GUINEA

COUNTRY REPORT

GIS Hydropower Resource Mapping and Climate Change Scenarios for the ECOWAS Region

ECOWAS Centre for Renewable Energy and Energy Efficiency
www.ecreee.org

AUSTRIAN DEVELOPMENT COOPERATION

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Program Responsibility:

The ECOWAS Small-Scale Hydropower Program was approved by ECOWAS Energy Ministers in 2012. In the frame of this program ECREEE assigned Poyry Energy GmbH in 2015 for implementation of a GIS Hydro Resource Mapping and Climate Change Scenarios in ECOWAS countries with Hydropower potentials. One deliverable of this project are 14 country reports summarizing the GIS Hydro Resource mapping and climate change scenarios. The overall methodology background information and lessons learnt of these Country Reports are described in the final report *"GIS Hydropower Resource Mapping and Climate Change Scenarios for the ECOWAS Region - Methodology & Lessons Learnt."*
www.ecowrex.org/smallhydro

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PREFACE

The 15 countries of the Economic Community of West African States (ECOWAS) face a constant shortage of energy supply, which has negative impacts on social and economic development, including also strongly the quality of life of the population. In mid 2016 the region has about 50 operational hydropower plants and about 40 sites are under construction or refurbishment. The potential for hydropower development – especially for small-scale plants – is assumed to be large, but exact data were missing in the past.

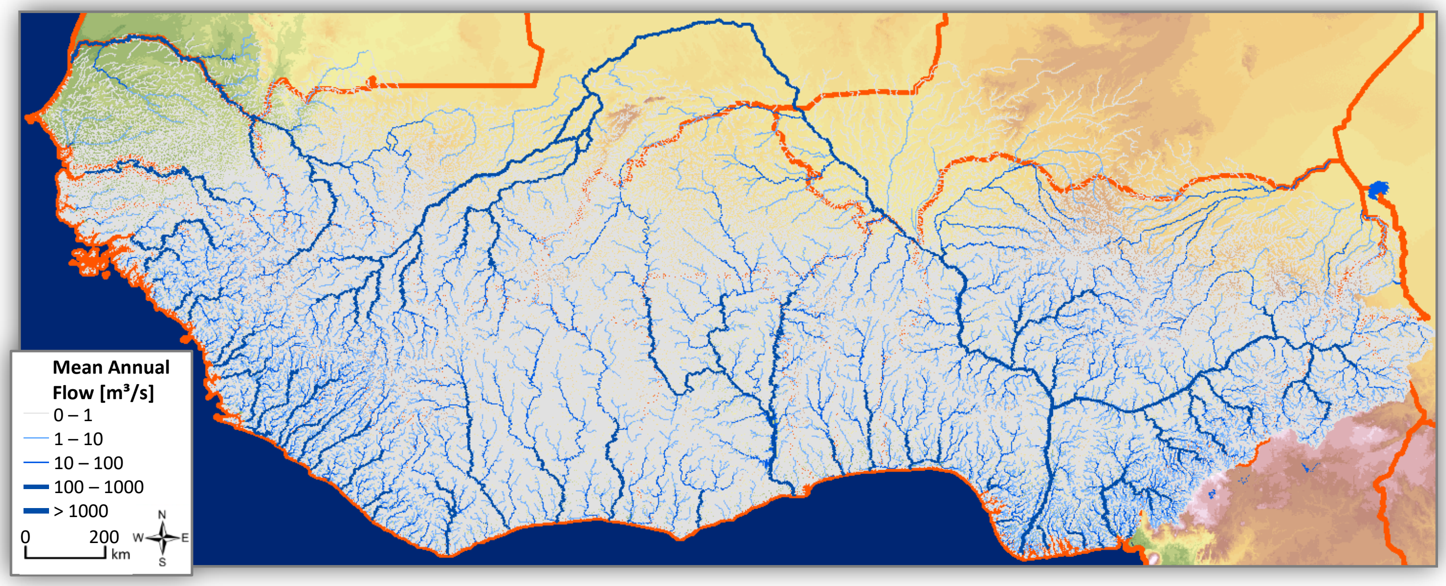
The ECOWAS Centre for Renewable Energy and Energy Efficiency (ECREEE), founded in 2010 by ECOWAS, ADA, AECID and UNIDO, responded to these challenges and developed the ECOWAS Small-Scale Hydropower Program, which was approved by ECOWAS Energy Ministers in 2012. In the frame of this program ECREEE assigned Pöyry Energy GmbH in 2015 for implementation of a hydropower resource mapping by use of Geographic Information Systems (GIS) for 14 ECOWAS member countries (excluding Cabo Verde). The main deliverable of the project is a complete and comprehensive assessment of the hydro resources and computation of hydropower potentials as well as possible climate change impacts for West Africa. Main deliverables of the GIS mapping include:

- River network layer: GIS line layer showing the river network for about 500,000 river reaches (see river network map below) with attributes including river name (if available), theoretical hydropower potential, elevation at start and end of reach, mean annual discharge, mean monthly discharge, etc.
- Sub-catchment layer: GIS polygon layer showing about 1000 sub-catchments with a size of roughly 3000 km². This layer summarizes the data of all river reaches located within the sub-catchment.

Hydropower plants are investments with a lifetime of several decades. Therefore, possible impacts of climate change on future discharge were incorporated into the river network and sub-catchment GIS layers. The GIS layers are available in the ECREEE Observatory for Renewable Energy and Energy Efficiency (www.ecowrex.org).

This report summarizes the results of the GIS layers for Guinea and includes:

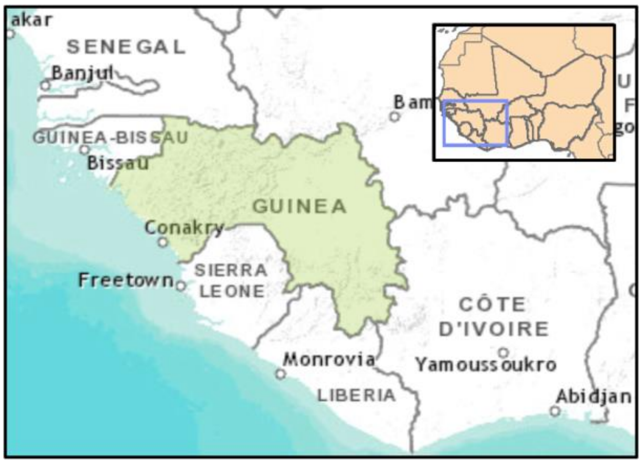
- General information
- Climate
- Hydrology
- Hydropower potential
- Climate change



GENERAL INFORMATION

Guinea is a medium-sized country in West Africa and has about 12 Mio inhabitants. The capital of Guinea is Conakry. The neighboring countries are Guinea-Bissau in the north-west, Senegal in the north, Mali in the north-east, Côte d'Ivoire in the east was well as Liberia and Sierra Leone in the south (see map below).

Hydropower plays a significant role for energy generation in Guinea. Currently there are 14 existing hydropower plants, including six small hydropower plants, four medium hydropower plants and four large hydropower plants (see table below).

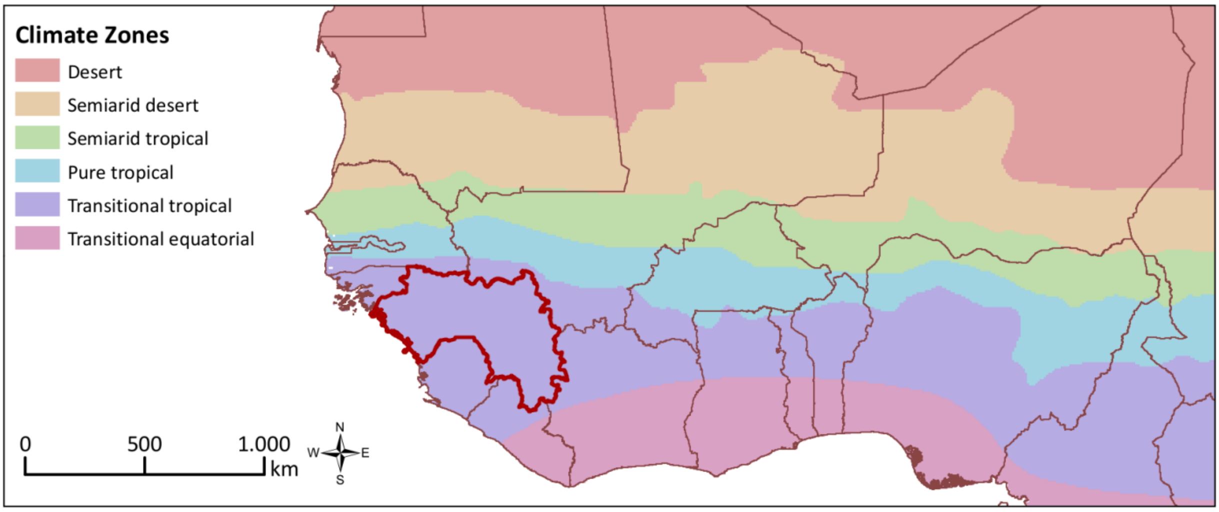


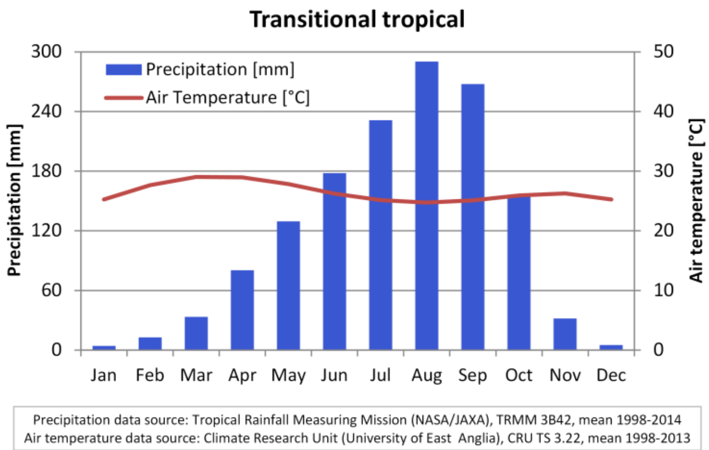
General Information for Guinea	
Inhabitants (2014)	12.3 Mio.
Area (2014)	245,860 km²
GDP per capita (2014)	540 USD
Electrification rate total/urban/rural (2012)	18/69/2 %
Hydro installed capacity (2014)	128 MW
Electricity generation (2014)	686 GWh
Electricity generation from hydropower (2014)	425.8 GWh
Number of existing hydropower plants with installed capacity < 1 MW (2016)	14
Number of existing small hydropower plants with installed capacity 1-30 MW (2016)	6
Number of existing medium hydropower plants with installed capacity 30-100 MW (2016)	4
Number of existing large hydropower plants with installed capacity >100 MW (2016)	4

Source: ECOWAS Country Profiles (www.ecowrex.org)
Reference year given in brackets.

CLIMATE

The climate in West Africa can be grouped into six zones with distinctive seasonal rainfall patterns (L'Hôte et al., 1996). Guinea is located entirely in the "Transitional tropical" climate zone, which is characterized by high rainfall amounts between July and September, but also significant rainfall amounts in May, June and October. The seasonality in rainfall is controlled by the seasonal movement of the Inter Tropical Convergence Zone (ITCZ). Air temperature is highest in April before the start of the rainy season. After the rainy season in October there is a secondary peak in air temperature, whereas August, December and January are the coldest months of the year. The diagram below summarizes the mean monthly rainfall and air temperature in the Transitional tropical climate zone.

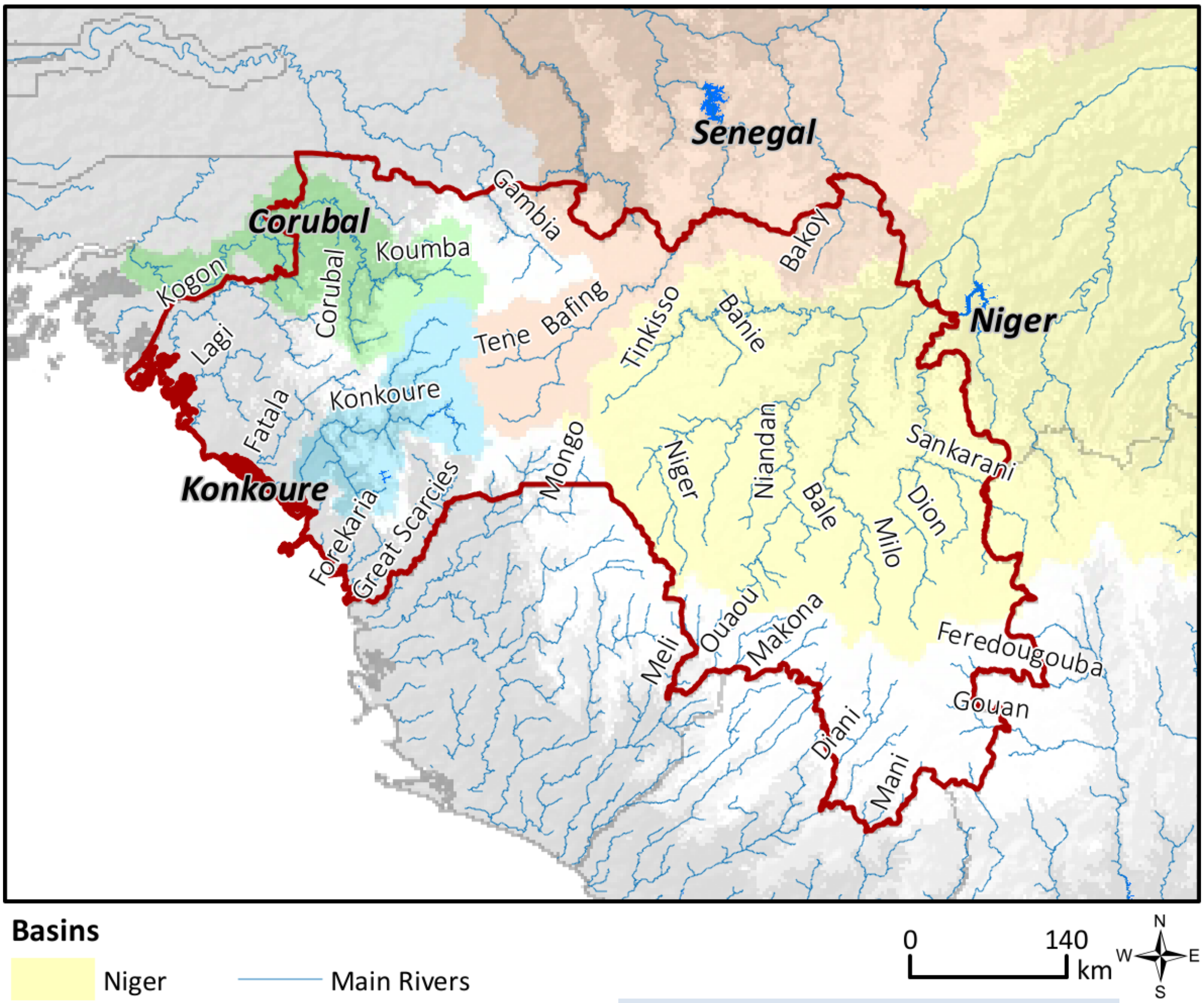




HYDROLOGY

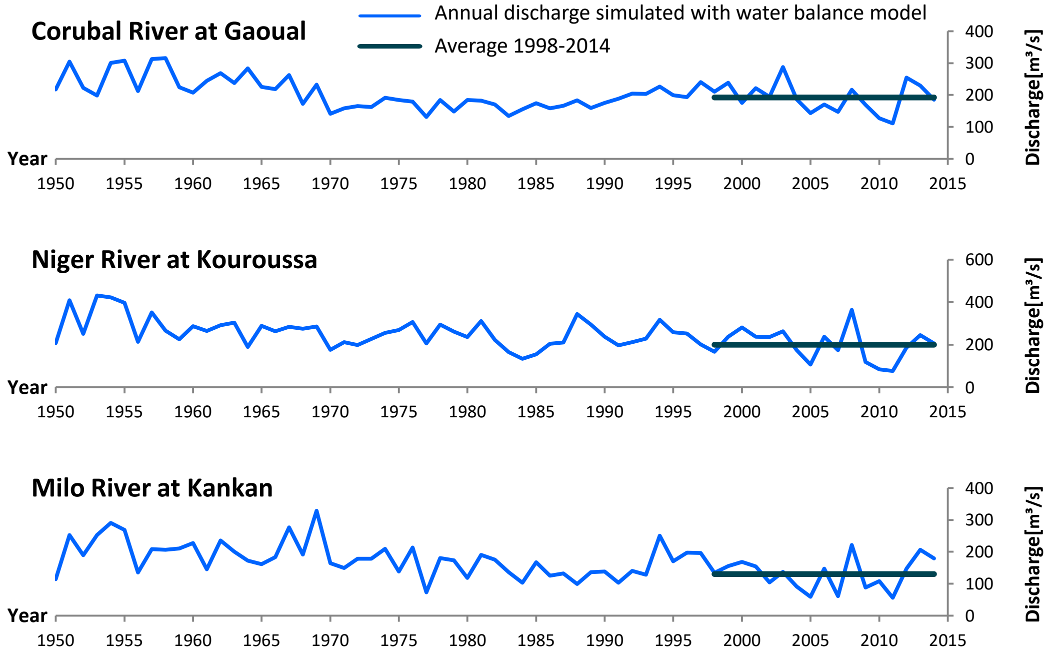
Several large rivers of regional importance have their sources in Guinea. The Fouta Djallon highlands in the central part of Guinea is the headwater region of the Corubal, Konkoure, Senegal and Gambia rivers. The Konkoure basin covers 7 % of the country and is entirely located in Guinea. The Corubal basin also covers 7 % of the country before flowing into neighboring Guinea Bissau. The Senegal basin covers 13 % of the country and flows to the north. The Niger River, which is the largest river in West Africa, has its source in the eastern part of Guinea, and several large tributaries (e.g. Milo River) discharge into the Niger River before the water flows into Mali to start a journey of several months over more than 3000 km. Overall 39 % of Guinea is located in the Niger basin.

The figures on the following page illustrate the annual and seasonal variations in discharge for the Niger, Milo and Corubal rivers. At all three rivers flows were higher in the 1950s and 1960s than in more recent periods such as 1998-2014. All three rivers also show similar seasonality in discharge with high flows between August and October and low flows between January and May.

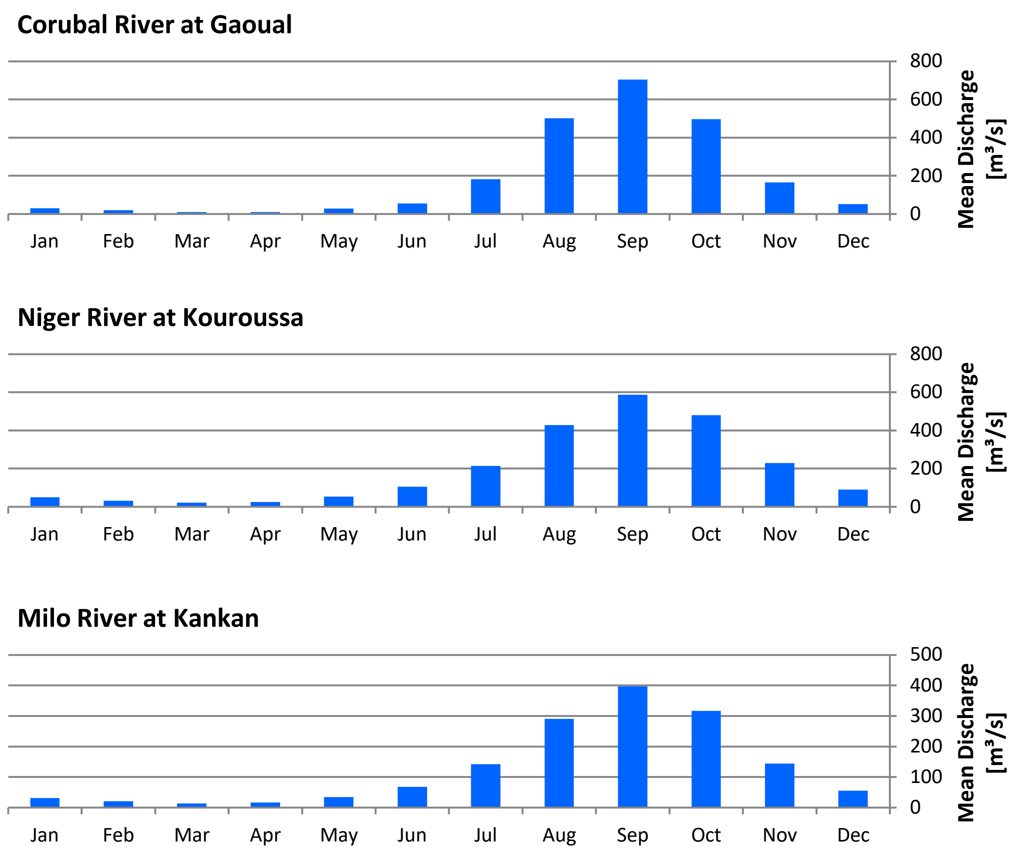


Percentage of country's area located in the four largest river basins	
Niger basin	39.1 %
Senegal basin	12.9 %
Corubal basin	7.2 %
Konkoure basin	6.8 %

Historic Variation in Annual Discharge



Seasonality in Discharge



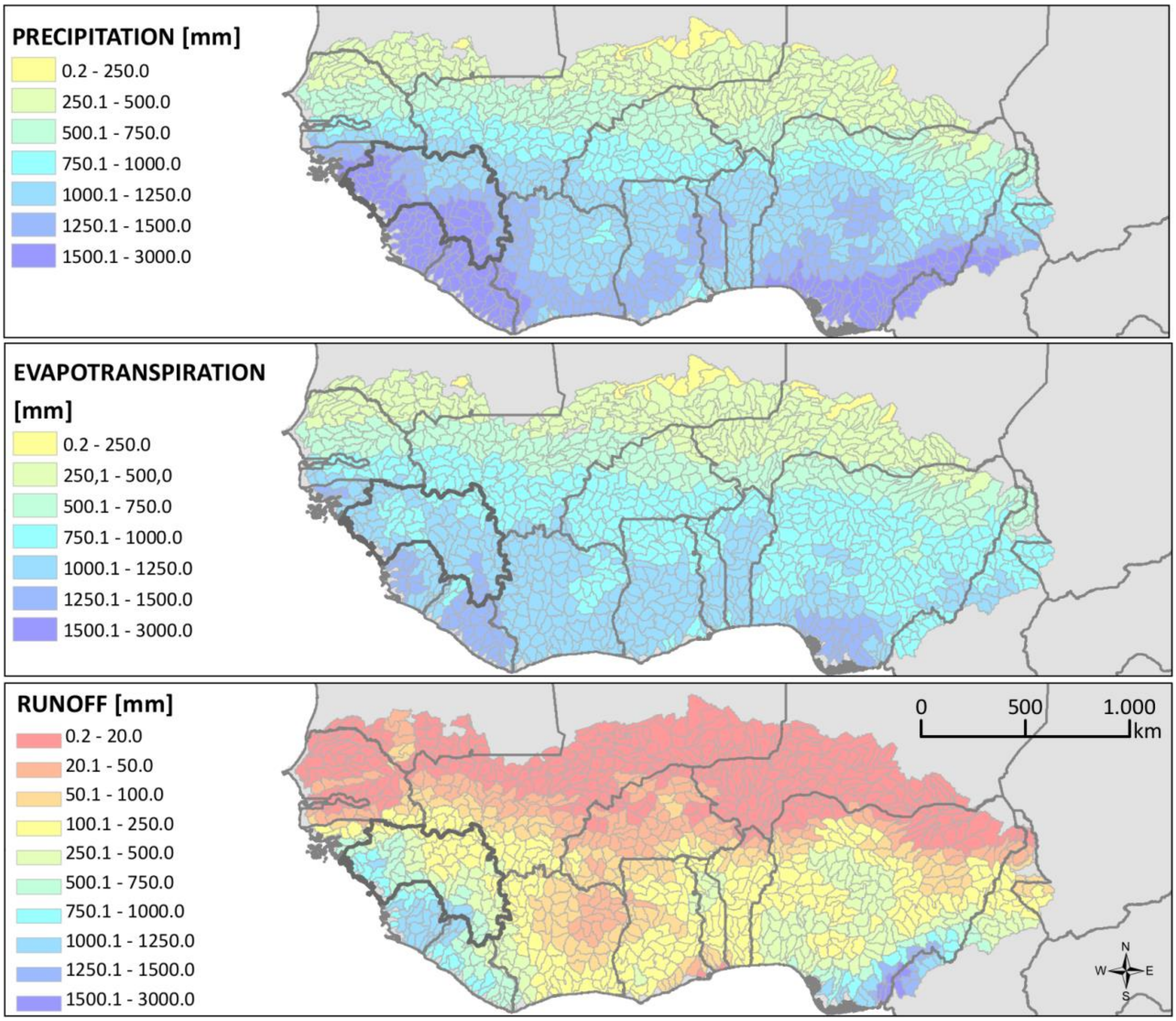
Annual Water Balance

The long-term mean annual water balance describes the partitioning of precipitation (rainfall) into actual evapotranspiration (transpiration by plants, evaporation from soil) and runoff, as over long time periods the change in storage (soil moisture, ground water) can be assumed to be negligible for the mean annual water balance.

The regional distribution of the water balance components in West Africa is strongly controlled by spatial variations in mean annual precipitation. An annual water balance model calibrated with observed discharge data of 400 gauges was used to determine mean annual actual evapotranspiration and runoff for the period 1998-2014, as shown in the maps below. In most parts of West Africa mean annual actual evapotranspiration is considerably larger than mean annual runoff.

In contrast, in the mountainous parts of Guinea mean annual runoff is of similar magnitude as mean annual evapotranspiration. Annual runoff can reach up to 50 % of annual rainfall, in coastal areas runoff is about 40 % of rainfall. In the drier north-eastern part of the country about 80 % of rainfall is lost via evapotranspiration and only 20 % of rainfall generates runoff.

Mean annual discharge is computed by aggregating runoff along the river network, which together with channel slope determines the hydropower potential (see next section).



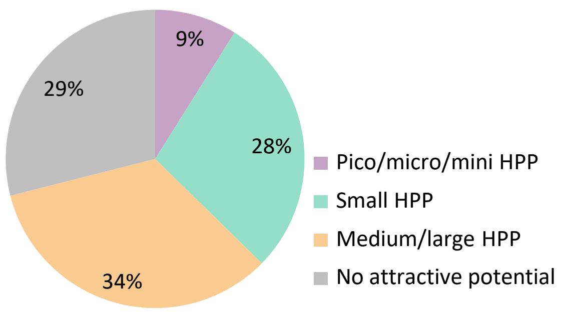
HYDROPOWER POTENTIAL

The theoretical hydropower potential of a river is defined as the amount of power that would be produced if the full head of the river was used and if 100 % of the mean annual discharge was turbinated (i.e. no spillway losses or environmental flow constraints). In this study overall plant efficiency (turbines, hydraulic losses) is assumed with 87 %.

The theoretical hydropower potential for Guinea is estimated to be 5877 MW (reference period 1998-2014), which is the total of all rivers in the country.

The following table and figure show how the total potential of the country is subdivided into theoretical potential for hydropower plants (HPP) of different plant size. A classification scheme based on mean annual discharge (m^3/s) and specific hydropower potential (MW/km) was applied to determine the preferred plant size for river reaches with a typical length of 1 to 10 km. Four classes were considered for the preferred plant size, including pico/micro/mini HPP (< 1 MW installed capacity), small HPP (1-30 MW installed capacity), medium/large HPP (> 30 MW installed capacity), and "No attractive potential" for river reaches with too low specific hydropower potential. For the latter in some cases it may still be worthwhile to utilize this potential in e.g. multi-purpose schemes. The technical potential was not assessed in this study.

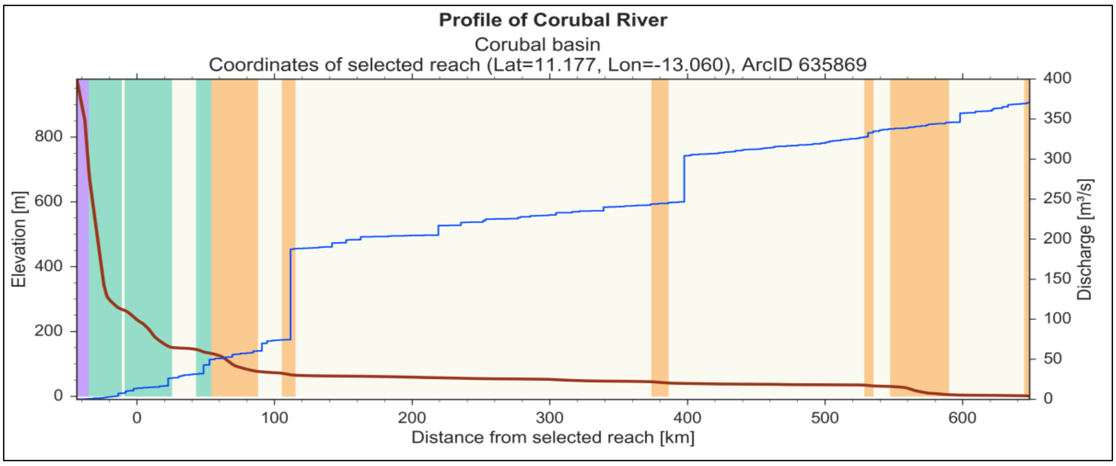
Theoretical Hydropower Potential Guinea: 5877 MW

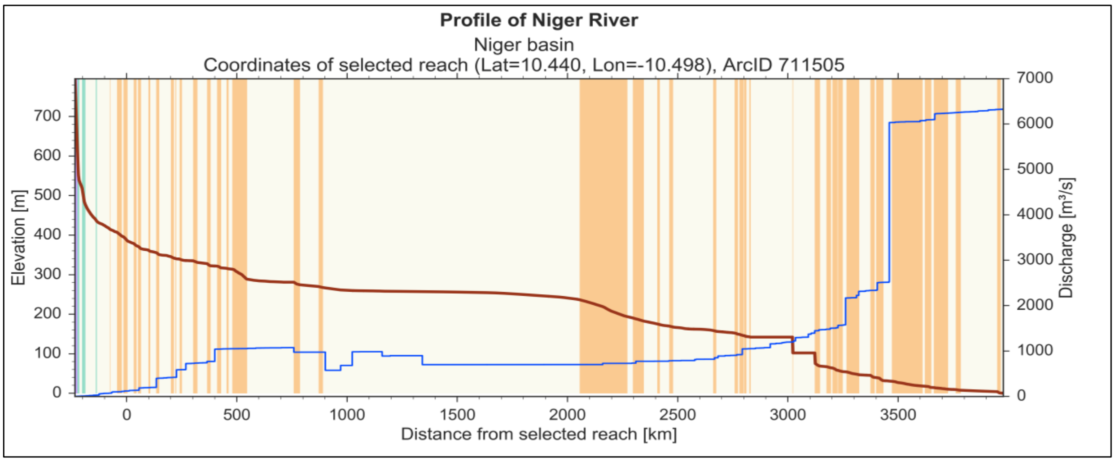


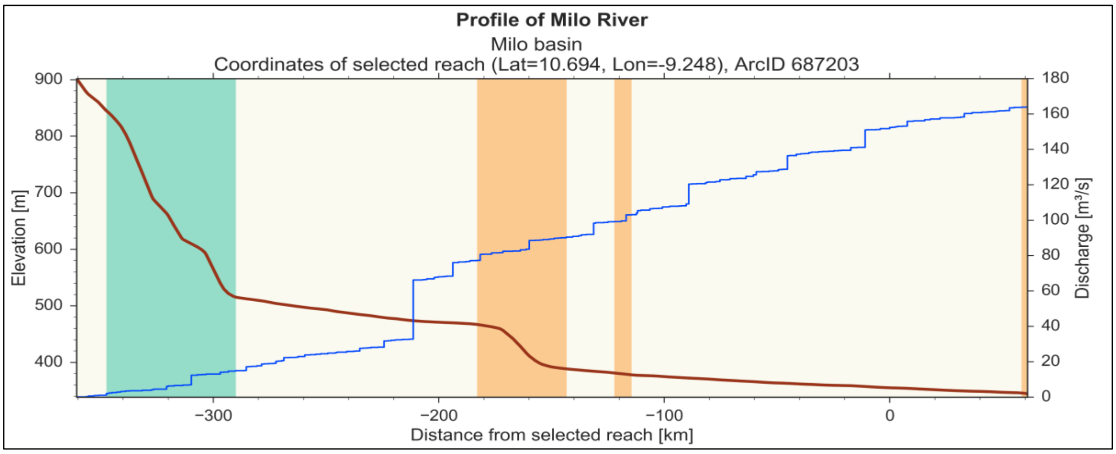
Theoretical Hydropower Potential of Rivers in Guinea	
Pico/micro/mini HPP	524 MW
Small HPP	1670 MW
Medium/large HPP	1980 MW
No attractive potential	1703 MW
Total of all rivers in country	5877 MW
Total of rivers with attractive theoretical potential for pico/micro/mini, small, or medium/large HPP	4174 MW

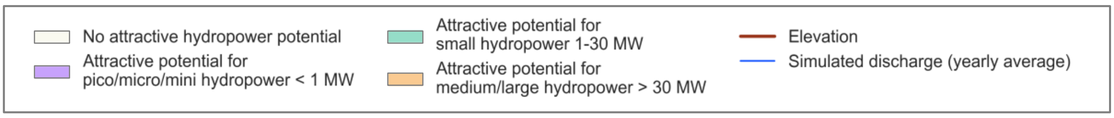
Longitudinal Profiles of Selected Rivers

The following graphs show longitudinal profiles of the Corubal, Niger and Milo rivers, plotting elevation (red) and mean annual discharge (blue) from the source to the mouth of the river. Inflow from tributaries is identifiable as sudden increase in river discharge. Diversions and floodplain losses cause a decrease of discharge in some sections of the Niger River. The background color indicates if a river reach has an attractive theoretical hydropower potential for pico/micro/mini HPP (< 1 MW installed capacity), small HPP (1-30 MW installed capacity), or medium/large HPP (> 30 MW installed capacity).







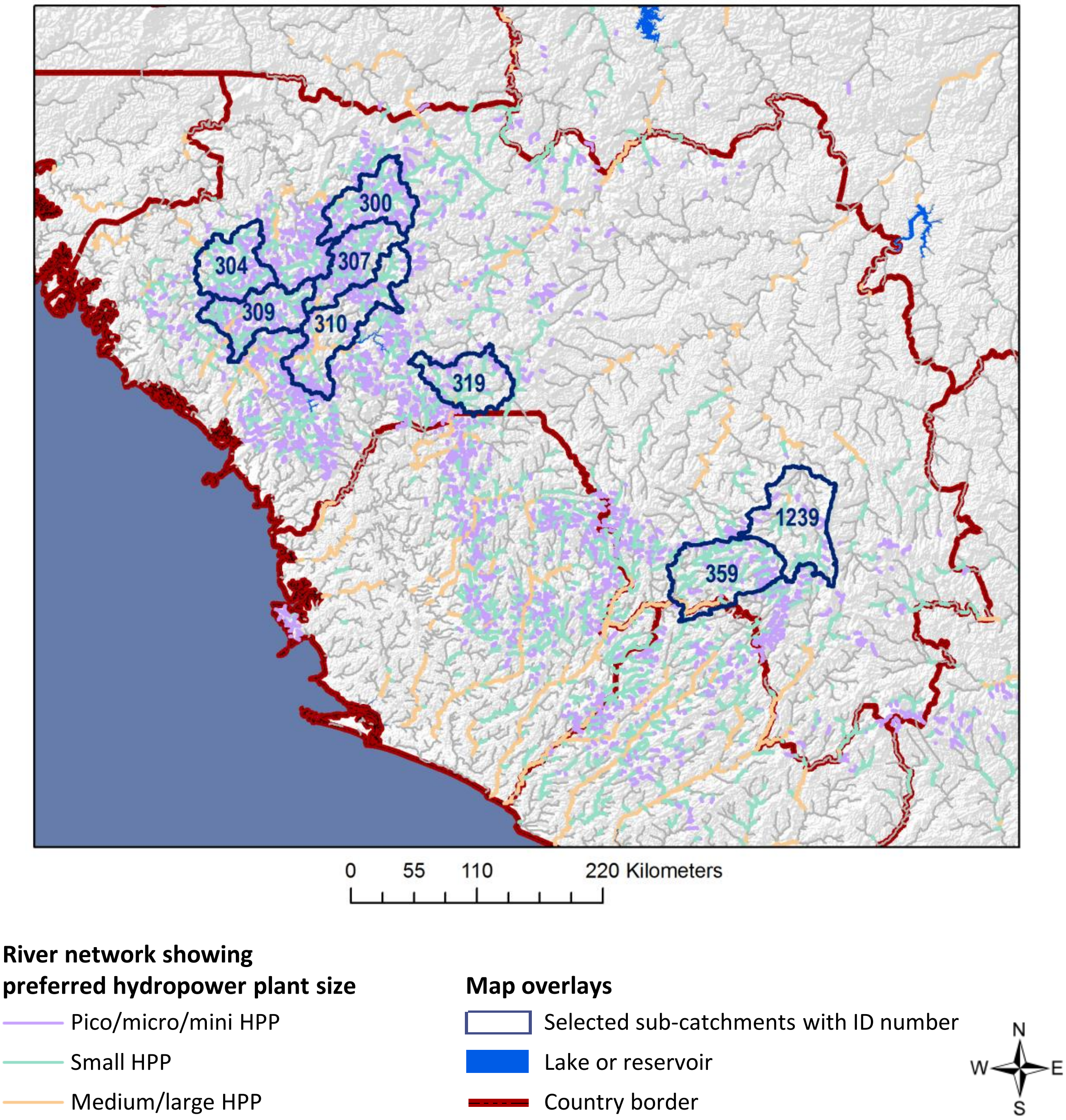


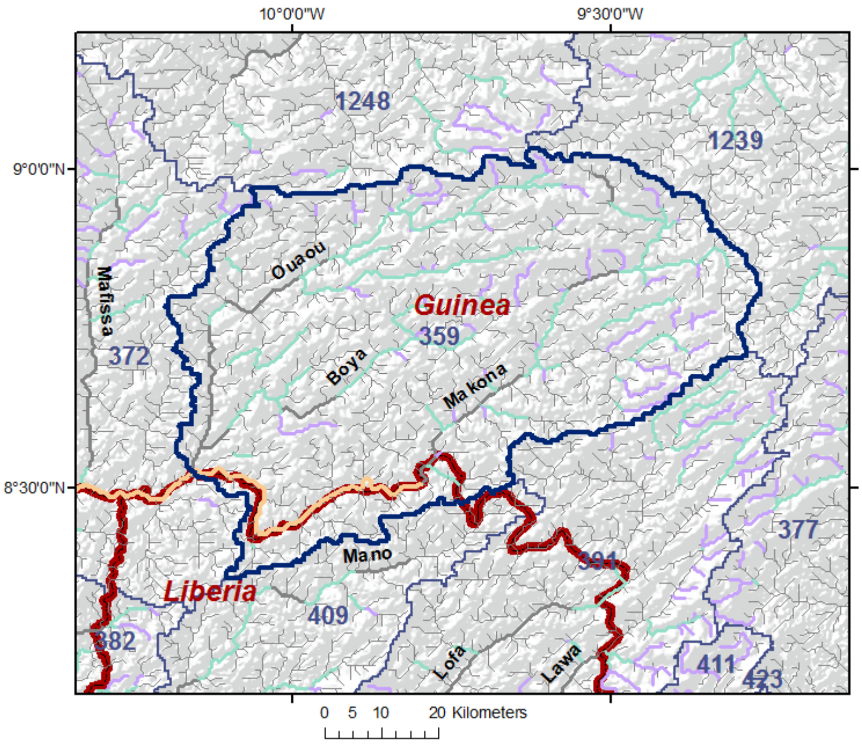
Hydropower Potential in Selected Sub-catchments

The maps and tables on the following pages give information about the theoretical hydropower potential of selected sub-catchments in Guinea. Sub-catchments with attractive theoretical hydropower potential are found in the Fouta Djallon highlands in the central part of Guinea but also in the southern parts of the country.

The table data summarizes the total theoretical hydropower potential of all river reaches within the sub-catchment. River reaches were grouped according to preferred plant size for pico/micro/mini HPP (< 1 MW installed capacity), small HPP (1-30 MW installed capacity), or medium/large HPP (> 30 MW installed capacity). Similarly, the color code of the river network displayed in the maps indicates the preferred plant size. A grey color indicates no attractive potential for hydropower development.

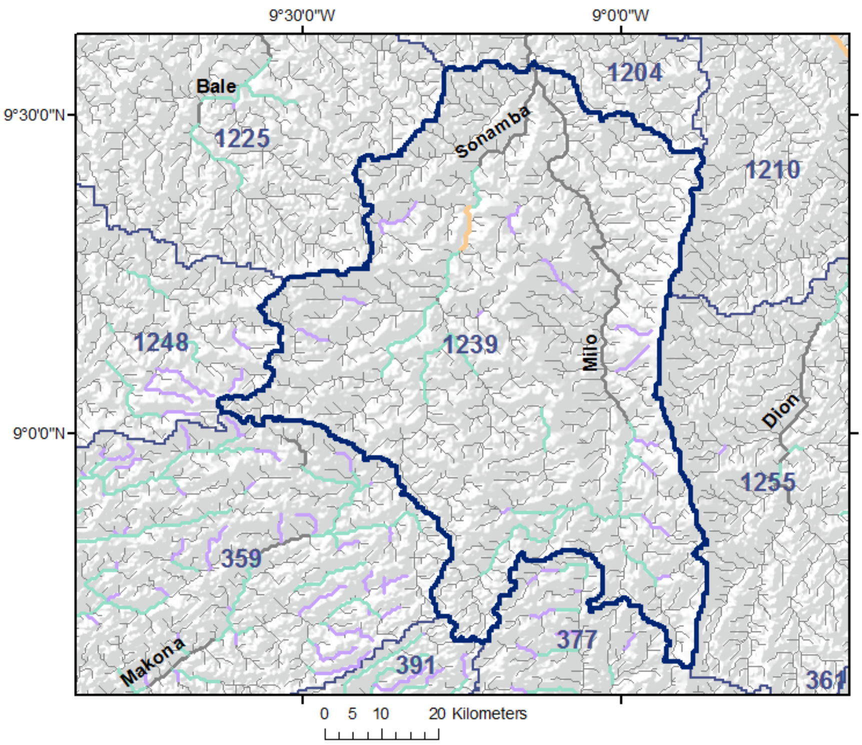
All of the selected sub-catchments have attractive theoretical hydropower potential for development of pico/micro/mini HPP, small HPP and medium/large HPP. Currently only a small fraction of this theoretical potential is utilized by existing hydropower plants, which are also shown in the maps.





Theoretical Hydropower Potential of Rivers in Sub-Catchment #359	
Pico/micro/mini HPP	14.6 MW
Small HPP	97.4 MW
Medium/large HPP	60.1 MW

This sub-catchment forms the headwater region of the Makona River and includes the Ouaou and Boya rivers. There is considerable potential for pico/micro/mini HPP and small HPP at these rivers and smaller tributaries. All of the potential for medium/large HPP is located at sections of the Makona River where the river forms the international border with Liberia.



Theoretical Hydropower Potential of Rivers in Sub-Catchment #1239	
Pico/micro/mini HPP	4.6 MW
Small HPP	46.0 MW
Medium/large HPP	27.4 MW

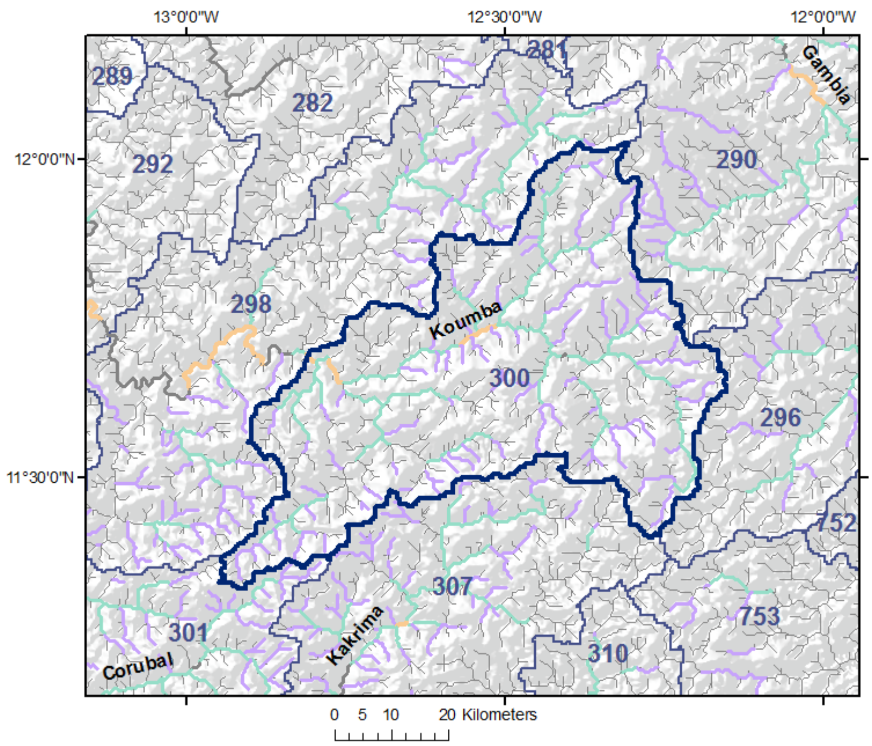
This sub-catchment in southern Guinea forms the headwater region of the Milo River and includes the Sonamba River. Both rivers have considerable potential for small HPP. The Sonamba River also has potential for medium/large HPP, whereas the potential for pico/micro/mini HPP is located at several small tributaries.

River network showing preferred hydropower plant size

- Pico/micro/mini HPP
- Small HPP
- Medium/large HPP
- No attractive potential

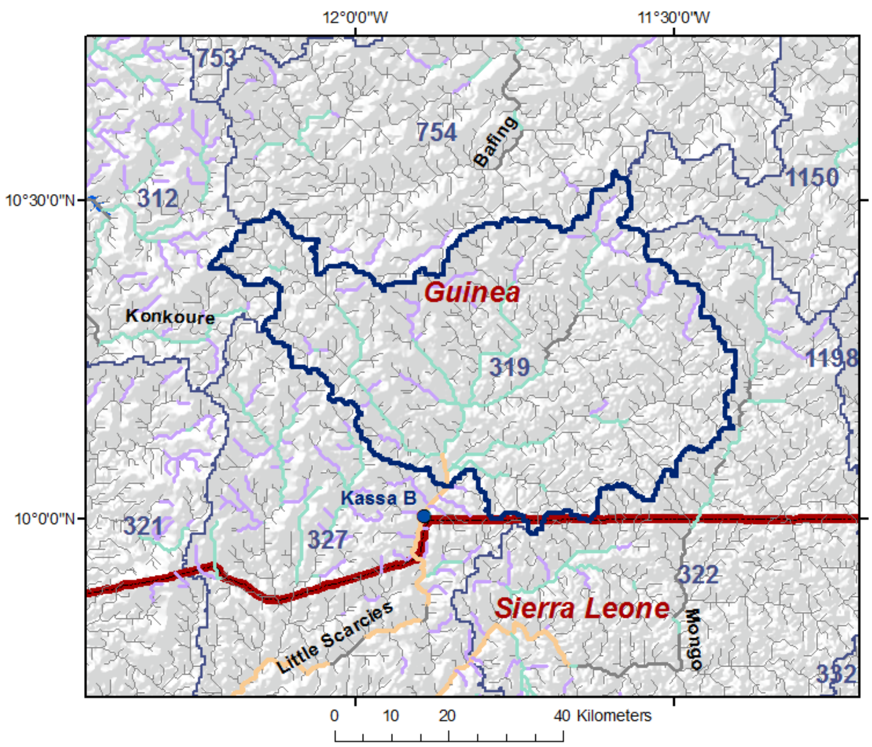
Map overlays

- Existing hydropower plant
- Lake or reservoir
- Sub-catchment boundary
- Country border



Theoretical Hydropower Potential of Rivers in Sub-Catchment #300	
Pico/micro/mini HPP	34.9 MW
Small HPP	129.9 MW
Medium/large HPP	18.0 MW

The headwater region of the Koumba River has high theoretical potential for pico/micro/mini HPP and small HPP. Some of the potential is located at the Koumba River, but most of the potential is located at numerous tributaries.



Theoretical Hydropower Potential of Rivers in Sub-Catchment #319	
Pico/micro/mini HPP	11.2 MW
Small HPP	95.2 MW
Medium/large HPP	10.9 MW

This sub-catchment is situated in the highest part of the Little Scarcies basin. There is considerable potential for pico/micro/mini and small HPP at the Little Scarcies River and its tributaries.

River network showing preferred hydropower plant size

- Pico/micro/mini HPP
- Small HPP
- Medium/large HPP
- No attractive potential

Map overlays

- Existing hydropower plant
- Lake or reservoir
- Sub-catchment boundary
- Country border

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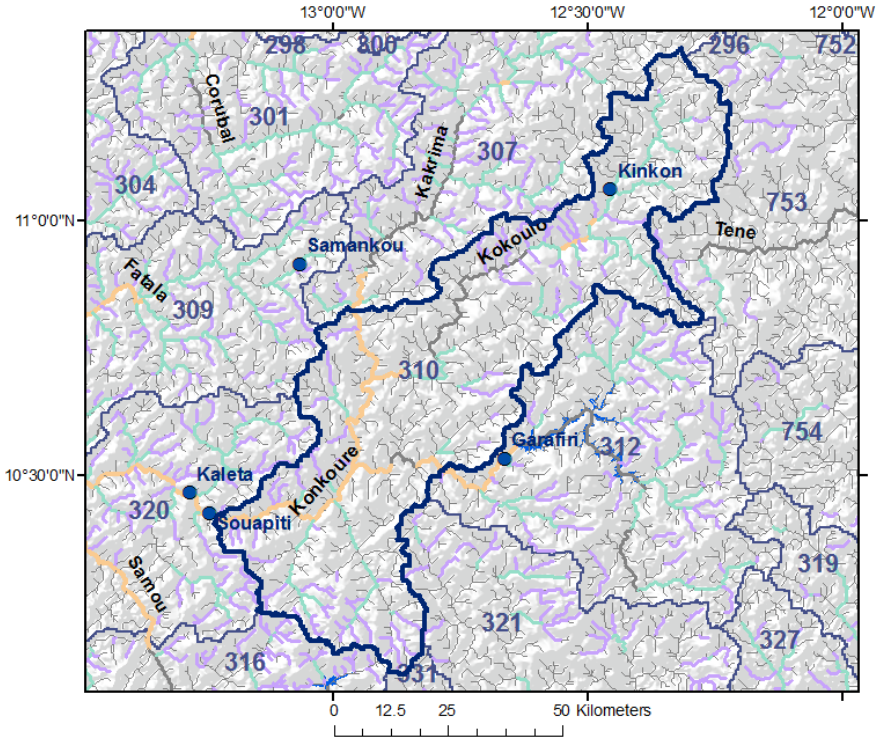
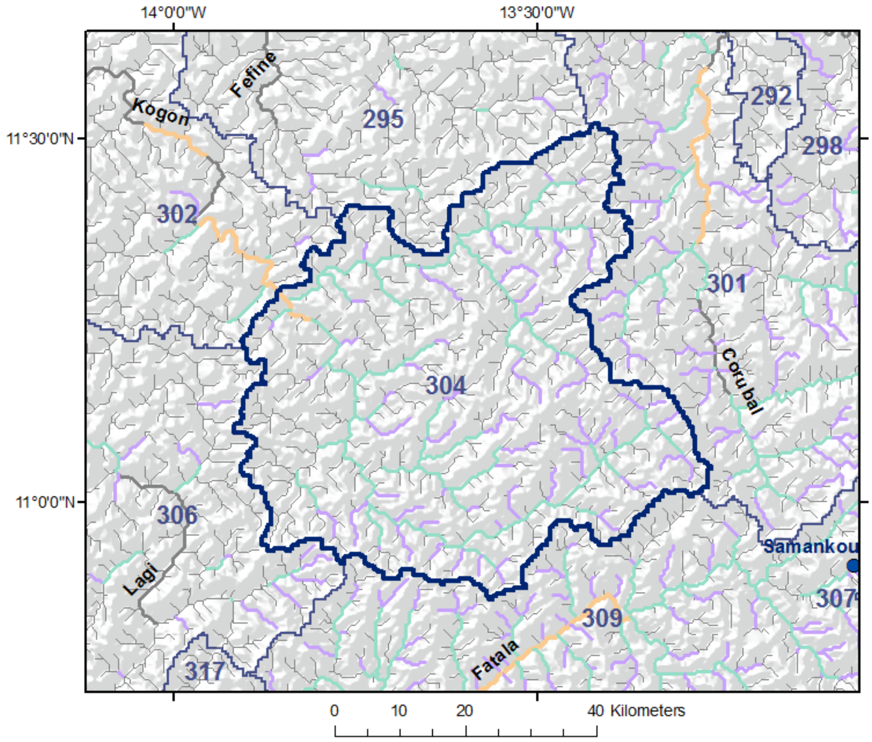


Theoretical Hydropower Potential of Rivers in Sub-Catchment #310	
Pico/micro/mini HPP	39.8 MW
Small HPP	90.5 MW
Medium/large HPP	235.0 MW

This sub-catchment of the Konkoure River includes the lower section of the Kakrima River and the entire Kokoulo River. Several hydropower plants exist in this area. The Kokoulo River and its tributaries have considerable potential for pico/micro/mini and small HPP. The potential for mediuam /large HPP is located at the Kakrima and Konkoure rivers.



Theoretical Hydropower Potential of Rivers in Sub-Catchment #304	
Pico/micro/mini HPP	18.3 MW
Small HPP	78.1 MW
Medium/large HPP	6.5 MW

This sub-catchment is located in the headwater region of the Kogon River, where there are several rivers that have considerable potential for pico/micro/mini and small HPP.

River network showing preferred hydropower plant size

- Pico/micro/mini HPP
- Small HPP
- Medium/large HPP
- No attractive potential

Map overlays

- Existing hydropower plant
- Lake or reservoir
- Sub-catchment boundary
- Country border

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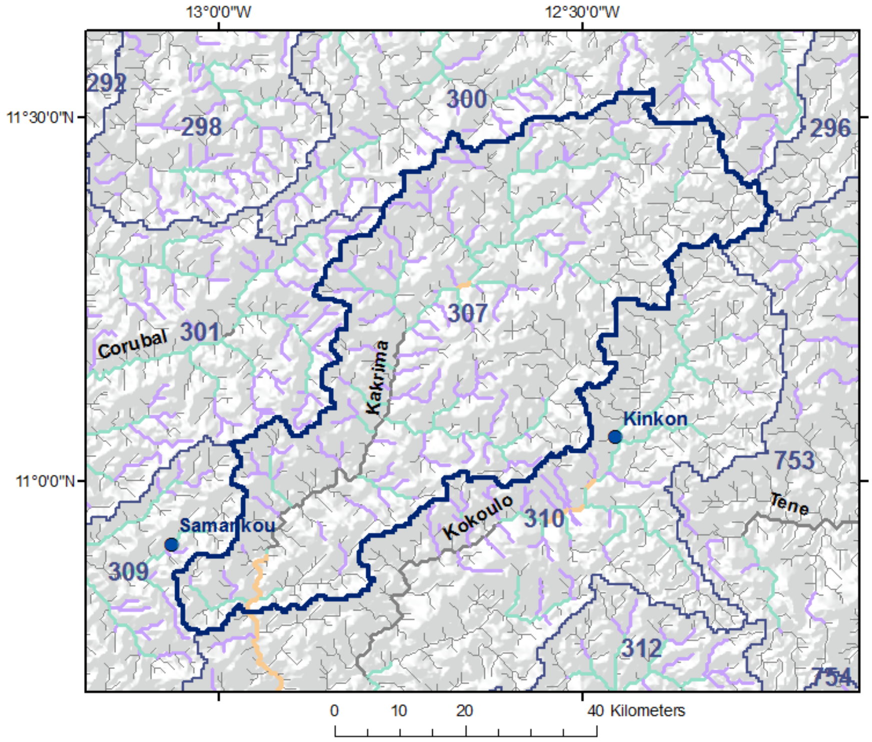
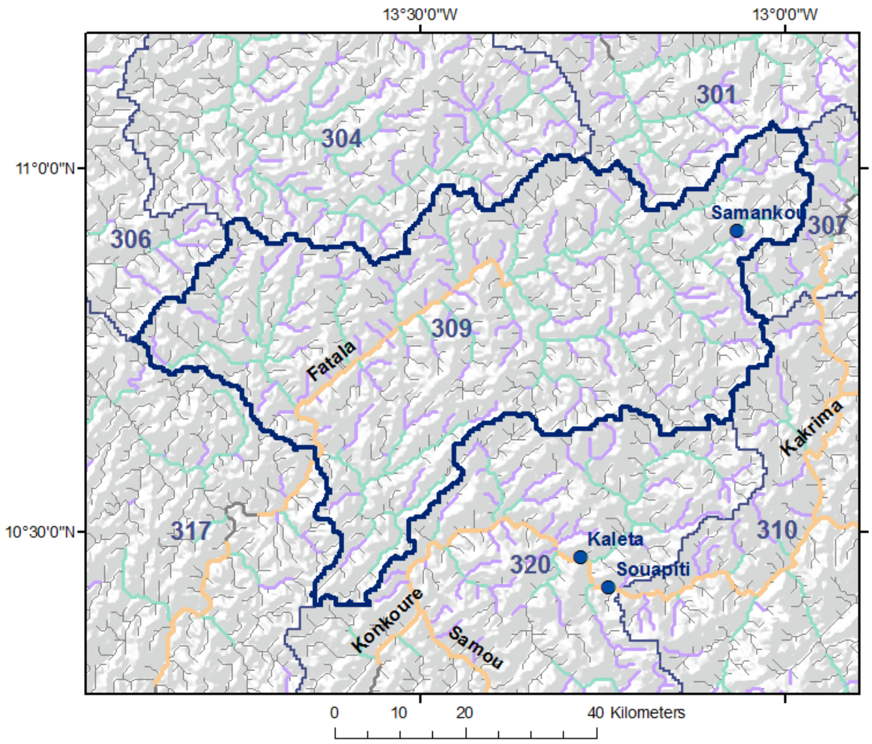


Theoretical Hydropower Potential of Rivers in Sub-Catchment #307	
Pico/micro/mini HPP	35.8 MW
Small HPP	140.6 MW
Medium/large HPP	12.2 MW

This sub-catchment is located in the headwater region of the Kakrima basin. There are several tributaries with considerable potential for pico/micro/mini HPP and small HPP.



Theoretical Hydropower Potential of Rivers in Sub-Catchment #309	
Pico/micro/mini HPP	25.3 MW
Small HPP	77.0 MW
Medium/large HPP	81.3 MW

In the headwater region of the Fatala River there are several tributaries that have considerable potential for pico/micro/mini HPP and for small HPP. The Fatala River itself has considerable potential for medium/large HPP.

River network showing preferred hydropower plant size

- Pico/micro/mini HPP
- Small HPP
- Medium/large HPP
- No attractive potential

Map overlays

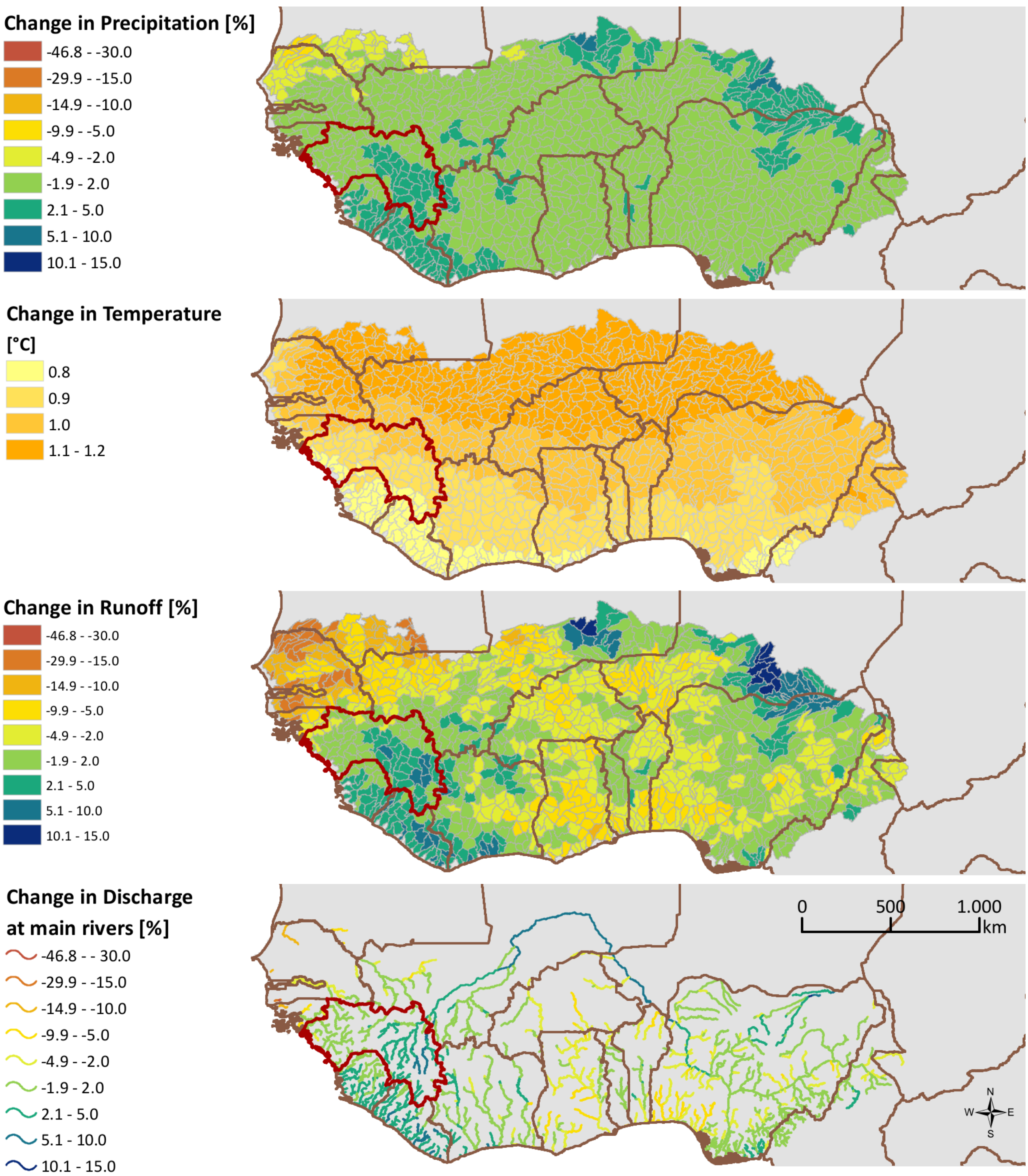
- Existing hydropower plant
- Lake or reservoir
- Sub-catchment boundary
- Country border

N W E S

CLIMATE CHANGE

Climate change may have considerable impact on future water resources and thus hydropower generation. The following figures show an assessment of climate change projections for West Africa based on 15 Regional Climate Models of the CORDEX-Africa ensemble. Two Representative Concentration Pathways (RCP4.5 and RCP8.5) were considered, thus yielding a total of 30 climate model runs. Future runoff was simulated by driving a water balance model with precipitation and temperature climate change signals with respect to the reference period 1998-2014.

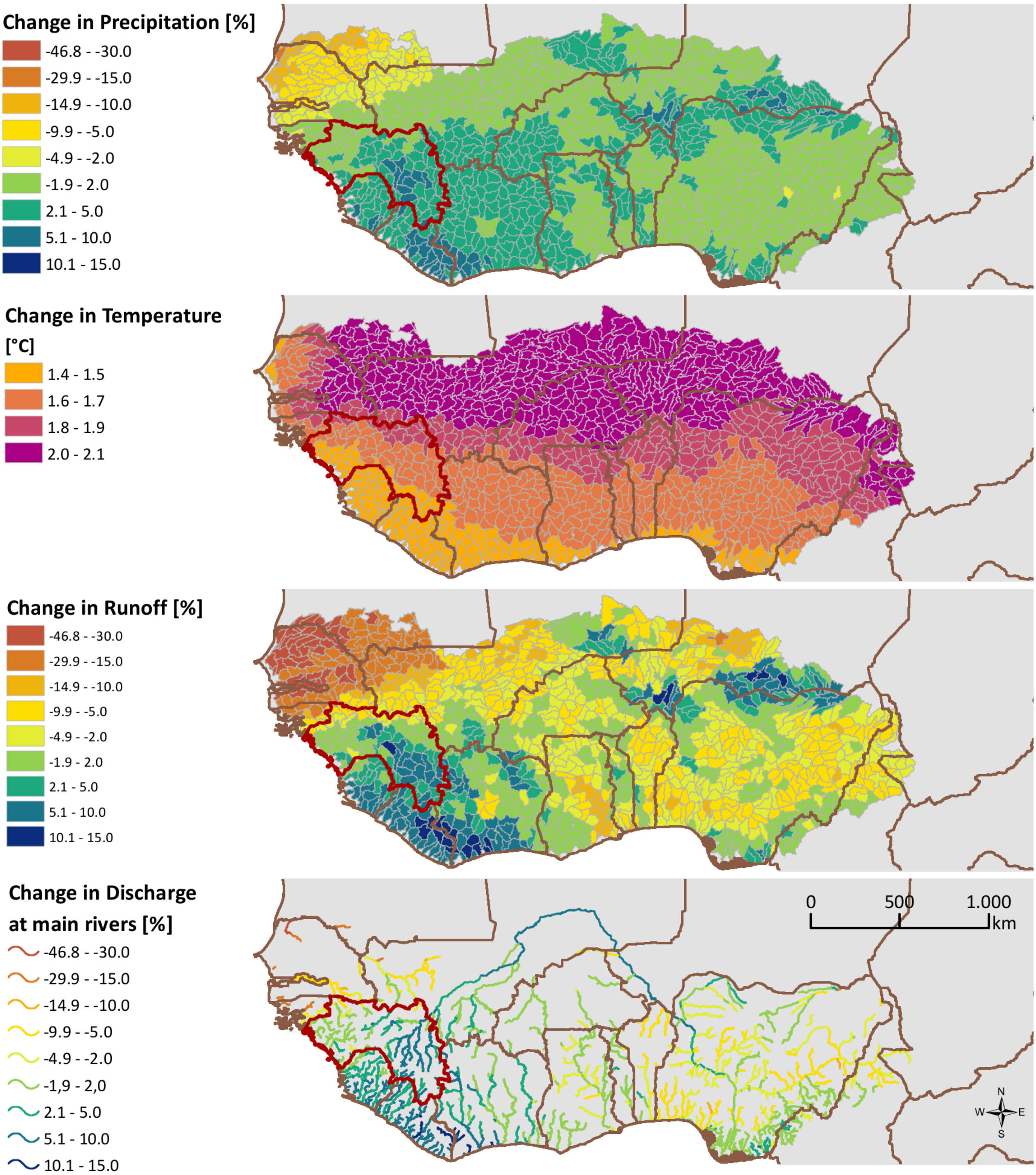
Projections for the Near Future 2026-2045



Projections for the Far Future 2046-2065

The maps below show the expected impact of climate change on future mean annual water resources. From the 30 climate model runs the median result was computed to generate the maps, which show change signals comparing the future periods 2026-2045 (previous page) and 2046-2065 (this page) vs. the reference period 1998-2014.

No considerable change in precipitation is projected for the western part of Guinea, whereas precipitation is projected to increase in the eastern parts of Guinea. The combined effects of future precipitation and considerable warming (which affects evapotranspiration) were simulated with a water balance model to compute future runoff. In Guinea an increase is projected for future runoff in the central and southern parts of the country (median result of 30 climate model runs).



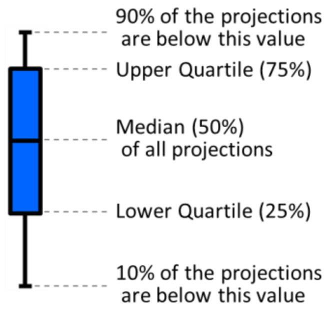
Projected Change in Discharge for Selected Gauges

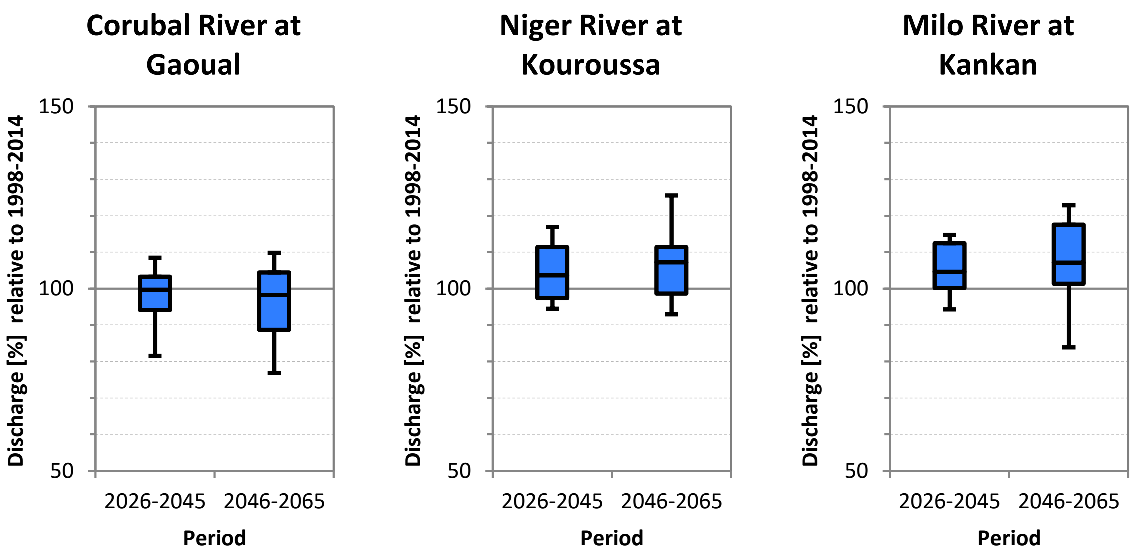
Future mean annual discharge was estimated with data from 30 different climate model runs. Boxplots are presented to summarize the spread in the simulation results (see explanation at right).

For rivers in the western part of Guinea, both increase and decrease in future discharge is projected by individual climate models. The median change is close to zero (as an example see below the results for the Corubal River). In contrast, projections for rivers in the eastern part of Guinea consistently show an increase in future discharge by a majority of climate model runs (see examples for the Niger and Milo rivers below).

Overall the climate change impact assessment shows that given the projections with the most detailed climate models currently available (CORDEX-Africa) future discharge is expected to slightly increase for rivers in the eastern part of Guinea. This would be beneficial for hydropower development.

Boxplot summarizing projections with 30 climate model runs





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Observed discharge data were used for hydrological model calibration and were obtained from the following sources: Global Runoff Data Centre (GRDC), Volta Basin Authority, Niger Basin Authority, Senegal & Gambia Basin Authorities (OMVS, OMVG), Liberia National Hydrological Service, Sierra Leone National Hydrological Service, Japan International Cooperation Agency (JICA).

Precipitation data 1998-2014 are based on Tropical Rainfall Measurement Mission (TRMM 3B42 v7). Additional precipitation data 1950-2010 for model calibration were obtained from the Global Precipitation Climatology Centre (GPCC). Air temperature and potential evapotranspiration data were obtained from the Climatic Research Unit (CRU, Univ. East Anglia), with additional data from the CLIMWAT database of FAO. River network and elevation data were derived from the Hydrosheds dataset (USGS). Climate model data were obtained from the Coordinated Regional Downscaling Experiment for Africa (CORDEX-Africa), which is a project of the World Climate Research Program.

The delineation of climate zones is based on: L`Hôte Y, Dubreuil P, Lerique J. 1996. *Carte des types de climats en Afrique Noire à l'ouest du Congo. Rappels, et extension aux régimes hydrologiques*. In: L'hydrologie tropicale: géoscience et outil pour le développement (Actes de la conférence de Paris, mai 1995). IAHS Publ. no. 238, p. 55-65

More information about the general methodology for the GIS hydropower resource mapping is available in: Kling H, Stanzel P, Fuchs M. 2016. *Regional assessment of the hydropower potential of rivers in West Africa*. Energy Procedia, Elsevier, Special Issue of ERE, 8 pp.