a natural response to climate change*. Gland, Switzerland: IUCN. 16pp.

http://cmsdata.iucn.org/downloads/iucn_eba_brochure.pdf

Guariguata, M.R.; Cornelius, J.P.; Locatelli, B.; Forner, C.; Sánchez-Azofeifa, G.A. Mitigation needs adaptation: Tropical forestry and climate change. *Mitigat. Adapt. Strat. Global Change* **2008**, *13*, 793-808.

Locatelli, B.; Kanninen, M.; Brockhaus, M.; Colfer, C.J.P.; Murdiyarso, D.; Santoso, H. *Facing an Uncertain Future: How Forest and People can Adapt to Climate Change*; CIFOR: Bogor, Indonesia, 2008; p. 86.

Somorin, O.A., Brown, H.C.P., Sonwa, D., Visseren-Hamakers, I.J., Nkem, J.N. and Arts, B. (2012) Congo Basin forests in a changing climate: policy discourse on adaptation and mitigation. Global Environmental Change 22 (1), 288–298.

Sonwa D., Gapia M, Pokam W, Losembe F. and Mfochivé O. (2012) The link between forest, water and people: an agenda to promote in the context of climate change in Central Africa, Nature & Faune, Volume 27, Issue 1, pp 48-52

Sonwa D J, Bele Y M, Somorin O. A., Nkem J N (2010) Central Africa is not only carbon stock: preliminary efforts to promote adaptation to climate change for forest and communities in Congo Basin. Nature & Faune, Vol 25, Issue 1, pp 52-57

Références.

AMCEN, 2011: Addressing Climate Change Challenges in Africa; A Practical Guide Towards Sustainable
Development.

A. Colls, N. Ash, and N. Ikkala (2009). *Ecosystem-based Adaptation: a natural response to climate change*. Gland, Switzerland: IUCN. 16pp.

http://cmsdata.iucn.org/downloads/iucn_eba_brochure.pdf

Fischlin, A., G.F. Midgley, J.T. Price, R. Leemans, B. Gopal, C. Turley, M.D.A. Rounsevell, O.P. Dube, J. Tarazona, A.A. Velichko, 2007:Ecosystems, their properties, goods, and services. *Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of WorkingGroup II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*, M.L. Parry, O.F. Canziani, J.P. Palutikof,P.J. van der Linden and C.E. Hanson, Eds., Cambridge University Press, Cambridge, 211-272.

Bele, M.Y., Somorin, O., Sonwa, D.J., Nkem, J.N. and Locatelli, B. 2011 Politiques sur les forêtset l'adaptation aux changements climatiques au Cameroun. Document de travail. CIFOR, Bogor, Indonésie

GIEC, 2007: Résumé à l'intention des décideurs. In: Bilan 2007 des changements climatiques: Impacts, adaptation et vulnérabilité. Contribution du Groupe de travail II au quatrième Rapport d'évaluation. Rapport du Groupe d'experts intergouvernemental sur l'évolution du climat, M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden and C.E. Hanson, (éd.), Cambridge UniversityPress, Cambridge,Royaume-Uni.

Hockey, P.A.R., 2000: Patterns and correlates of bird migrations in sub-Saharan Africa; Journal of Birds, Australia, 100, 401–417.

Hannah, L., Dave, R., Lowry, P.P., Andelman, S., Andrianarisata, M., Andriamaro, L., Cameron, A., Hijmans.
R., Kremen, C., MacKinnon, J. *et al*. 2008 Climate change adaptation for conservation in Madagascar. Biology Letters, 4(5):590-594..

Müller, Christoph: Climate change impact on Sub-Saharan Africa : an overview and analysis of scenarios and models / Christoph Müller. – Bonn : DIE, 2009 – (Discussion Paper / DeutschesInstitutfürEntwicklungspolitik; 3/2009)

Nogherotto, R., Coppola, E., Giorgi, F. and Mariotti, L. (2013), Impact of Congo Basin deforestation on the African monsoon.Atmosph. Sci. Lett., 14: 45–51. doi: 10.1002/asl2.416

Olivry J.C., Bricquet J.P., Mahé G. (1993) : Vers un appauvrissement durable des ressources en eau de l'Afrique humide? Proceedings of the Symposium « Hydrology of Warm Humid Regions » IAHS Sc.Assembly Yokohama July 1993 . IAHS n°216, pp. 66-78

Sonwa D J. &Nkem NJ.Idinoba ME. & Bele MY.&Jum C (2012) Building regional priorities in forests for development and adaptation to climate change in the Congo Basin.Mitigation and Adaptation Strategies for Global Change. 17:441–450.

Thuiller,W., O. Broennimann, G. Hughes, J.R.M. Alkemade, G.F. Midgley and F. Corsi, 2006:Vulnerability
of African mammals to anthropogenic climate change under conservative land transformation
assumptions, Glob. Change Biol., 12, 424-440.

References.

Hannah, L., Dave, R., Lowry, P.P., Andelman, S., Andrianarisata, M., Andriamaro, L., Cameron, A., Hijmans. R., Kremen, C., MacKinnon, J. *et al*. 2008 Climate change adaptation for conservation in Madagascar. Biology
Letters, 4(5):590-594.

Nancy Birdsall and Michele de Nevers. 2012. "Adaptation Finance How to Get Out from between a Rock and a Hard Place." CGD Policy Paper 001. Washington, D.C.: Center for Global Development.
http://www.cgdev.org/content/publications/detail/1425965

O'Riordan, J. 2008 Climate Change Adaptation and Biodiversity: Transitioning to an Ecosystem- Based
Economy in British Columbia (rapport succinct) Adaptation to Climate Change Team Simon Fraser
University. www.sfu.ca/ACT.

AMCEN, 2011: Addressing Climate Change Challenges in Africa; A Practical Guide Towards Sustainable
Development.

A. Colls, N. Ash, and N. Ikkala (2009). *Ecosystem-based Adaptation: a natural response to climate*
change. Gland, Switzerland: IUCN. 16pp. http://cmsdata.iucn.org/downloads/iucn_eba_brochure.pdf

Sonwa D J. & Nkem NJ. Idinoba ME. & Bele MY. & Jum C (2012) Building regional priorities in forests for development and adaptation to climate change in the Congo Basin. Mitigation and Adaptation Strategies for Global Change. 17:441–450.

Nguema J., Pavageau C. 2012. Adaptation et atténuation au changement climatique en Guinée Equatoriale : acteurs et processus politiques. Document de travail. CIFOR Bogor, Indonésie.

Gapia M., Bele Y 2012. Adaptation et atténuation au changement climatique en République
Pongui B., Kenfack C. 2012. Adaptation et atténuation au changement climatique en république du Congo : acteurs et processus politiques. Document de travail. CIFOR Bogor, Indonésie [Published]

Adger, W. N., 2000. Institutional adaptation to environmental risk under the transition in Vietnam. *Annals of the Association of American Geographers*, 90 (4). 738-758.
Adger, W. N. and Vincent, K., 2005. Uncertainty in adaptive capacity. *C.R. Geoscience*, 337. 399-410.
Agrawal, A., 2001. Common property institutions and sustainable governance of resources. *World Development*, 29 (10). 1649-1672.
Agrawal, A., 2008. The role of local institutions in adaptation to climate change. *International Forestry Resources and Institutions Program*, #W08I-3. 1-45.
Agrawal, A., 2010. Local institutions and adaptation to climate change. *Social Dimensions of Climate Climate: Equity and Vulnerability in a Warming World*, R. Mearns and A. Norton (eds.). The World Bank, Washington, DC. 173-197.
Agrawal, A., Chatre, A. and Hardin, R., 2008. Changing governance of the world's forests. *Science*, 320. 1460-1462.
Agrawal, A. and Gibson, C. C., (eds.) 2001. *Communities and the Environment: Ethnicity, Gender, and the State in Community-Based Conservation*. Rutgers University Press, New Brunswick, New Jersey, USA.
Agrawal, A. and Yadama, G., 1997. How do local institutions mediate market and population pressures on resources? Forest *Panchayats* in Kumaon, India. *Development and Change*, 28. 435-465.
Annecke, W., 2002. Climate change, energy-related activities and the likely social impacts on women in Africa. *International Journal of Global Environmental Issues*, 2 (3/4). 206-222.
Bandiaky, S. and Tiani, A.-M., 2010. Gender representation and participation in decentralized forest management: Case studies from Cameroon and Senegal. *Governing Africa's Forests in a Globalized World*, L. A. German, A. Karsenty and A. M. Tiani (eds.). Earthscan, London. 144-159.
Bele, Y., Somorin, O. A., Sonwa, D. J., Nkem, J. N. and Locatelli, B., 2011. Forests and climate change adaptation policies in Cameroon. *Mitigation and Adaptation Strategies for Global Change*, 16 (3). 369-385.
Brown, H. C. P., 2010. *Institutional Dynamics and Climate Change in the Congo Basin Forests of Central Africa, Report of Second Phase: Central African Republic and Democratic Republic of Congo*. CIFOR.
Brown, H. C. P., 2011. Gender, climate change and REDD+ in the Congo Basin forests of Central Africa. *International Forestry Review*, 13 (2). In press.
Brown, H. C. P., Buck, L. and Lassoie, J. P., 2008. Governance and social learning in the management of non-wood forest products in community forests in Cameroon. *International Journal of Agricultural Resources, Governance and Ecology*, 7 (3). 256-275.

Brown, H. C. P. and Lassoie, J. P., 2010a. Institutional choice and local legitimacy in community-based forest management: Lessons from Cameroon. *Environmental Conservation*, 37 (3). 261-269.
Brown, H. C. P. and Lassoie, J. P., 2010b. The interaction between market forces and management systems: A case study of non-wood forest products in the humid forest zone of Cameroon. *International Forestry Review*, 12 (1). 13-26.
Brown, H. C. P., Nkem, J. N., Sonwa, D. J. and Bele, Y., 2010. Institutional adaptive capacity and climate change response in the Congo Basin forests of Cameroon. *Mitigation and Adaptation Strategies for Global Change*, 15. 263-282.
Brown, H. C. P., Smit, B., Somorin, O. A. and Sonwa, D. J., 2013. Insitutional perceptions, adaptive capacity, and climate change response in a post-conflict country: A case study from the Central African Republic. *Climate and Development*, Accepted.
Brown, H. C. P., Smit, B., Sonwa, D. J., Somorin, O. A. and Nkem, J. N., 2011. Institutional perspectives of opportunities and challenges of REDD+ in the Congo Basin. *The Journal of Environment & Development*, 20 (4). 381-404.
Buck, L., Wollenberg, E. and Edmunds, D., 2001. Social learning in the collaborative management of community forests: Lessons from the field. *Social Learning in Community Forests*, E. Wollenberg, D. Edmunds, L. Buck, J. Fox and S. Brodt (eds.). CIFOR, Jakarta, Indonesia. 1-20.
Dixon, R. K., Smith, J. and Guill, S., 2003. Life on the edge: Vulnerability and adaptation of African ecosystems to global climate change. *Mitigation and Adaptation Strategies for Global Change*, 8 (2). 93-113.
Gurung, J. D. and Quesada, A., 2009. *Gender-Differentiated Impacts of REDD to be addressed in REDD Social Standards*. Women Organizing for Change in Agriculture and Natural Resource Managment and Global Gender and Climate Alliance.
Hemmati, M. and Rohr, U., 2009. Engendering the climate-change negotiations: Experiences, challenges and steps forward. *Gender and Development*, 17 (1). 19-32.
Koch, I. C., Vogel, C. and Patel, Z., 2007. Institutional dynamics and climate change adaptation in South Africa. *Mitigation and Adaptation Strategies for Global Change*, 12. 1323-1339.
Mwangi, E., Meinzen-Dick, R. and Sun, Y., 2011. Gender and sustainable forest managment in East Africa and Latin America. *Ecology and Society*, 16 (1). 17.
Nkem, J. N., Kalame, F. B., Idinoba, M., Somorin, O. A., Ndoye, O. and Awono, A., 2010. Shaping forest safety nets with markets: Adaptation to climate change under changing roles of tropical forests in Congo Basin. *Environmental Science & Policy*, 13. 498-508.
Ostrom, E., 1990. *Governing the Commons: The Evolution of Institutions for Collective Action*. Cambridge University Press, Cambridge.
Ostrom, E., 1997. Local institutions for resource management. *Beyond Fences, Seeking Social Sustainability in Conservation*, G. Borrini-Feyerabend (ed.). IUCN, Gland, Switzerland. 14-16.
Ostrom, E., 2005. *Understanding Institutional Diversity*. Princeton University Press, Princeton, NJ.

Oyono, P. R., 2004a. Institutional Deficit, Representation, and Decentralized Forest Management in Cameroon. *Environmental Governance in Africa Working Papers,* J. C. Ribot (ed.). World Resources Institute, Washington, D.C. 1-36.
Oyono, P. R., 2004b. The social and organisational roots of ecological uncertainties in Cameroon's forest management decentralisation model. *European Journal of Development Research*, 16 (1). 174-191.
Oyono, P. R. and Efoua, S., 2006. La représentation environnementale au Cameroun: une exploration des liens entre les choix institutionnnels, la démocratie local et les résultats de la gestion décentralisée des forêts. *Africa Development*, XXXI (2). 149-184.
Pielke, R. A. J., 1998. Rethinking the role of adaptation in climate policy. *Global and Environmental Change*, 8 (2). 159-170.
Ribot, J. C., 2002. *African Decentralization: Local Actors, Powers and Accountability*. Edited by U. N. R. I. f. S. Development, *UNRISD Programme on Democracy, Governance and Human Rights*. UNRISD, Geneva, Switzerland.
Ribot, J. C., 2003. Democratic decentralization of natural resources: Institutional choice and discretionary power transfers in Sub-Saharan Africa. *Public Administration and Development*, 23 (1). 53-65.
Rietbergen-McCracken, J., Editor, 2011. Gender in Cancun. *Arborvitae,* 3.
Smit, B. and Wandel, J., 2006. Adaptation, adaptive capacity and vulnerability. *Global Environmental Change*, 16. 282-292.
Somorin, O. A., 2010. Climate impacts, forest-dependent rural livelihoods and adaptation strategies in Africa: A review. *African Journal of Environmental Science and Technology*, 4 (13). 903-912.
Somorin, O. A., Brown, H. C. P., Visseren-Haamakers, I., Sonwa, D. J., Arts, B. and Nkem, J. N., 2012. The Congo Basin forest in a changing climate: Policy discourse on adaptation and mitigation. *Global Environmental Change,* 22 (1). 288-298.
Sonwa, D. J., Somorin, O. A., Jum, C., Bele, Y. and Nkem, J. N., 2012. Vulnerability, forest-related sectors and climate change adaptation: The case of Cameroon. *Forest Policy and Economics,* doi: 10.1016/j.forpol.2012.06.009.

References climat passe

Aguilar, E., et al. (2009), Changes in temperature and precipitation extremes in western central Africa, Guinea Conakry, and Zimbabwe, 1955–2006, *J. Geophys. Res.*, 114, D02115, doi:10.1029/2008JD011010.

Balas, N., S. E. Nicholson, and D. Klotter, 2007: The relationship rainfall variability in West Central Africa to sea-surface temperature fluctuation. *Int. J. Climatol.*, 27, 1335–1349.

Dezfuli, Amin K., Sharon E. Nicholson, 2013: The Relationship of Rainfall Variability in Western Equatorial Africa to the Tropical Oceans and Atmospheric Circulation. Part II: The Boreal Autumn. *J. Climate*, 26, 66–84.

G. M. Guenang, F. Mkankam Kamga. 2012. Onset, retreat and length of the rainy season over Cameroon. *Atmospheric Science Letters*, DOI: 10.1002/asl.371

Hirst, A. C. and S. Hastenrath, 1983: Diagnostics of hydrometeorological anomalies in the Zaire (Congo) Basin. *Quarterly Journal of the Royal Meteorological Society*, 109, 881–892.

Jackson, B., S. E. Nicholson, and D. Klotter, 2009: Mesoscale Convective Systems over Western Equatorial Africa and Their Relationship to Large-scale Circulation. Mon. Wea. Rev., 137, 1272–1294.

Matsuyama, H., T. Oki, M. Shinoda, and K. Masuda, 1994: The Seasonal Change of the Water Budget in the Congo River Basin. *J. Meteor. Soc. Japan*., 32, 281–299.

McCollum JR, Gruber A, Ba MB (2000) Discrepancy between gauges and satellite estimates of rainfall in equatorial Africa. *J Appl Meteor*, 39, 666–679

Nicholson, S. E., Amin K. Dezfuli and **K. Douglas**, 2012: A Two-Century Precipitation Dataset for the Continent of Africa. Bull. Amer. Meteor. Soc., 93, 1219–1231.

Nicholson, S. E. and **Amin K. Dezfuli**, 2013: The Relationship of Rainfall Variability in Western Equatorial Africa to the Tropical Oceans and Atmospheric Circulation. Part I: The Boreal Spring. *J. Climate*, 26, 45–65.

Nicholson, S. E. and **J. P. Grist**, 2003: The seasonal evolution of the Atmospheric Circulation over West Africa and Equatorial Africa. *J. Climate*, 16, 1013–1030.

Olivry, J. C., B. J. P., and G. Mahe, 1993: Vers un appauvrissement durable des ressources en eau de l'Afrique humide. *IAHS Publ*, 216, 67–68.

Pokam, W.M., Djiotang, T. A. L., and Mkankam, K. F. 2012: Atmospheric water vapor transport and recycling in Equatorial Central Africa through NCEP/NCAR reanalysis data, *Clim Dyn*, 38(9-10), 1715-1729.

Samba, G., Nganga D., and Mpounza M., 2007: Rainfall and temperature variations over Congo-Brazzaville between 1950 and 1998. Theor. Appl. Climatol., 91, 85–97.

Sanga-Ngoie K, Fukuyama, J.B. 1996: Interannual and long-term climate variability over the Zaïre river basin

during the last 30 years. J Geophys Res 101(16): 351–360

Vondou, D. A., A. Nzeukou, A. Lenouo, and F. M. Kamga, 2010: Seasonal variations in the diurnal patterns of convection in Cameroon-Nigeria and their neighboring areas. Atmos. Sci. Lett., 11, 290–330.

REFERENCES BIBLIOGRAPHIQUES

FIRST PART

Potential References (Not all are in the text now and other are here and not in the text)

Adger, N., 2006. Vulnerability. Global Environmental Change 16, 268–281.

Bele, M.Y., Somorin, O., Sonwa, D.J., Nkem, J.N., Locatelli, B., 2011. Forests and climate change adaptation policies in Cameroon. Mitigation and Adaptation Strategies for Global Change 16, 369–385.

Desanker, P.V., Justice, C.O., 2001. Africa and global climate change: critical issues and suggestions for further research and integrated assessment modeling. Climate Research 17, 93–103.

Ecosecurities, 2009. Gestion des terres et options de financement lies aux changements climatiques en Afrique centrale : activités d'atténuation et d'adaptation aux changements climatiques en afrique centrale et options pour améliorer l'accès aux financements liés aux changements climatiques et pertinents pour la ccd. Document de travail Mécanisme Mondial de l'UNCCD, Rome Italie. 89 pp.

Forner, C. 2006. Will Forests Survive the Adaptation Debate?—Linking Ecosystem Services to Development and Adaptation Policies. Unpublished paper CIFOR/CATIE, 16 pp.

IPCC — Intergovernmental Panel on Climate Change, 2007a. Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge. Cambridge University Press, Cambridge.

IPCC — Intergovernmental Panel on Climate Change (IPCC), 2007b. Climate change 2007: the physical science basis. Contribution of Working Group I to the Fourth Assessment Report of the Interg

Kalame, F.B., 2011. Forest governance and climate change adaptation: Case studies of four African countries. Academic dissertation, University of Helsinki, Viikki Tropical Resources Institute VITRI, Tropical Forestry Reports.

Kasulu et al. 2009

Kleine, M., Buck, A. y Eastaugh, C., eds. 2010. Making African forests fit for climate change: A REGIONAL VIEW OF CLIMATE-CHANGE IMPACTS ON FORESTS AND PEOPLE, AND OPTIONS FOR ADAPTATION. Vienna, IUFRO Headquarters. 40 pp.

Locatelli, B., Kanninen, M., Brockhaus, M., Colfer, C.J.P., Murdiyarso, D., Santoso, H., 2008. Facing an uncertain future: how forests and people can adapt to climate change. Forest Perspectives No.5. Centre for International Forestry Research, Bogor, Indonesia.

Molua, E.L., Lambi, C.M., 2007. The Economic Impact of Climate Change on Agriculture in Cameroon. Policy Research Working Paper Series 4364, the World Bank.

Nasi et al 2009

Somorin, O.A., Brown, H.P.C., Visseren-Hamakers, I.J., Sonwa, J.D., Arts, B., Nkem, J., 2012. The Congo Basin forests in a changing climate: policy discourses on adaptation and mitigation (REDD+). Global Environmental Change 22 (1), 288–298.

Sonwa, D., Bele, Y., Somorin, O., Nkem, J., 2010. Central Africa is not only carbon stock: preliminary efforts to promote.
adaptation to climate change for forest and communities in Congo Basin. Nature and Faune 25 (1), 52–57.

Sonwa, D.J., Nkem, J.N., Idinoba,M.E., Bele,M.Y., Jum, C., 2012a. Building regional priorities in forests for development and
adaptation to climate change in the Congo Basin. Mitigation and Adaptation Strategies for Global Change 17, 441–450.
http://dx.doi.org/10.1007/s11027-011-9335-5.

Sonwa, D.J., Somorin, O.A., Jum, C., Bele, M.Y., Nkem, J.N., 2012b. Vulnerability, forest-related sectors and climate change
adaptation: the case of Cameroon. Forest Policy and Economics 23, 1–9.

Tadoum et al. 2012

Tompkins, E.L., Adger, W.N., 2004. Does adaptive management of natural resources enhance resilience to climate change?
Ecology and Society 9 10.

Merci d'insérer ici vos références / Please insert here your references

GIZ 2011 : Etat des lieux sur les modélisations de changements climatiques dans les pays de l'espace COMIFAC et informations sur la disponibilité des données hydrométéorologiques des pays concernés

Hänsler et al., 2013: Climate Change Scenarios for the Congo Basin:

To clarify: German International Cooperation (GIZ), the Climate Service Centre (CSC) in Hamburg, Germany and the Wageningen University and Research Centre (WUR) in the Netherlands