

NIGER

COUNTRY REPORT



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



Imprint



Title: GIS Hydropower Resource Mapping and Climate Change Scenarios for the ECOWAS Region, Country Report for Niger

Publisher: ECOWAS Centre for Renewable Energy and Energy Efficiency (ECREEE), Praia, Cabo Verde. *All results and maps are published on the ECOWAS Observatory for Renewable Energy and Energy Efficiency - www.ecowrex.org/smallhydro*

Contact: info@ecreee.org

March 2017

Program Responsibility:

The ECOWAS Small-Scale Hydropower Program 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 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

Project Team:



Pöyry Energy GmbH, Vienna, Austria

Mr. Harald Kling (project management, team leader hydrology)

Mr. Martin Fuchs (team leader hydropower)

Mr. Philipp Stanzel (team leader climate change)

Ms. Maria Paulin

Mr. Bernhard Wipplinger

Mr. Stefan Wimmer

Ms. Elisabeth Freiburger

Mr. Christoph Libisch

Mr. Raimund Mollner

Mr. Rudolf Faber

Mr. Herbert Weilguni



ECOWAS Centre for Renewable Energy and Energy Efficiency, Praia, Cabo Verde

Mr. Mahama Kappiah, Executive Director

Mr. Hannes Bauer, Project Management, Lead hydropower Program

Mr. Daniel Paco, GIS Expert

The ECOWAS Small-Scale Hydropower Program is managed by:

ECOWAS Centre for Renewable Energy and Energy Efficiency (ECREEE)

Mr. Hannes Bauer, ECREEE

Contact: info@ecreee.org

Project Funding



Austrian Development Cooperation – ADC

Spanish Ministry of External Affairs and Cooperation - AECID

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.

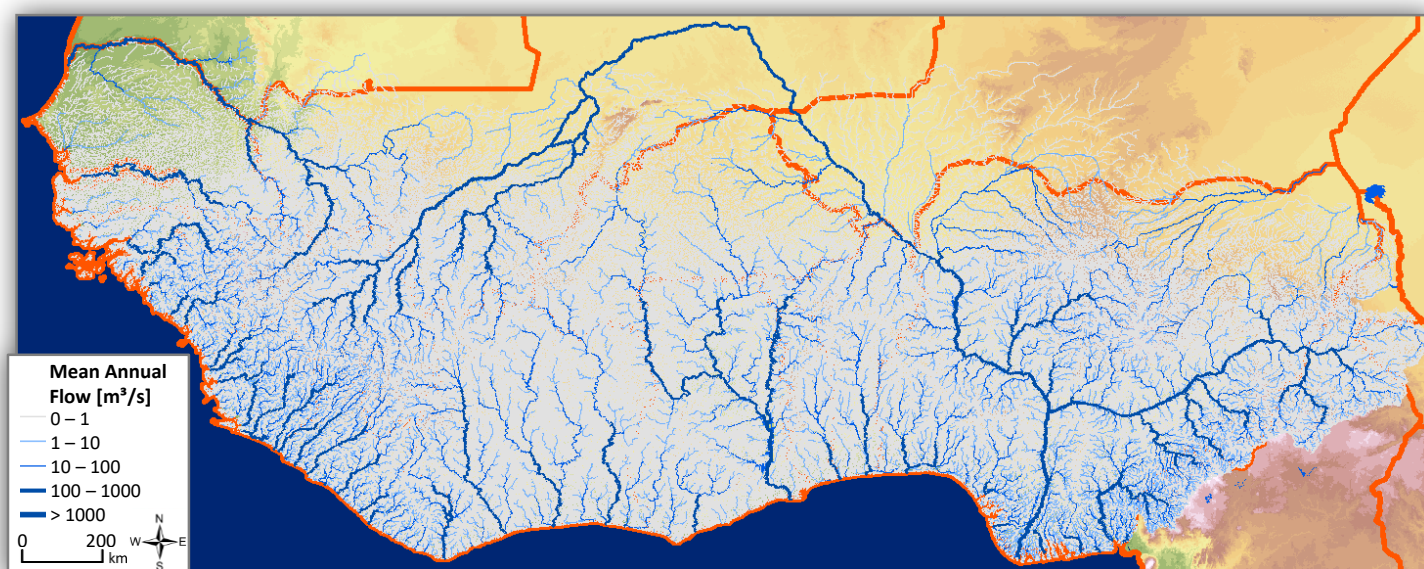
The ECOWAS Centre for Renewable Energy and Energy Efficiency (ECREEE), founded in 2010 by ECOWAS, ADA, AECID and UNIDO, responded to these challenges and developed the ECOWAS Small-Scale Hydropower Program, which was approved by ECOWAS Energy Ministers in 2012. In the frame of this program ECREEE assigned 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 Niger and includes:

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



GENERAL INFORMATION

The Republic of Niger is one of the largest countries in West Africa, but only has a population of 19 Mio inhabitants. The capital of Niger is Niamey in the south-western part of the country. The neighboring countries are Burkina Faso in the south-west, Mali in the west, Algeria in the north-west, Libya in the north, Chad in the east, as well as Nigeria and Benin in the south (see map below).

Hydropower currently plays no role for energy generation in Niger, as there are no operational hydropower plants. However, Kandadji hydropower plant is currently under construction at the Niger River.

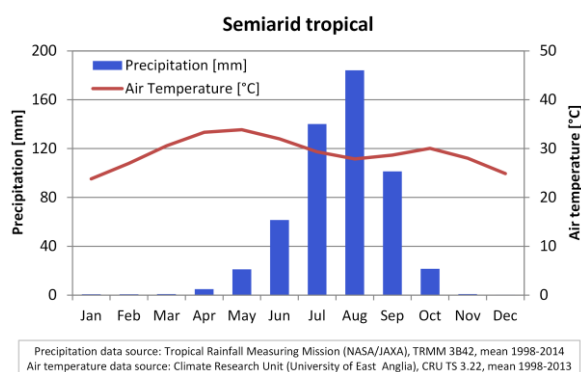
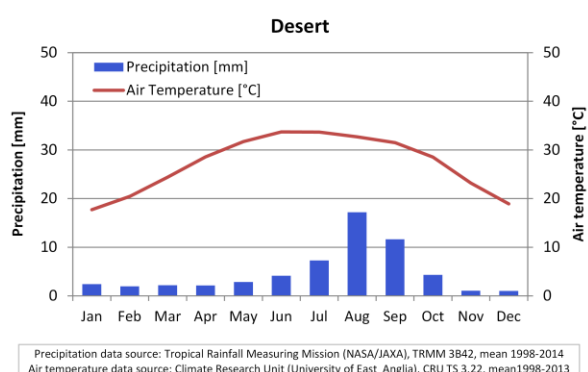
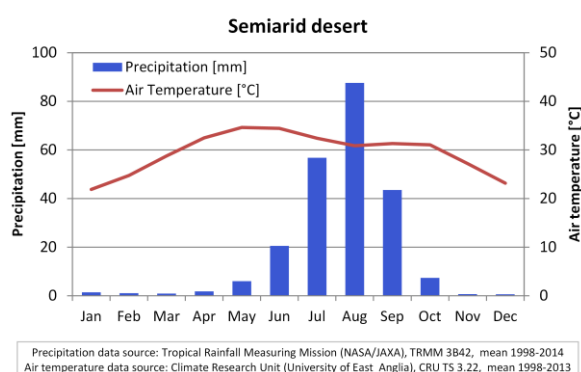
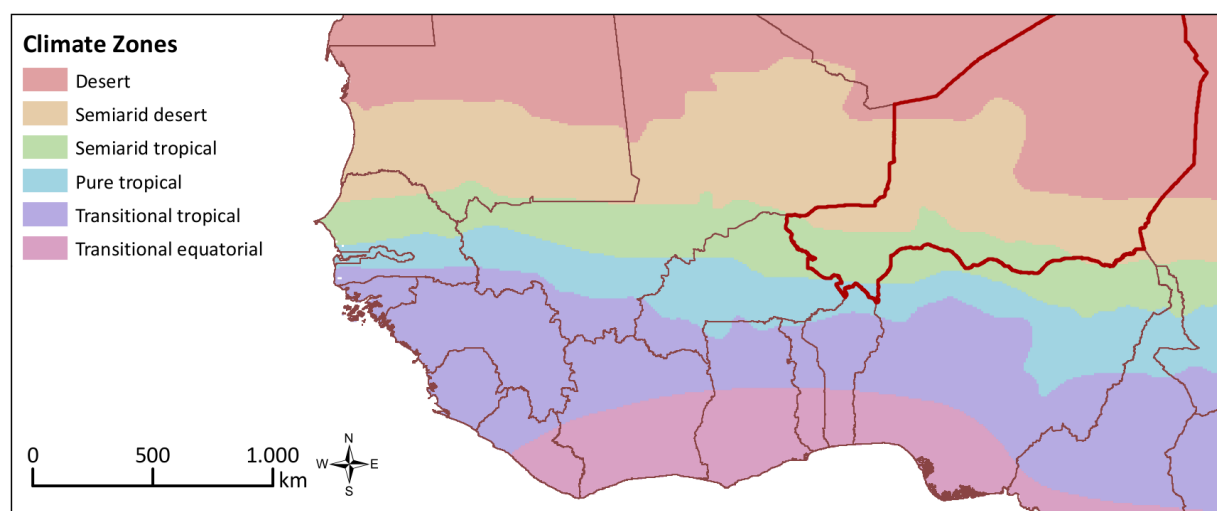


General Information for Niger	
Inhabitants (2014)	19.1 Mio.
Area (2014)	1,267,000 km ²
GDP per capita (2014)	427 USD
Electrification rate total/urban/rural (2013)	9/45/1 %
Hydro installed capacity (2013)	0 MW
Electricity generation (2013)	443 GWh
Electricity generation from hydropower (2013)	0 GWh
Number of existing hydropower plants with installed capacity < 1 MW (2016)	0
Number of existing small hydropower plants with installed capacity 1-30 MW (2016)	0
Number of existing medium hydropower plants with installed capacity 30-100 MW (2016)	0
Number of existing large hydropower plants with installed capacity >100 MW (2016)	0

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). In Niger the climate ranges from “Semi-arid tropical” in the south, over “Semi-arid desert” in the central parts, to “Desert” in the north. The diagrams below summarize the mean monthly rainfall and air temperature in these climate zones.

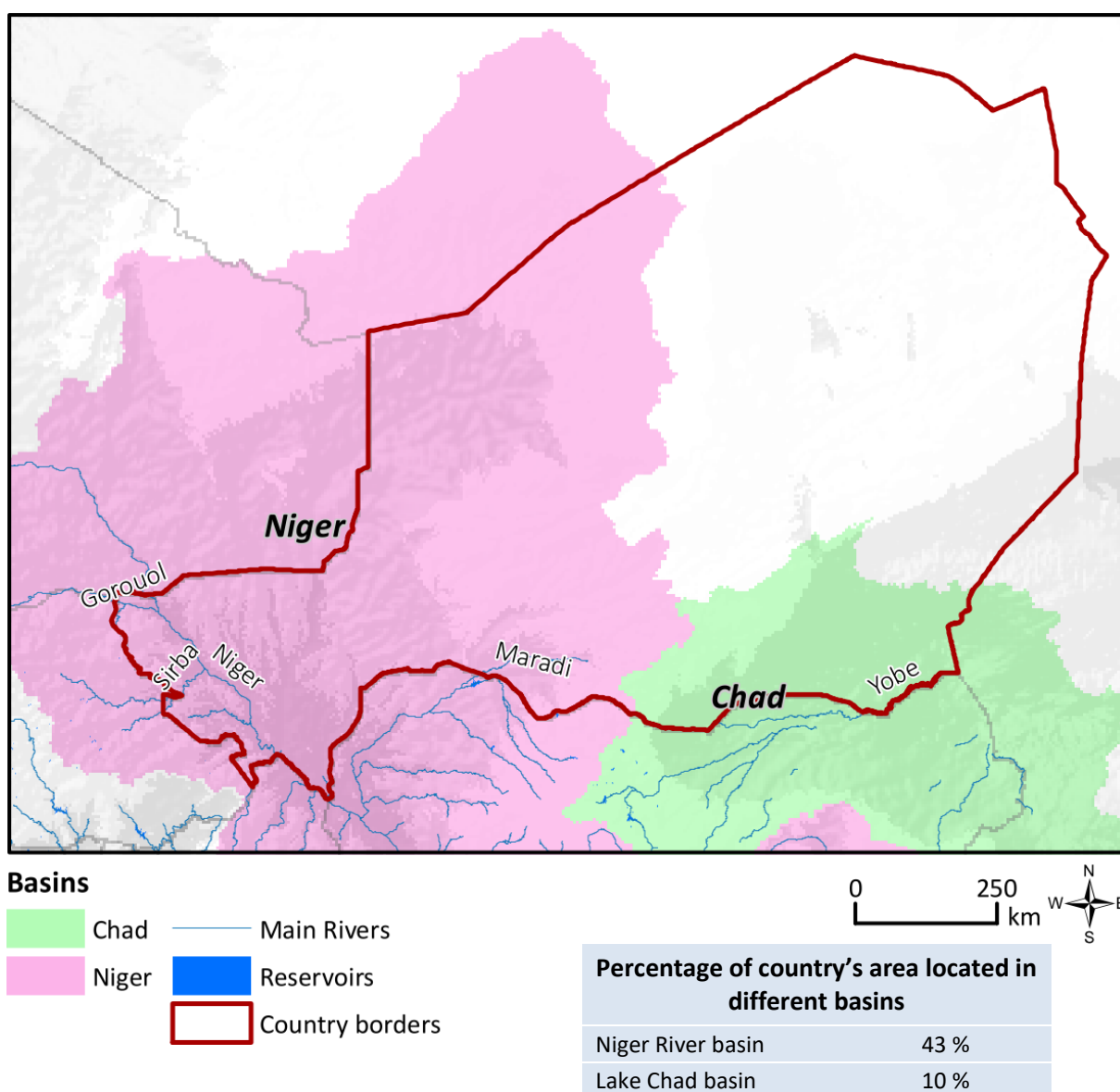


HYDROLOGY

The Niger River is by far the most important river in the Republic of Niger. The Niger River traverses the western part of the country, entering from Mali and flowing in south-easterly direction where the river forms the border with Benin before flowing into Nigeria. About 40 % of the country is located in the Niger basin, but this includes desert area that in reality do not have any significant discharge. 10 % of the country belongs to the basin of Lake Chad, which includes the Yobe River (see map and table below).

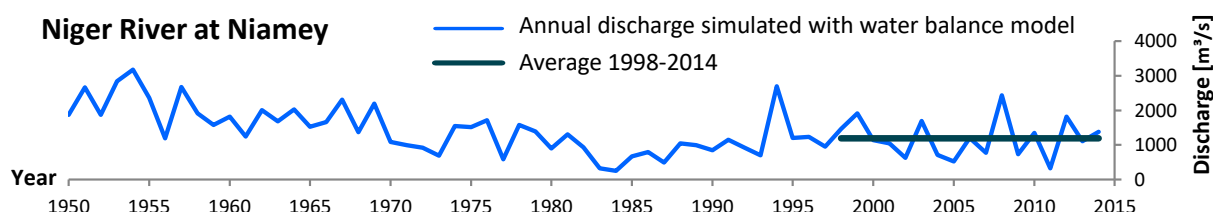
Other notable rivers include the Sirba River and the Maradi River. The Sirba River enters from Burkina Faso and can cause floods in August and September. The Maradi River enters from Nigeria, flows a short section in Niger towards the west and then re-enters Nigeria near Goronyo reservoir.

The figures on the following page illustrate the annual and seasonal variations in discharge for the Niger River.



Historic Variation in Annual Discharge

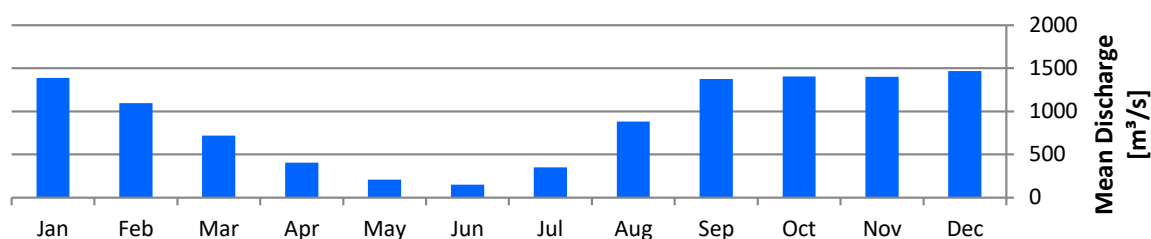
The Niger River at Niamey shows strong variations in annual discharge over the last 60 years. The 1950s and 1960s were the wettest period, followed by some extremely dry years in the 1980s, whereas the period 1998-2014 represents moderately wet conditions in the historic context.



Seasonality in Discharge

The seasonality in discharge of the Niger River at Niamey is the result of the 'White Flood' from local tributaries in August and September and the 'Black Flood' between October and March, which basically is the outflow from the Inner Niger Delta upstream in Mali. Low flow occurs in May and June.

Niger River at Niamey



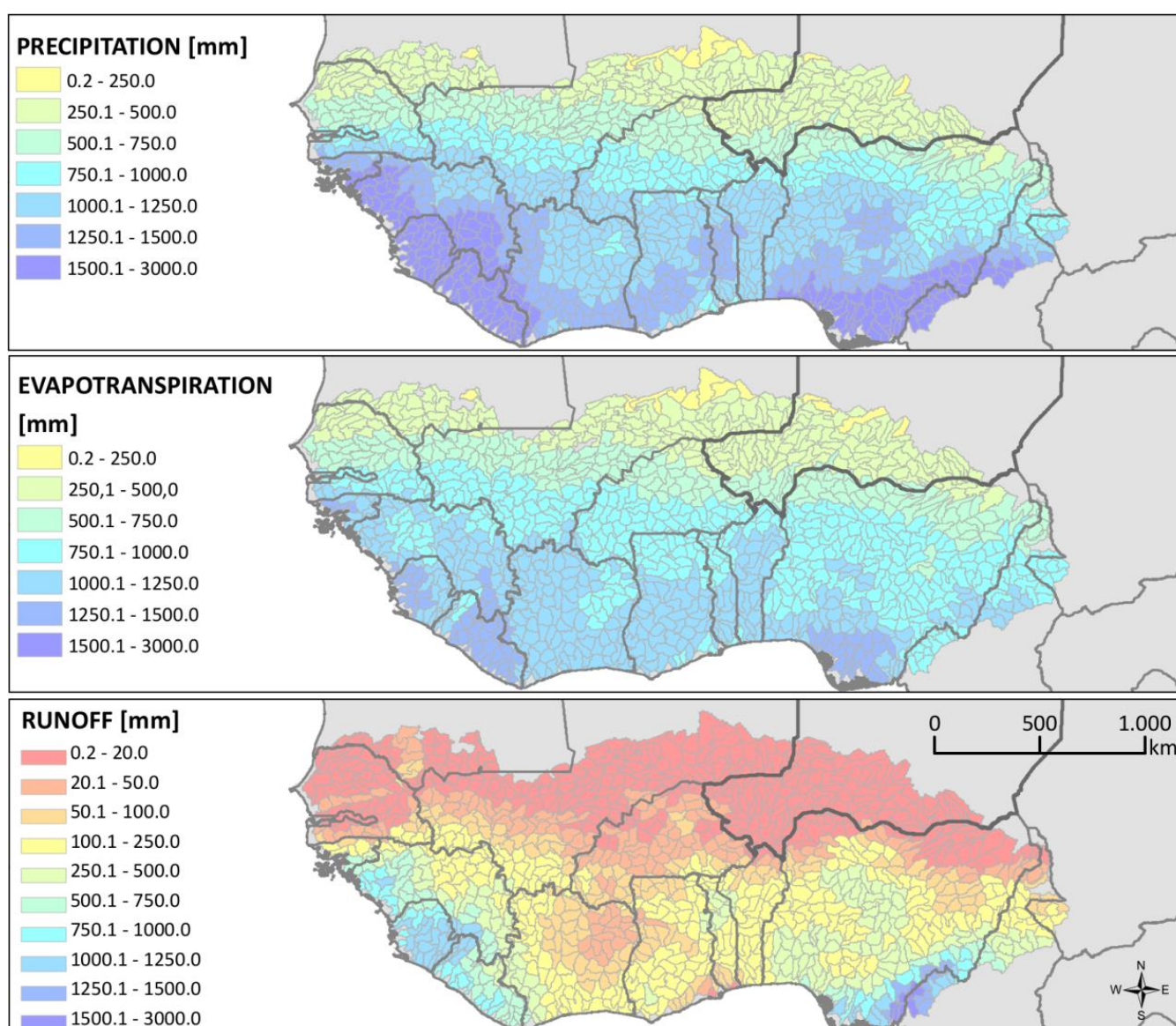
Annual Water Balance

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.

This is also the case for the mean annual water balance in the Republic of Niger. However, even though mean annual runoff is very low in the country, most of the rivers have their headwater regions in wetter areas, like the Niger River (Guinea, Mali) and Sirba River (Burkina Faso).

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

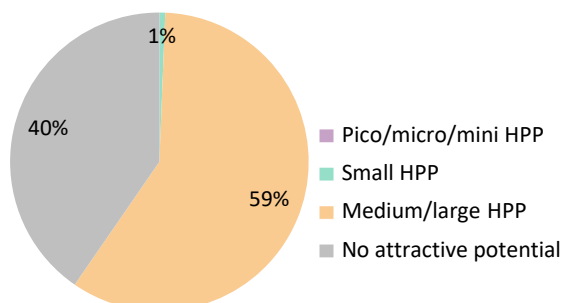
The theoretical hydropower potential of a river is defined as the amount of power that would be produced if the full head of the river was used and if 100 % of the mean annual discharge was turbinated (i.e. no spillway losses or environmental flow constraints). In this study overall plant efficiency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

The theoretical hydropower potential for the Republic of Niger is estimated to be 529 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 (m³/s) and specific hydropower potential (MW/km) was applied to determine the preferred plant size for river reaches with a typical length of 1-10 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.

Almost all of the attractive theoretical potential is classified as medium/large HPP, and there is no significant potential for pico/micro/mini HPP and small HPP in the country. The technical potential was not assessed in this study.

**Theoretical Hydropower Potential
Republic of Niger: 529 MW**

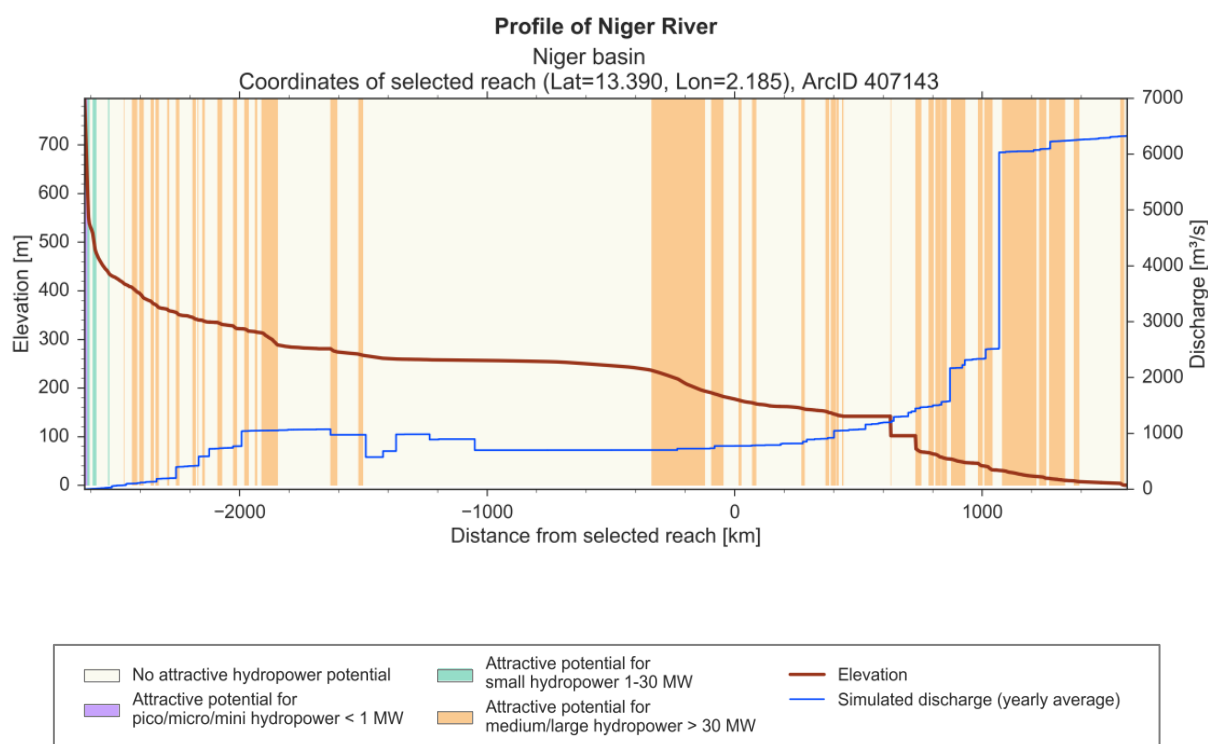


Theoretical Hydropower Potential of Rivers in the Republic of Niger	
Pico/micro/mini HPP	0 MW
Small HPP	3 MW
Medium/large HPP	312 MW
No attractive potential	214 MW
Total of all rivers in country	529 MW
Total of rivers with attractive theoretical potential for pico/micro/mini, small, or medium/large HPP	315 MW

Longitudinal Profiles of Selected Rivers

The following graph shows the longitudinal profile of the Niger River, plotting elevation (red) and mean annual discharge (blue) from the source to the mouth of the river. Inflow from tributaries is clearly identifiable as sudden increase in river discharge. Diversions and floodplain losses cause a decrease of discharge in some sections of the Niger River. The Kainji and Jebba reservoirs in Nigeria are identifiable by constant elevation in the reservoir lake and sudden drop of elevation at the dam site.

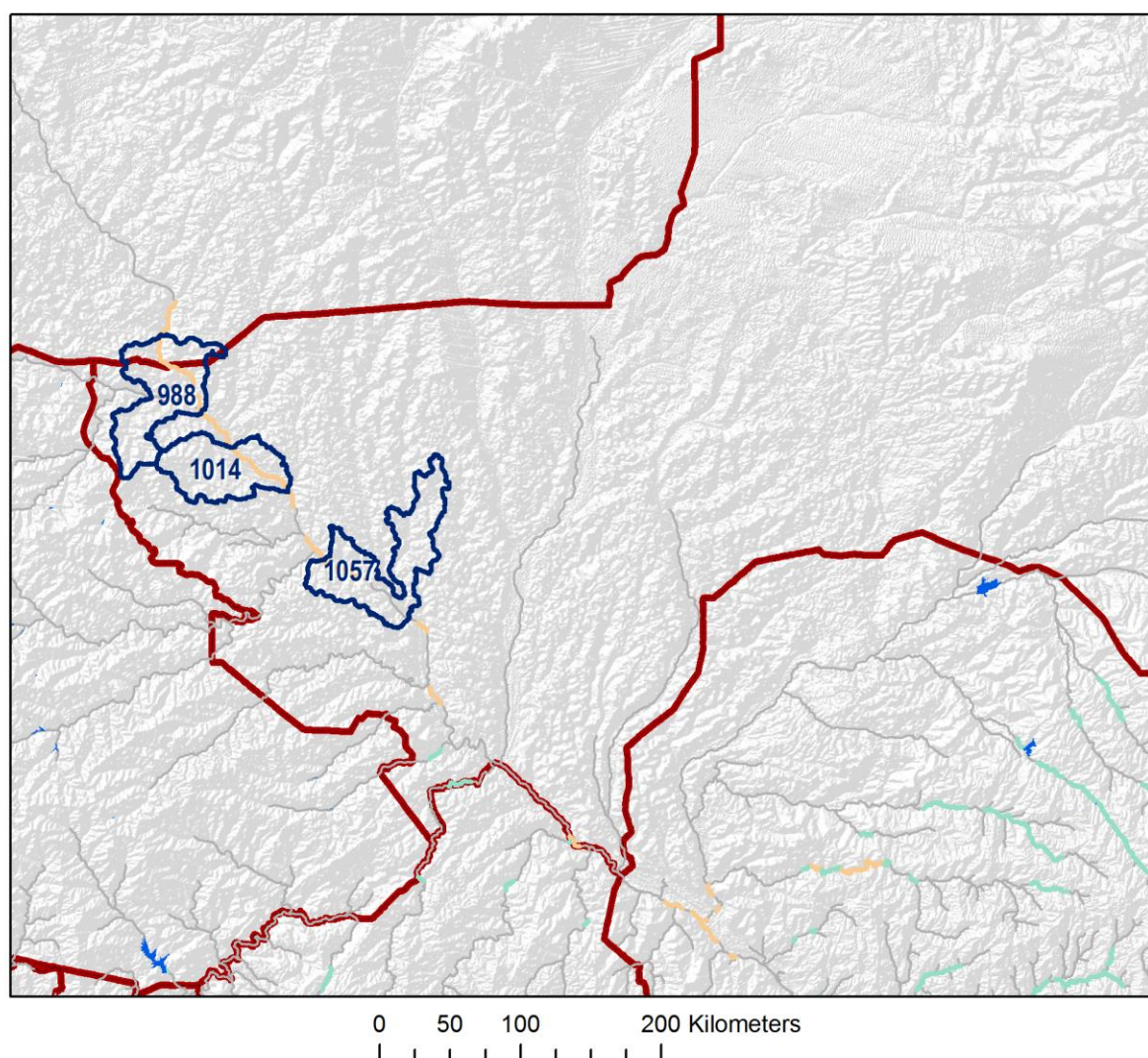
The background color indicates if a river reach has an attractive theoretical hydropower potential for pico/micro/mini HPP (< 1 MW installed capacity), small HPP (1-30 MW installed capacity), or medium/large HPP (> 30 MW installed capacity).



Hydropower Potential in Selected Sub-catchments

The following maps and tables give information about the theoretical hydropower potential of selected sub-catchments in the Republic of Niger. All of the selected sub-catchments are located along the Niger River.

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.



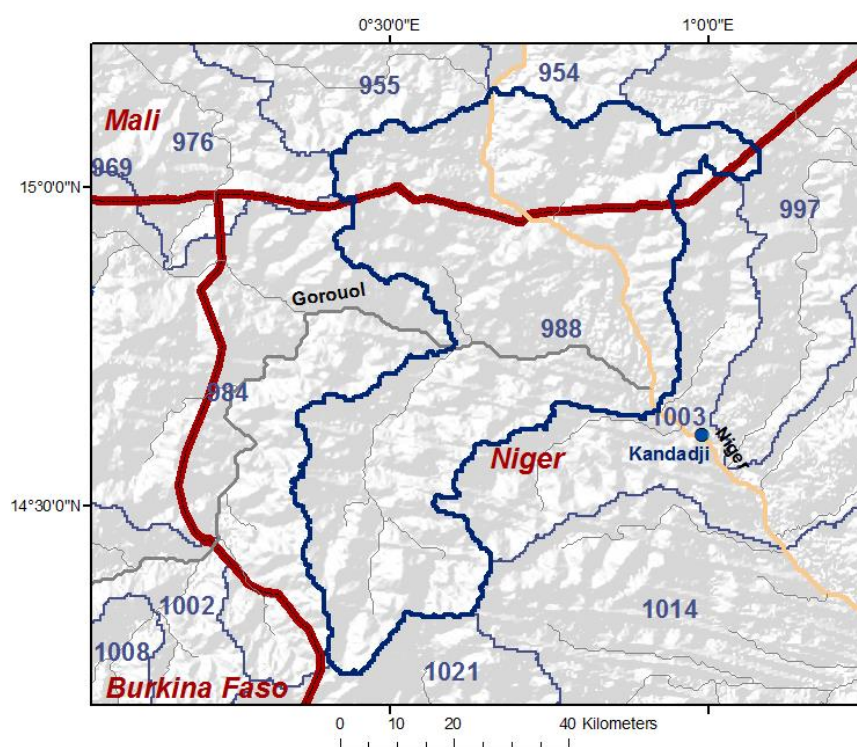
River network showing preferred hydropower plant size

- Pico/micro/mini HPP
- Small HPP
- Medium/large HPP

Map overlays

- Selected sub-catchments with ID number
- Lake or reservoir
- Country border

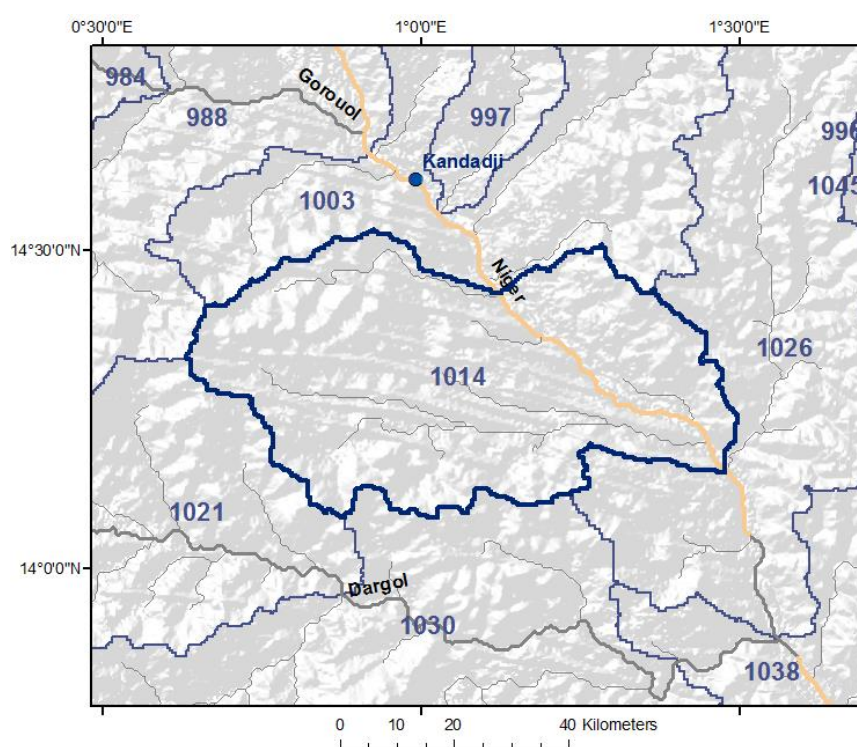




Theoretical Hydropower Potential of Rivers in Sub-Catchment #988

Pico/micro/mini HPP	0 MW
Small HPP	0 MW
Medium/large HPP	80.8 MW

The Niger River upstream of the Kandadji HPP dam site has considerable potential for medium/large HPP. There is no potential for pico/micro/mini or small HPP.



Theoretical Hydropower Potential of Rivers in Sub-Catchment #1014

Pico/micro/mini HPP	0 MW
Small HPP	0 MW
Medium/large HPP	70.9 MW

Also the Niger River downstream of the Kandadji HPP dam site has considerable theoretical potential. There is no potential for pico/micro/mini or small HPP.

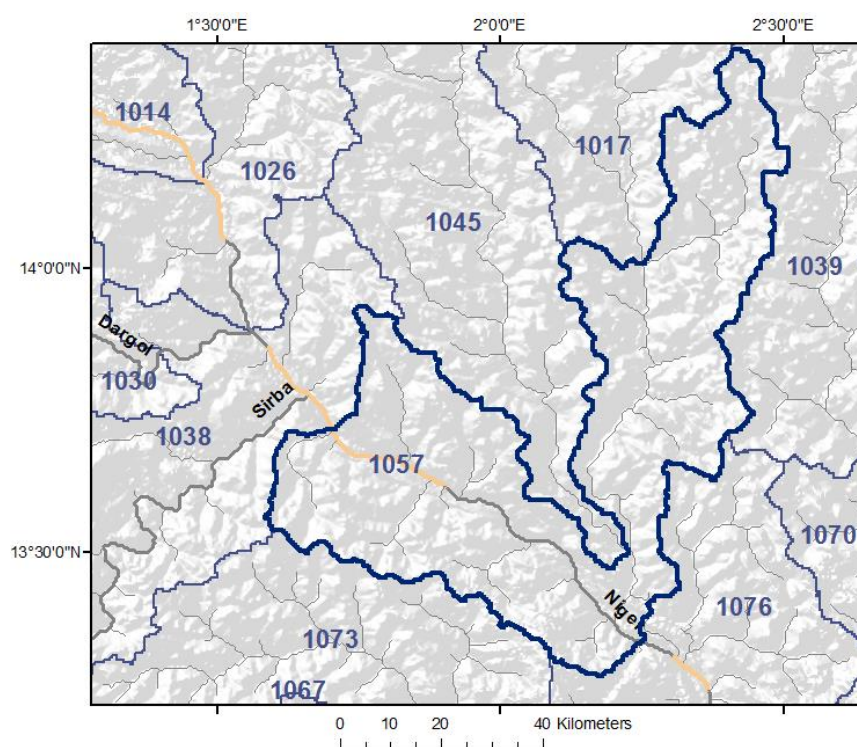
River network showing preferred hydropower plant size

- 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





Theoretical Hydropower Potential of Rivers in Sub-Catchment #1057

Pico/micro/mini HPP	0 MW
Small HPP	0 MW
Medium/large HPP	28.7 MW

The Niger River a short distance upstream of Niamey has some theoretical potential for medium/large HPP. There is no potential for pico/micro/mini or small HPP.

River network showing preferred hydropower plant size

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

Map overlays

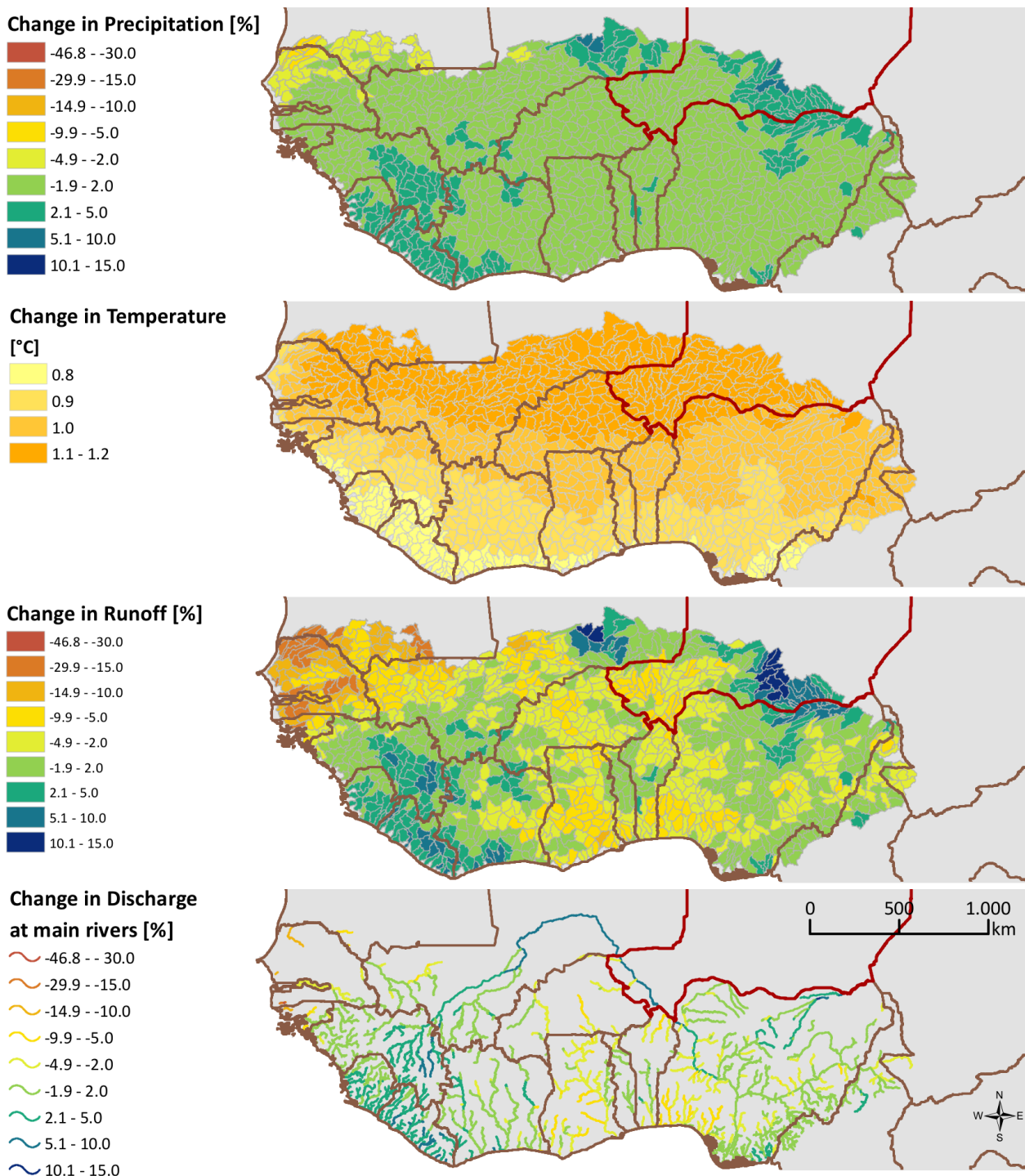
- Existing hydropower plant
- Lake or reservoir
- Sub-catchment boundary
- Country border



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.

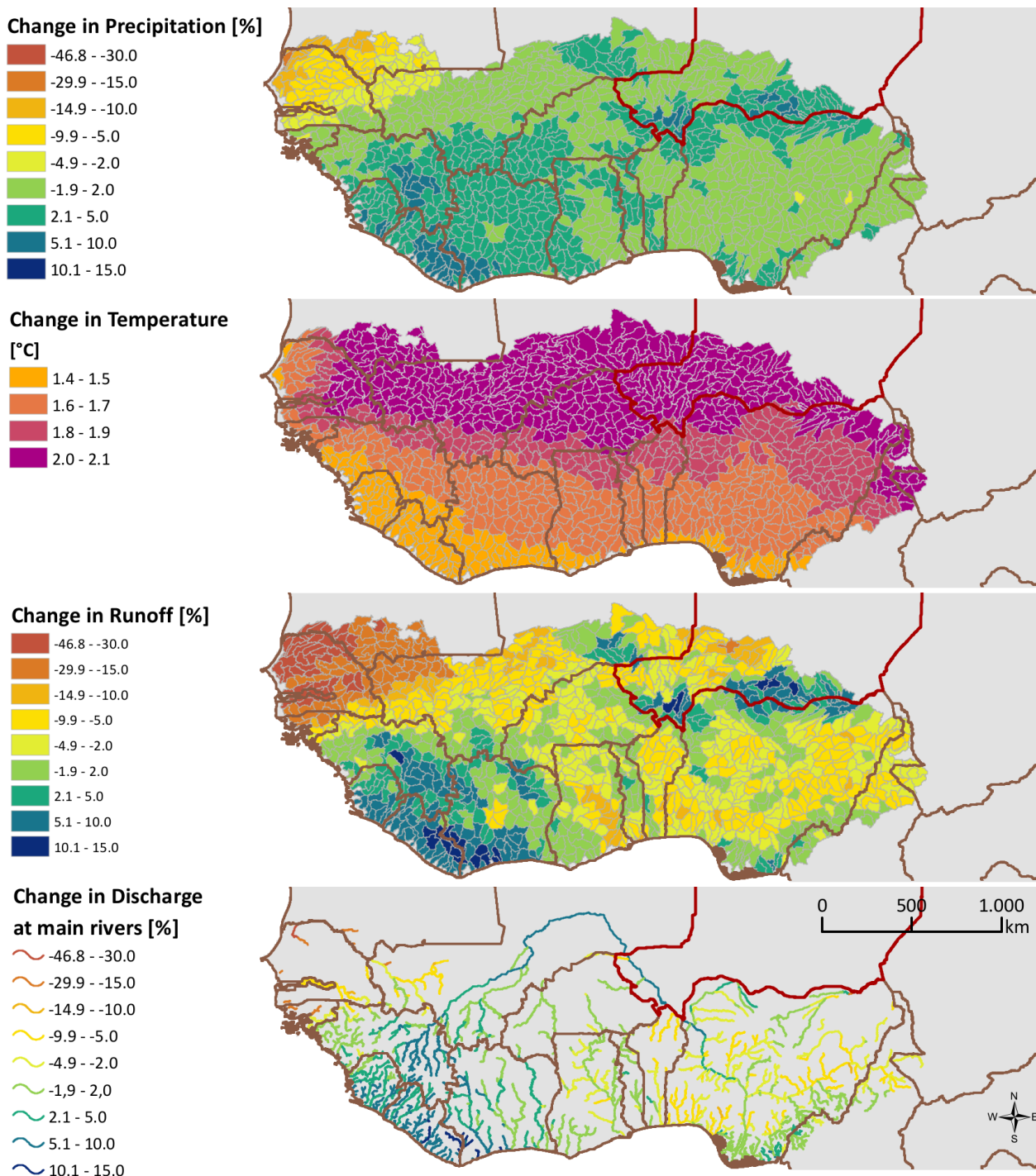
Projections for the Near Future 2026-2045



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.

In large parts of West Africa increase or almost no change is projected for future precipitation. This is also the case for Niger. The combined effects of future precipitation and considerable warming (which affects evapotranspiration) were simulated with a water balance model to compute future runoff. In Niger runoff is projected to decrease in the central parts and increase in the southern parts of the country (median of 30 model runs).



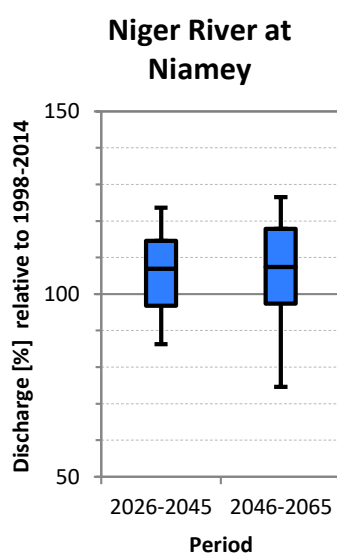
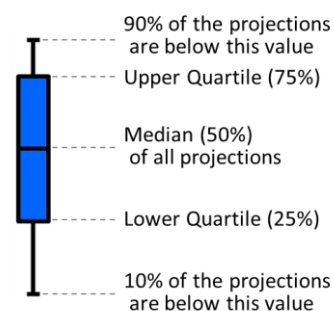
Projected Change in Discharge for Selected Gauges

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 the Niger River at Niamey future discharge is projected to increase by about +7%. Some of the individual climate model runs show a decrease in future discharge, whereas the majority of the climate model runs show an increase in future discharge (see boxplot below).

Overall the climate change impact assessment shows that given the projections with the most detailed climate models currently available (CORDEX-Africa) Niger River discharge at Niamey is projected to increase in the future. This would be beneficial for hydropower development along the Niger River in the Republic of Niger.

Boxplot summarizing projections with 30 climate model runs



ACKNOWLEDGEMENTS

This study was conducted by Pöyry Energy GmbH (Vienna, Austria) for the ECOWAS Centre for Renewable Energy and Energy Efficiency (ECREEE, Praia, Cabo Verde). This is a contribution to the ECOWAS Small-Scale Hydro Power Program, which aims to develop the small-scale hydropower sector in West Africa and is funded by the Austrian Development Agency (ADA) and the Spanish Agency for International Development Cooperation (AECID).

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, Lericque 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.

