# Climate Change Scenarios for the Congo Basin

## Executive Summary

The African continent has an elevated susceptibility towards the stress caused by climate change combined with relatively low adaptation capacities as highlighted by the 4th Assessment Report (IPCC AR4) of the Intergovernmental Panel on Climate Change (IPCC). The forests of the Congo basin are the second largest continuous rainforest in the world, covering an area of approximately 1.8 Million $km^2$. The Congo forests are extremely important for storing carbon and their impact on the global water cycle through local water recycling. Nevertheless, there are only a limited number of studies focusing on climate change and the resulting impacts for the Congo basin. One of the major reasons for this is the lack of observational climate and hydrological data, which makes it difficult to evaluate the performance of modelling studies. The elevated vulnerability of the sectors agriculture / food security, water supply and ecosystems implicates that the concepts of sustainable management and the development strategies take climate change aspects into account and be adjusted if needed. In order to achieve that, the so far existing data from the sub-region are insufficient. It is thus of major importance to generate specific and solid sub-regional data on climate change, its impacts on key sectors of the Central African economy and ecology and on potential adaptation options to combat the effects of climate change.

Since 2008, the International Climate Initiative (ICI) of the German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU) has been financing climate and biodiversity projects in developing and newly industrialising countries, as well as in countries in transition. The ICI is a key element of Germany's fast-start financing. It is in the framework of ICI that in 2009, BMU mandated the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH to implement the project "Climate Change Scenarios for the Congo Basin". The main aim of the project was to provide national and regional decision makers with relevant climate change scenarios for the countries in the greater river Congo basin region in order to allow these decision makers i) to adapt their management strategies related to natural resources (such as forests, water, agriculture) to climate change and ii) to strengthen the science base for their interest in the post-Kyoto negotiations context.

It was a joint project of GIZ, the Climate Service Centre (CSC) in Hamburg, Germany and the Wageningen University and Research Centre (WUR) in the Netherlands running from late 2010 to early 2013 with a total budget of 1.530.000€. GIZ as the lead implementing organisation was responsible for sub-contracting the internationally established research institutions for the scientific part of the project and for creating a link between these institutions and the respective countries of the sub-region. GIZ further facilitated the transfer of the results towards the decision makers of the COMIFAC member countries.

The scientific part was subdivided between CSC and WUR and a dedicated interdisciplinary workflow has been established – connecting projected climate changes and thereby resulting impacts on the hydrology, forestry and agriculture with direct and indirect monetary threats and chances, and finally giving advice with respect to management strategies and the political decision making process. A sketch of the workflow of the project is given in Figure 1.

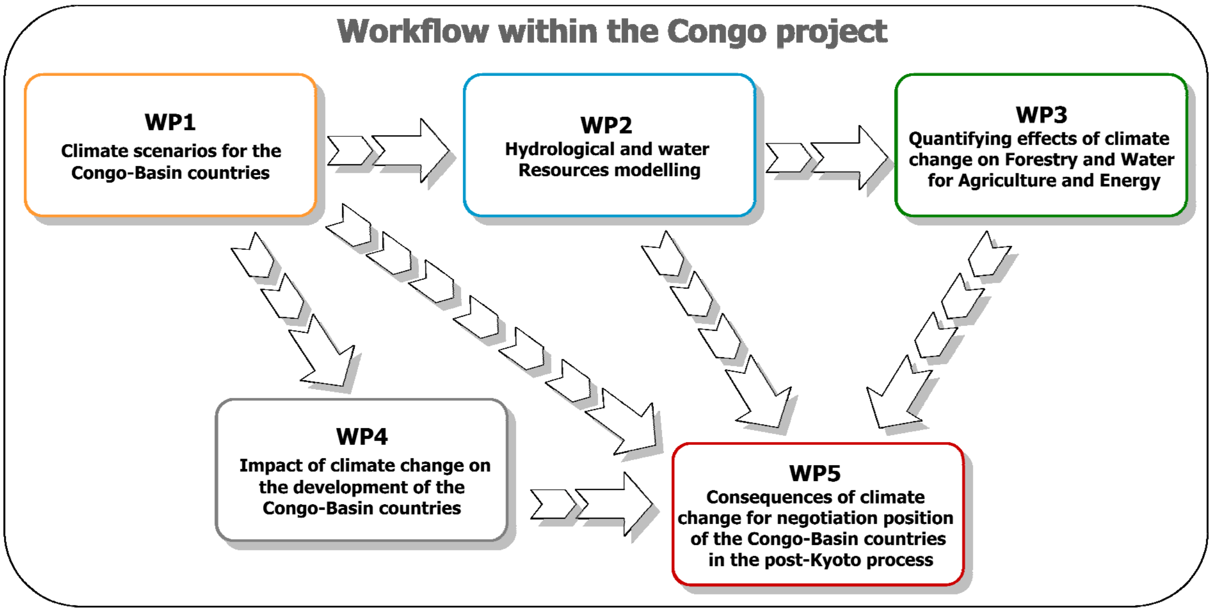


Figure 1: Interdisciplinary work-flow by work-packages (WP) of the project "Climate Change Scenarios for the Congo Basin". WP1 was conducted by CSC; subsequent WPs 2-5 were conducted by WUR.

CSC was responsible for the regional climate change assessment. In a first step, available projections from state-of-the-art global climate models (from the CMIP3 and CMIP5 projects) have been analysed. Furthermore, recent projections from CMIP5 global climate models have been downscaled with regional climate models to enlarge the available dataset of independent climate change projections. Subsequently a dataset consisting of 77 different climate change projections from global and regional climate models was used for the regional climate change assessment. Out of this large ensemble, six representative projections were then used by WUR to conduct further simulations by feeding their results into two impact models, namely the Lund-Potsdam-Jena-managed land model (LPJml) and the distributed Variable Infiltration Capacity model (VIC). Based on these simulations, the impact of climate change on regional water availability, with its possible impacts on hydro-power generation potential, agricultural water use and productivity and the carbon stocks in the vegetation have been studied. On the basis of the model results, suitable adaptation and management options have been developed in the project. The major findings of the project are summarized in the subsequent paragraphs. A summary of the underlying data and models used in the different work packages is depicted in Figure 2.

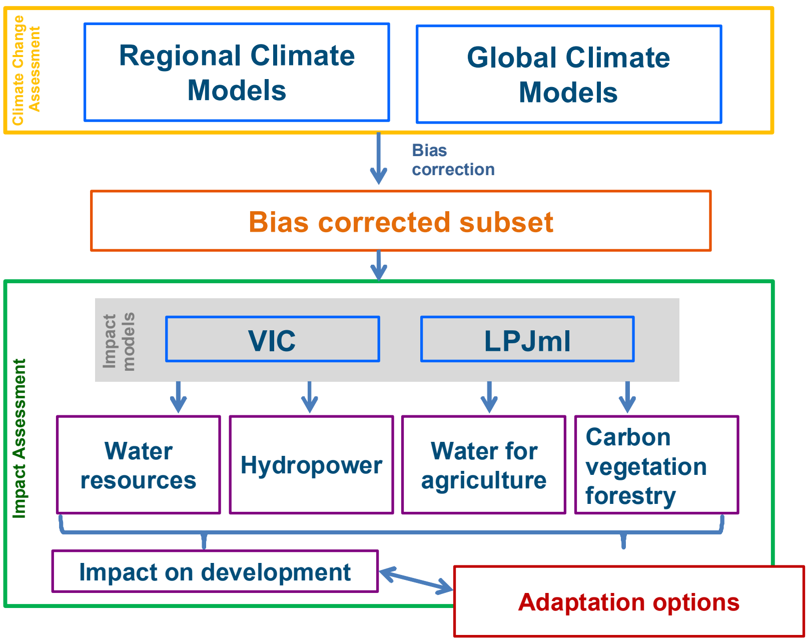


Figure 2: Modelling chain of the project "Climate Change Scenarios for the Congo Basin"

**Regional Climate Change Assessment:**
The climate change assessment described in this report was based on a unique large set of projections from global climate models from the CMIP3 project (database of the 4th IPCC assessment report) and the CMIP5 project (database of the upcoming 5th IPCC assessment report due in 2013). Moreover bias-corrected and statistical downscaled projections of the EU-WATCH project have been included along with the projections of regional climate models. Although most of the regional climate projections are developed within the framework of this project, a few simulations from the preliminary CORDEX Africa data archive are also considered for the analysis.

For the analysis of potential climate changes two potential future developments have been considered – a “*high*” emission scenario (combining climate projections following the SRES A2 and RCP8.5 emission scenarios) and a “*low*” emission scenario (combining climate projections following the SRES B1 and RCP4.5 and RCP2.6 emission scenarios). Altogether an ensemble of 46 different projections has been analysed for the case of the low emission scenario and an ensemble of 31 projections for the high emission scenario. This unique large dataset of different kind of projections (from global climate models, regional climate projections and statistically bias-corrected and downscaled global projections) allows the identification of robust patterns and associated ranges of projected changes for the first time over this region.

The major findings of the climate change assessment can be summarized as follows. For the near surface air temperature, all assessed models agree on a substantial warming towards the end of the century in all seasons of the year regardless of the underlying scenario. On an annual basis a warming in the range of +1.5 and +3°C for the low and in the range between +3.5 and +6°C for the high emission scenario can be considered to be likely towards the end of the 21st century. In general projected temperature increase is slightly above average in the northern parts of the region and slightly below average in the central parts. Also for temperature extremes (frequency of cold/hot days and nights) all models agree on a decrease/increase in the future. Especially the hot days and nights are projected to occur much more frequently in the future, particularly in the case of the high emission scenario. Since for the temperature related parameters all 77 analysed projections agree in the sign of the projected changes, therefore these changes can be considered to have a very large robustness.

For total precipitation the agreement between the assessed projections is not as high as for the temperature. For all zones some models project an increase in annual total precipitation and some project a decrease. If the full range of projected changes in annual total precipitation is considered, all models agree on a change not higher than ±30% towards the end of the 21st century for most parts of the domain with a general tendency of a slight increase in future annual total precipitation. However, in the dryer northern part, a larger increase in annual total precipitation (full range up to about +75%) is projected, mainly related to the northward expansion of the tropical convection zone, which was already described in the scientific literature. These findings are independent of the underlying emission scenario. If only the likely range is considered, projected changes in annual total precipitation are 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. This finding once again points to the conclusion that - on the basis of the assessed large ensemble of climate change projections – it is not likely that drastic changes in annual total rainfall will occur in the future over the greater Congo basin region.

Although the annual total precipitation amounts might not change dramatically, the rainfall characteristics are projected to undergo some substantial changes. An example for this is the likely increase in the intensity of heavy rainfall events in the future (likely range for most parts positive, up to ~ +30%). Also the frequency of dry spells during the rainy season is projected to substantially increase in the future over most parts of the domain. This indicates a more sporadic rainfall distribution in the future.

In summary the climate change assessment for the greater Congo basin did reveal that projected rainfall changes are unlikely to lead to a general water shortage in the region, however some prolonged and more frequent dry periods might become more likely in the future. This finding is independent of the underlying emission scenario. In terms of the projections in near surface air temperature, the projected warming is substantially larger under the high emission scenario, and therefore might also have a substantially larger impact on the living environment in the region.

**Regional Climate Change Impacts Assessment:**
It is impossible to use all 77 climate change scenarios for the impact analyses so instead we used a rather representative subset of climate scenarios. Most of the assessments were based on six different global climate change scenarios; however for some studies like the analysis of the forest carbon cycle only two global climate scenarios could be used. This difference in the number of GCM input data into the different assessments causes a limitation of this study that should be kept in mind when comparing the results of the different assessments to each other. However, differences in future climate change impacts that arise between the high and low scenario *within* the same assessment *can* be reliably compared.

Projected changes in rainfall and temperature will result in substantial changes in the hydrology of the Congo basin. Due to temperature increases evaporation potentially also increases. However projected changes in evapotranspiration in the region are not completely consistent in the different assessments. This is probably caused by the fact that different hydrological models were used and that different numbers of climate scenarios have been used as input for the hydrological models. For the climate scenarios analysed, the rainfall generally increased more than the evaporation and as a result the run-off increased up to 50%. Run-off and stream flow will especially increase in the wet season. This indicates that flood risks will increase significantly in the future throughout the basin. Floods will increase most in the central and western part of the Basin. While run-off and stream flow will clearly increase during the wet seasons, 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 inline with the projected intensification of heavy rainfall events.

In general, our analyses shows 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 will also 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.

Climate change will have a range of different impacts on forest ecosystems. The higher atmospheric $CO_2$ 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 $CO_2$ concentrations are essential to further narrow down prediction ranges.

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 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 the analysis indicates that more frequent droughts will affect agriculture production and water stress.

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 the 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. Nevertheless 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. 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.

**Regional Climate Change Adaptation Options:**

In terms of adaptation, first of all there is a need to improve preparedness for extreme weather events such as droughts and floods because these kinds of events will occur more often in the future due to climate change. 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 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 should 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 still have very big development challenges. The general income tends to be low and there are still high poverty rates. These immediate development needs are overall 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 be integrated in future development plans. A more 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 more severely affected by climate change. The climate change related increased variability in agricultural production might lead to increased migration from these countries into the Congo basin.