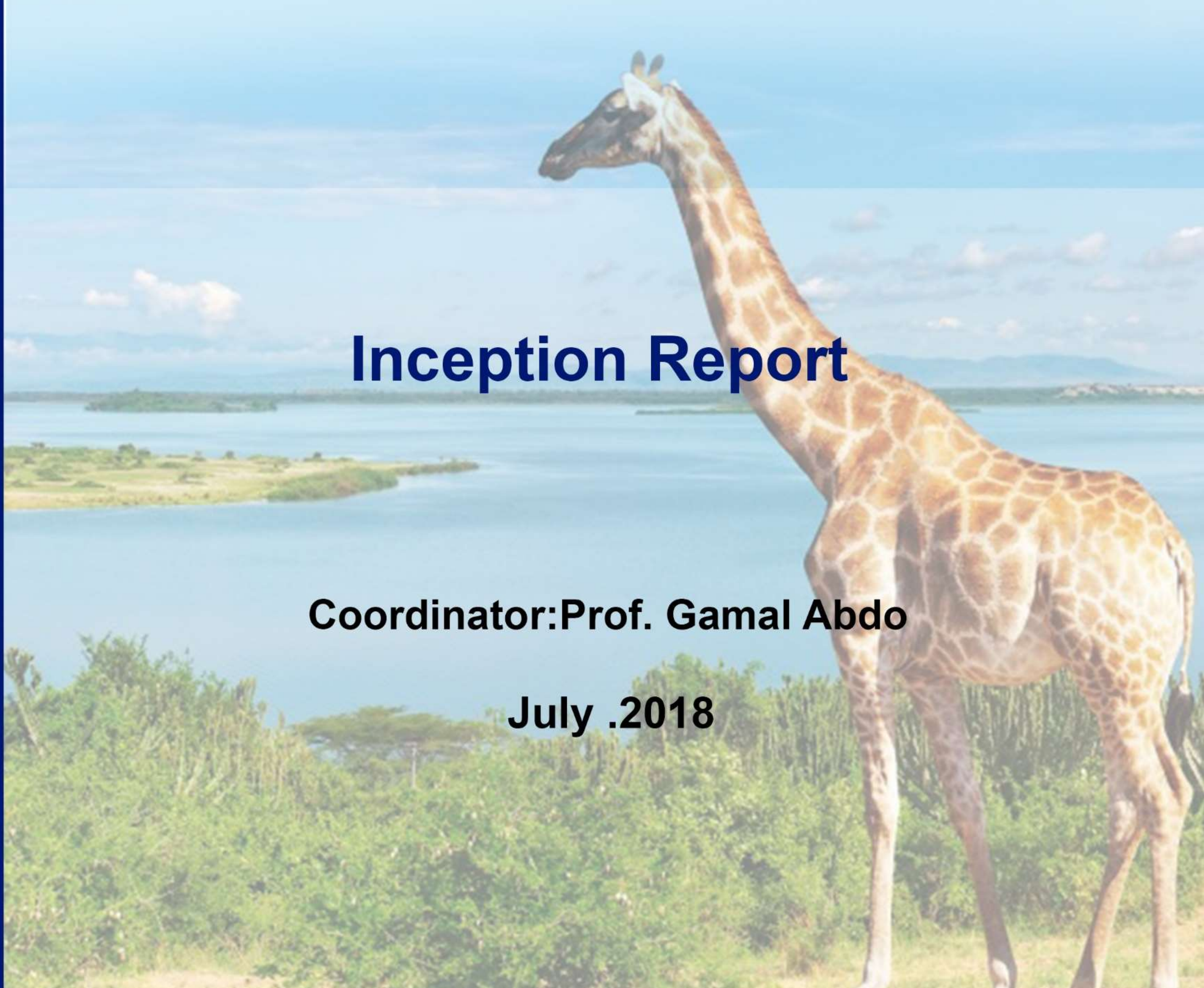
Water Research Center (WRC), University of Khartoum (UofK)

AU-NEPAD CEANWATCE ACEWATER2 PROJECT

Water and COoperation within the NIle River Basin (WACONI)
Blue Nile Basin Downstream the Grand Ethiopian Renaissance Dam



Inception Report

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List of Abbreviations

ARC 2.0	African Rainfall Climatology Version 2
CEANWATCE	Central/Eastern Africa Network of Water Centers of Excellence
CHIRPS 2.0	Climate Hazards group Infrared Precipitation with Stations version 2.0
DIU	Dams Implementation Unit
FAO	Food and Agriculture Organization
FSL	Full Supply Level
GERD	Grand Ethiopian Renaissance Dam
HEC	Hydrologic Engineering Center
HMS	Hydrologic Modeling System
ICPAC	IGAD Climate Prediction and Application Centre
IGAD	Intergovernmental Authority on Development
IWMI	International Water Management Institute
MIT	Massachusetts Institute of Technology
MoIHES	Ministry of Irrigation and Hydro-Electric Energy of Sudan
MoIHPS	Ministry of Irrigation and Hydro-Electric Power of Sudan
NSE	Nash–Sutcliffe Efficiency
MPE	Mean Error Percentage
MSWEP 2.0	Multi-Source Weighted-Ensemble Precipitation version 2.0.
NBI	Nile Basin Initiative
PERSIANN-CDR	Precipitation Estimation from Remotely Sensed Information Using Artificial Neural Networks–Climate Data Record

R^2	coefficient of determination
SMA	Sudan Meteorological Authority
TAMSAT 3.0	Tropical Applications of Meteorology Using Satellite Data and Ground-Based Observations version 3.0
WEFE	Water, Energy, Food, and Ecosystems
WRC	Water Research Center

1. Introduction and background

With an area of around 3.3 million km^2, the Nile River Basin covers approximately 10% of the African continent, 2% of the Earth land surface, and is considered as the longest River in the world with around 6700 km length (Mohamed and Loulseged, 2008; Ribbe and Ahmed, 2006). It extends over 11 countries in Africa including Burundi, Rwanda, the Democratic Republic of the Congo, Tanzania, Uganda, Kenya, Sudan, South Sudan, Ethiopia, Eritrea, and Egypt(Ribbe and Ahmed, 2006). Figure1 illustrates the Nile Basin boundary and the sharing countries. The average annual flow of the Nile at Aswan southern Egypt is approximately 84 BCM of which the Blue Nile contributes around 54 BCM, the White Nile around 28.5 BCM, and Atbara River around 12 BCM. About 10 BCM evaporates from the reservoir of the High Aswan Dam which results in reducing the annual yield of the Nile to 84 BCM(Blackmore and Whittington, 2008; Mohamed and Loulseged, 2008). Around 54% of the population of the Nile countries resides within the Nile Basin. The Nile population represents around 20% of the population of Africa and is expected to double by 2030 (NBI, 2012).

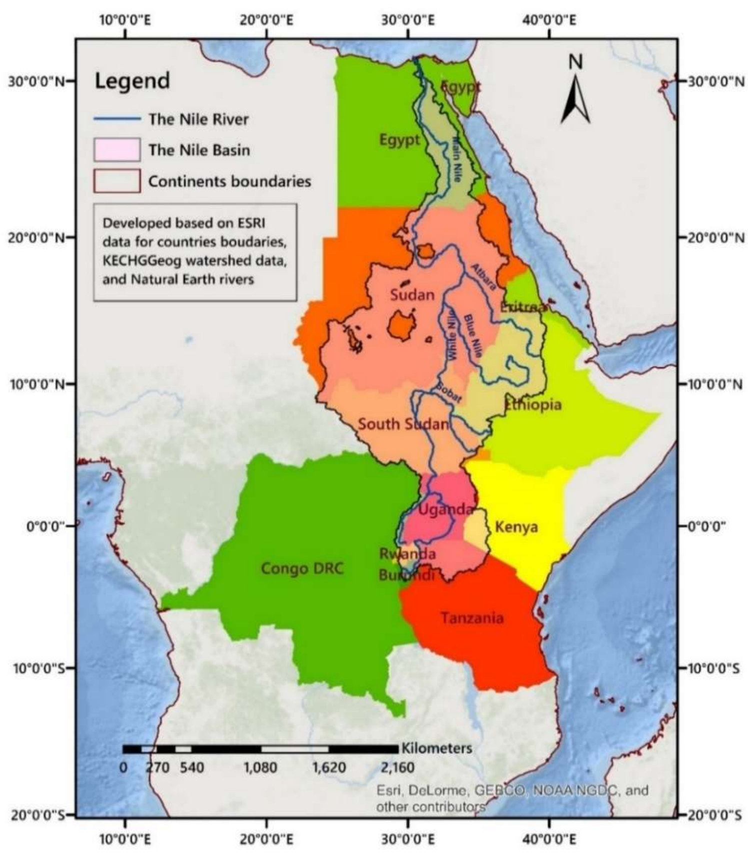

Figure 1 Nile Basin boundary and sharing countries

Whereas agriculture is the main contributor to the economies of the Nile Basin countries with more than 70%of the combined population depending on farming for income and livelihood(IWMI, 2012), hydropower has an enormous potential which has not yet been fully exploited. Ruvyironza River, Victoria Nile, Albert River, Bahr Eljebel, and the White Nile all together have a hydropower potential of over 4,000 MW, of which 380 MW is exploited. Moreover, the Blue Nile, the Baro River, the Atbara River, and the Main Nile have a potential of around 8,000 MW, 2300 MW, 450 MW, and 3100 MW respectively (IWMI, 2012; NBI, 2012). Despite the crucial role of the Nile water in producing energy and food and maintaining the ecosystems in an acceptable status, the interconnections of Water, Energy, Food, and Ecosystems (WEFE) are yet to be well understood.

Given the limited water resources of the Nile Basin and the many challenges related to WEFE, the Central/Eastern Africa Network of AU/NEPAD Water Centers of Excellence (CEANWATCE) selected the Nile Basin as a study region in the framework of ACEWATER2 project. Two case studies were selected: The Blue Nile Basin and Lake Victoria Basin. The Water Research Center (WRC) of the University of Khartoum will study the hydrology and water allocation of the Blue Nile Basin downstream the GERD (see Figure 2) with the aim of assessing the impacts of infrastructural developments (i.e. hydropower storage dams and irrigation schemes), climate change, and climate variability on the inter-linkages of WEFE.

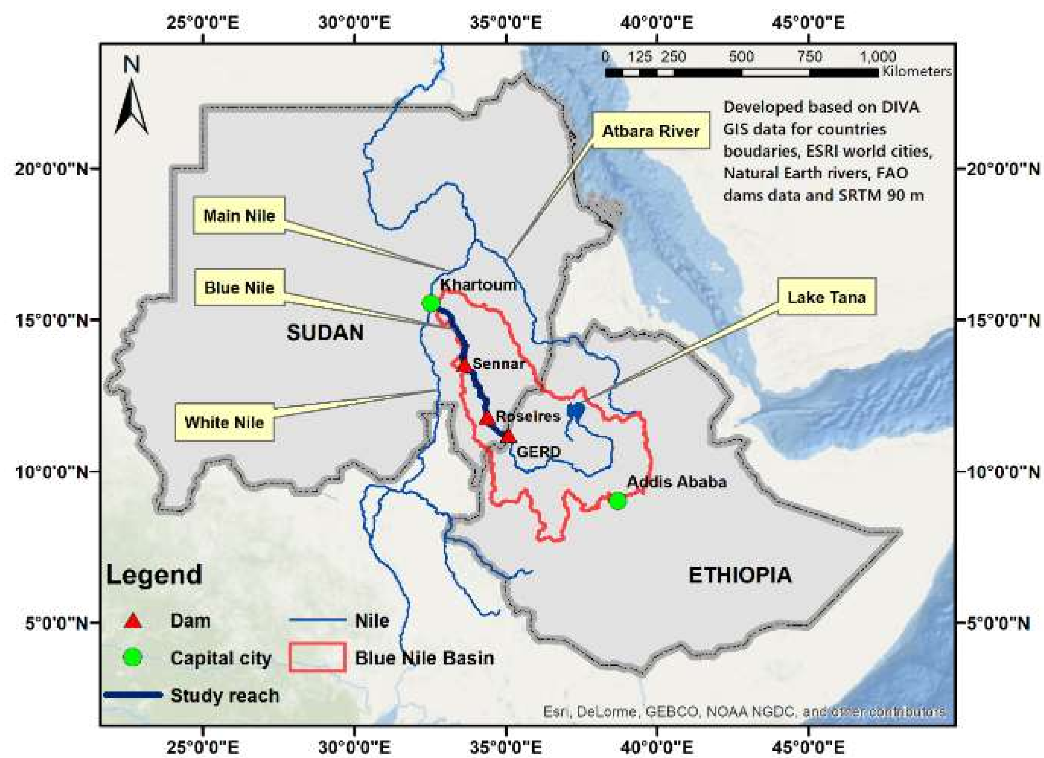

Figure 2 Study region of the Water Research Center

2. Study area

The study area covers the Blue Nile downstream of the GERD and encompasses several existing and/or planned dams (Figure 2), irrigation schemes (Figure 3), and thermal power plants as described below.

2.1. Dams

Sennar Dam, located on Blue Nile River some 350 km south-east Khartoum, became operational in 1925 to supply the Gezira scheme with irrigation water by gravity from head works located within the dam on the left bank of the Blue Nile (MoIHES, 1977). In 1959, a study was carried out to investigate the possibility of raising Sennar Reservoir by up to 4 meters (MoIHES, 1977). This study showed that without major works, large portions of many villages, towns and pumped irrigation schemes would be flooded, and the proposal was taken no further (MoIHES, 1977). In 1962 two 7.5 MW turbines were installed in a power station on the west side of the dam to utilize the downstream flow for hydropower generation (MoIHES, 1977). In 1955 the Sudanese government appointed the firms of Sir Alexander Gibb & Partners and Coyne et Bellier of Paris to conduct a joint study on the consequences of constructing a larger dam at Rosaries to allow for agricultural expansion and to add a 280 MW of hydropower capacity. The two firms suggested a design for a dam that would be constructed in two stages, the first stage with a Full Supply Level (FSL) of 480 m asl and the second stage with an FSL 10m higher than the first stage. The first stage of the dam was completed in the year 1966 followed by an attempt to construct the second stage in the 1990's which stopped because of the economic situation of Sudan at that time (Roseires Dam Heightening Unit, 2005). The heightening of the dam started again in May 2009 and was finished in January 2013 (DIU, 2016).The water stored in Rosaries and Sennar dam is essential in irrigating the Blue Nile agricultural schemes since the flow of the Blue Nile and its tributaries is limited during the dry season. The Sudanese authorities operate the two dams in a way that maximizes the benefit from irrigation and hydropower while minimizing the sedimentation to reduce the maintenance cost and to prolong the lifetime of the two reservoirs (Sutcliffe and Parks, 1999).The operation rules for both Rosaries and Sennar dams are strongly related to the natural flow of the Blue Nile measured at El-Diem near the Sudanese Ethiopian border(MoIHPS, 1968). Allowance is made for transmission losses which include evaporation and percolation losses (MoIHPS, 1968). Additionally, the outflow of Sennar Dam is always maintained higher than 8 MCM per day to meet the downstream water demands and to satisfy the environmental requirements (MoIHPS, 1968). On April 2, 2011, the Ethiopian government announced the construction start of the GERD with a storage capacity of 74 BCM to generate hydropower (Swanson, 2014). The GERD is located on the Blue Nile River 20 km upstream the Sudanese-Ethiopian border and is constructed by Salini Impregilo, an Italian construction company, with a total cost of around 4.8 billion USD (Salini Impregilo, 2016; Salman, 2016; Swanson, 2014). The dam is a roller compacted concrete dam with a height of 145 meters complemented by a saddle dam that is 5 km long and 50 m high (MIT 2014). The idea of the GERD dates to 1964 after the study conducted by the US Bureau of Reclamation on the utilization of the Blue Nile by Ethiopia, which recommended the construction of a dam with 11 BCM storage capacity at the current location of the GERD. The project was not implemented due to the political, diplomatic, technical, and economic limitations of Ethiopia at that time. In 2008, pre-feasibility studies for the GERD (was called the Border dam at that time and had a storage capacity of 14.5 BCM) was supposed to be prepared but disagreement over the cooperation framework and the consequent suspension of Egypt's membership from the NBI have delayed the implementation of the project (Mohammed, 2015; Tawfik, 2016).

2.2. Agricultural Schemes

Large-scale agricultural development began in 1925 with the construction of Sennar Dam and the commissioning of the Gezira Scheme. During the late 1950s and 1960s, the Managil extension took place which increased the total area of Gezira to around 840,000 ha (MoIHES, 1977).The combination of Gezira and Managil is considered the largest irrigation scheme in the world managed under one administrative unit (MoIHES, 1977).Weighty development in pumping irrigation on the Blue Nile has taken place in the 1960s and 1970s.The Blue Nile pumping schemes include Guneid, Rahad 1,Suki, North West Sennar Sugar scheme, HurgaNurEddin, and Abu Na'ama (IWMI, 2012; MoIHES, 1977). Nine irrigation schemes are planned for construction in the study area (see Figure 3). The schemes will abstract irrigation water from Rosaries Reservoir through irrigation canals located on the left and right sides of the dam. The planned schemes include Kenana 1, Kenana 2, Kenana 3, Kenana 4, Rosaries, Dinder South, Dinder North, Rahad 2 South, and Rahad 2 North. The planned schemes have a combined area of around one Million ha.

2.3. Thermal Power Plants

Thermal power production in the study area started in 1962 with the construction of Gunied Power Plant as part of Gunied Sugar Scheme (Rabah et al., 2016). In 1972 Sennar Thermal Power station was added with the construction of North West Sennar Sugar Scheme (Rabah et al., 2016). In 1984, Mahmoud Sharif Thermal Power Station had been constructed in Khartoum and was later expanded in 1992, 1994, and 2011 (Rabah et al., 2016). The thermal power plants in the study area have a combined installed capacity of around 450 MW and a total annual water consumption of approximately 34 MCM (Rabah et al., 2016).

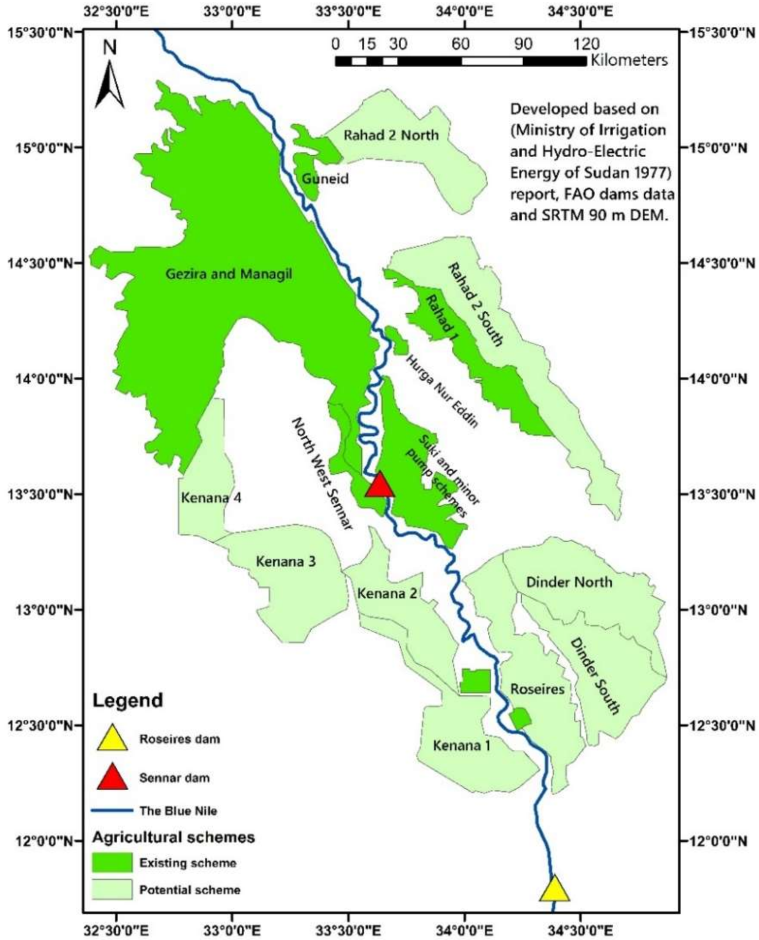

Figure 3: Existing and planned schemes in the study area

Source: (Basheer et al., 2018)

2.4. Ecosystem

Wildlife in the study area is dominated by large mammals, reptiles, and big birds (Abdelgaffar and Abdo, 2017). Part of the study area is protected under the RAMSAR agreement for wetlands because it forms a sanctuary for migratory birds (Abdelgaffar and Abdo, 2017). The study area encompasses the Dinder National Park, which is the first biosphere reserve in Sudan. The current area of the Dinder National Park amounts to around 10,300 km^2 (Abdelgaffar and Abdo, 2017). The park accommodates more than 17 types of big mammals and around 250 types of birds in addition to several kinds of small mammals, reptiles, fish, and amphibians (Abdelgaffar and Abdo, 2017).

3. Objectives

3.1. General objective

The general aim of this study is to assess the WEFE nexus in the Blue Nile Basin downstream the GERD in the present and also in future scenarios. The interconnections of water availability and loss, hydro and thermal energies, irrigated agriculture, and environmental flows are to be included in assessing water, energy, food, and ecosystems respectively (see Figure 4).

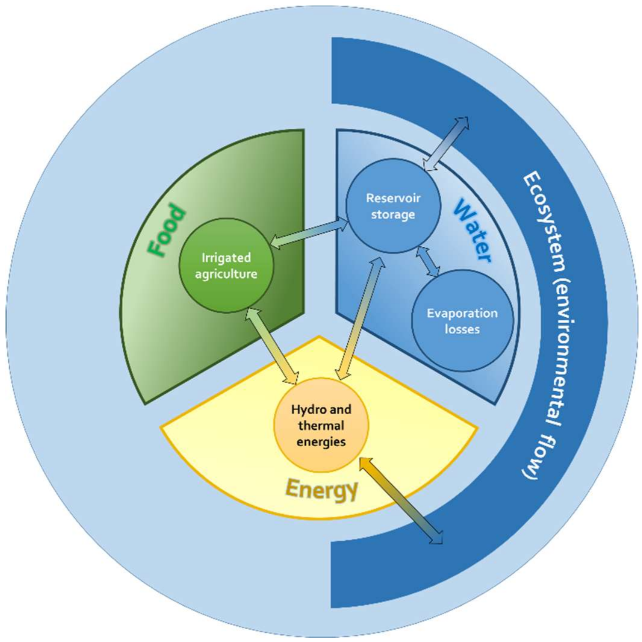

Figure 4 Interconnections of water, energy, food, and ecosystem to be considered

3.2. Specific objectives

- To develop a baseline database on water availability (rainfall and river flow), water uses by source and sector (agriculture and energy), and water and energy infrastructures (irrigation schemes, dams, and thermal plants), as well as ecosystem data.
- To assess the performance of satellite-based rainfall products that cover the study area with a long record and to use the best performing one in modeling the hydrological processes.
- To develop, calibrate, and validate a rainfall-runoff model to estimate the seasonal inflow of ungauged streams in the study area.
- To develop, calibrate, and validate a water allocation model for the study area.
- To develop agricultural development scenarios based on the existing and planned irrigation schemes in the study area. These scenarios will be based on

several cropping patterns of planned irrigation schemes in addition to different efficiencies of existing schemes.

- To develop dam operation scenarios based on the existing and under construction dams in the study area.
- To examine climate change and variability scenarios based on the analysis of the IGAD Climate Prediction and Application Centre (ICPAC).
- To conduct an overall assessment of the WEFE nexus in the study area in the present and future scenarios using indicators such as energy productivity, risk of shortage of irrigation water and risk of dropping below environmental flow.

4. Methodology

4.1. Review of available literature

An extensive literature review is to be conducted,and relevant information will be used in this study. The review areas include previous models of the study area, assessment of satellite-based rainfall products in the study area, WEFE nexus assessment in the study area, and climate change and variability studies conducted for the study area.

4.2. Performance evaluation of satellite-based rainfall products

Due to limited availability of measured rainfall data, open source data will be utilized. Point to pixel evaluation will be used to investigate the performance of the satellite-based rainfall products using the available records from ground gauges. This method will be used because it suits regions with limited and/or poorly distributed ground rainfall gauges. The freely accessible programming language R (R Core Team, 2015) will be used to download the SRPs, extract the pixel values at the locations of the ground rainfall gauges, analyze the data, and visualize the results. Several performance metrics will be used in assessing the satellite-based rainfall products: (1) error metrics that include Root Mean Square Error, Mean Bias Error, Mean Absolute Bias Error, and coefficient of determination (2) categorical metrics that include Frequency Bias, Probability of Detection, False Alarm Ratio, and Equitable Threat Score.

In order to calculate any of the categorical metrics, a threshold of 0.1 mm per day will be used to classify each time step within the evaluation period into a hit (h) when rainfall was both observed by the gauge and estimated by the satellite-based rainfall product; a miss (m) when rainfall is observed by the gauge but not estimated by the satellite-based rainfall product; a false alarm (f) when rainfall was estimated by the satellite-based rainfall product but not observed by the gauge; or null (n) when rainfall was neither observed by the gauge nor estimated by the satellite-based rainfall product (Diem et al., 2014; Ebert et al., 2007; Zambrano-Bigiarini et al., 2017).

4.3. Modeling

4.3.1. Modeling framework

A daily model will be developed for the study area that simulates water allocation, rainfall-runoff of un-gauged river streams, and irrigation water requirements of planned irrigation schemes. Several modeling tools will be used in this study (see Figure 5).

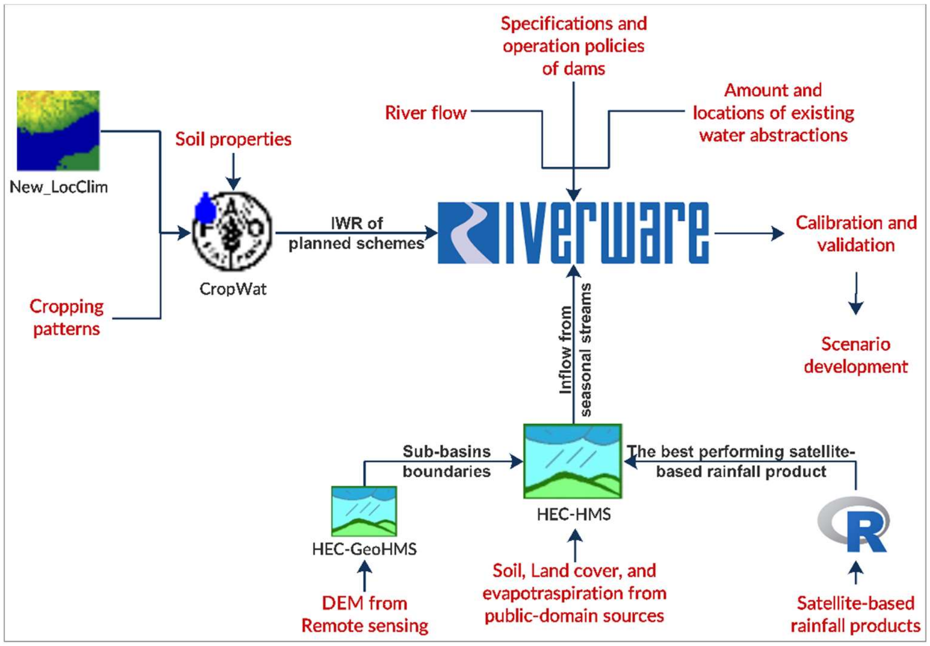

Figure 5 Modeling framework of this study

Water allocation in the study area will be simulated using RiverWare which is a general river and reservoir simulation software developed by the University of Colorado Boulder (Zagona et al., 2001). With a time step ranging from one hour to one year, RiverWare is capable of simulating hydraulic and hydrologic processes of reservoirs, river reaches, diversions, canals, abstractions, groundwater interaction, hydropower production, water ownership, and water accounting transactions. All the previously mentioned simulation capabilities are useful in operation scheduling, planning, and policy evaluation (Basheer et al., 2018; Wheeler et al., 2016; Zagona et al., 2008). The object-oriented approach of RiverWare allows the user to create a network of objects, link them, populate each one with data, and select the appropriate physical process (Zagona et al., 2008). Moreover, the Rule-based simulation, which RiverWare supports, gives the ability to simulate operation policies using logical policy statements rather than explicitly specified input values for operations (Zagona et al., 2008). This ability provides high flexibility in simulating complex river systems. Additionally, RiverWare includes an important utility called Multiple Run Management through which the user can run a model using traces of stochastically generated hydrologic inputs (Basheer et al., 2018; Zagona et al., 2008). RiverWare has appeared to be successful by its recent use in the transboundary negotiations over the Colorado River (Wheeler et al. 2016) and modeling the Eastern Nile Basin (Basheer et al., 2018; Basheer and Elagib, 2017; Wheeler et al., 2016). The WRC has a RiverWare license which will be used in this study.

HEC-HMS will be used to simulate the hydrological processes. HEC-HMS, developed by the Hydrologic Engineering Centre, is a freely accessible numerical model (computer program) that includes a large set of methods to simulate rainfall-runoff for dendritic watershed systems. HEC-HMS simulates watershed precipitation and evaporation, runoff volume, direct runoff, base flow, and channel flow (HEC, 2008). Moreover, HEC-GeoHMS will be used to visualize spatial information, document watershed characteristics, perform spatial analysis, delineate sub-basins and streams, and construct inputs to HEC-HMS (Asadi and Boustani, 2013; HEC, 2009).

The irrigation water demands of planned agricultural schemes will be estimated using CropWat. CropWat, developed by the Food and Agriculture Organization (FAO), is a freely accessible computer program for the calculation of crop water requirements and irrigation water requirements for different cropping patterns based on soil, climate, and crop data. The database of CropWat includes some crop and soil data which can be used when data is not available. Climatic data related to estimating crop water requirements will be obtained from a climatic database called ClimWat, which can be connected with CropWat (FAO, 2015). Table 1 shows the features considered and the method of assessment for the study area.

Table 1: Methods to be used for simulating various processes

Process	Method
Runoff volume	Deficit and constant loss
Direct runoff	Snyder's unit hydrograph
Baseflow	Monthly-Varying Baseflow
Flow routing	Lag time
Canopy interception	Simple canopy
Crop water requirements	FAO Penman-Monteith equation
Transmission losses	Percentage loss
Reservoir evaporation	Average monthly rate
Surface evapo-transpiration	Average monthly

4.3.2. Model calibration and validation

The model performance will be assessed according to the recommendations of Stern et al. (2016) which provided performance ranking for daily models based on quantitative comparison of simulated and observed flow values using three statistical performance metrics. The three metrics include the coefficient of determination (R^2), Nash–Sutcliffe Efficiency (NSE), and the Mean Error Percentage (MPE). R^2 ranges from zero to one, with higher values demonstrating better performance. NSE can take any value from one to -∞ with one indicating perfect prediction ability, zero indicating that the prediction of the model is as good as the average of the observed data, and negative values showing that the average of the observed data is better than the model prediction. Lastly, the Mean Error Percentage (MEP) ranges from -100 to +∞ with values closer to zero indicating better performance.

The performance of the model will be assessed using river discharge at three locations: Rosieres Dam, Sennar Dam, and Khartoum Gage. The model will be calibrated from 1983 to 1998 and validated from 1999 to 2013. The calibration parameters will include soil infiltration rate, maximum soil storage capacity, time of concentration of sub-basins, Snyder peaking coefficient, lag times, canopy interception, and transmission losses.

4.4. Scenario development and WEFE nexus assessment

4.4.1. Scenario development dimensions

Combinations of the following dimensions will be considered in developing the scenarios:

- Agricultural development based on sequential addition of the planned irrigation schemes and varying cropping patterns.
- Agricultural demand of existing irrigation schemes based on higher efficiency values.
- Hydrological sequences or traces developed using the index-sequential method (Kendall and Dracup, 1991; Ouarda et al., 1997).
- Operation of existing and under construction dams.
- Climate change and variability based on the analysis of ICPAC.

4.4.2. WEFE nexus assessment indicators

WEFE nexus will be assessed using the following indicators:

- The water-energy productivity, which is the amount of energy produced per unit of water lost in the process (Basheer and Elagib, 2017).

- The risk of shortage in supplying irrigation water, which is the percentage of days with supply shortage (Wheeler et al., 2016).
- The risk of dropping below the environmental flows.

4.5. Data Availability

4.5.1. Rainfall

Data record of eight rainfall gauges (see Figure 6) for the years 1999 to 2009 were obtained from the Sudan Meteorological Authority (SMA). The WRC is currently negotiating with SMA to get more recent data. Due to the limited number of available rainfall gauges in the study area, satellite-based rainfall estimates will be used as an input for hydrological modeling. Gauge-data will be utilized as a comparison benchmark to evaluate the performance of five satellite-based rainfall products; i.e. African Rainfall Climatology Version 2 (ARC2.0), Tropical Applications of Meteorology Using Satellite Data and Ground-Based Observations version 3.0 (TAMSAT3.0), Precipitation Estimation from Remotely Sensed Information Using Artificial Neural Networks–Climate Data Record (PERSIANN-CDR), Climate Hazards group Infrared Precipitation with Stations version 2.0 (CHIRPS 2.0), and Multi-Source Weighted-Ensemble Precipitation version 2.0 (MSWEP 2.0).

4.5.2. River flow

Daily River flow data at El-Diem station, which is located near the Ethiopian-Sudanese border, for the period 1980 to 2017, will be used as a baseline inflow to the GERD. Moreover, the outflow from Rosaries and Sennar dams in addition to the river flow at Khartoum gauge (at the mouth of the basin) will be used for calibrating and validating the model. Flow data for the years 1980 to 2017 at Eldiem, Rosieres, Sennar, and Khartoum are available for the WRC.

4.5.3. Water abstractions and dams' data

The Ministry of Water Resources, Irrigation, and Electricity of Sudan provided the water abstractions of existing irrigation schemes and thermal power plants. The data of Sennar and Rosaries dams are available for the WRC including elevation-volume tables, elevation-area tables, evaporation coefficients, outlet capacities, downstream rating curves, turbine specifications, environmental flows, and operating policies. For the GERD, elevation-volume tables, elevation-area tables, evaporation coefficients, outlet capacities, downstream rating curves, and turbine specifications are available for the WRC.

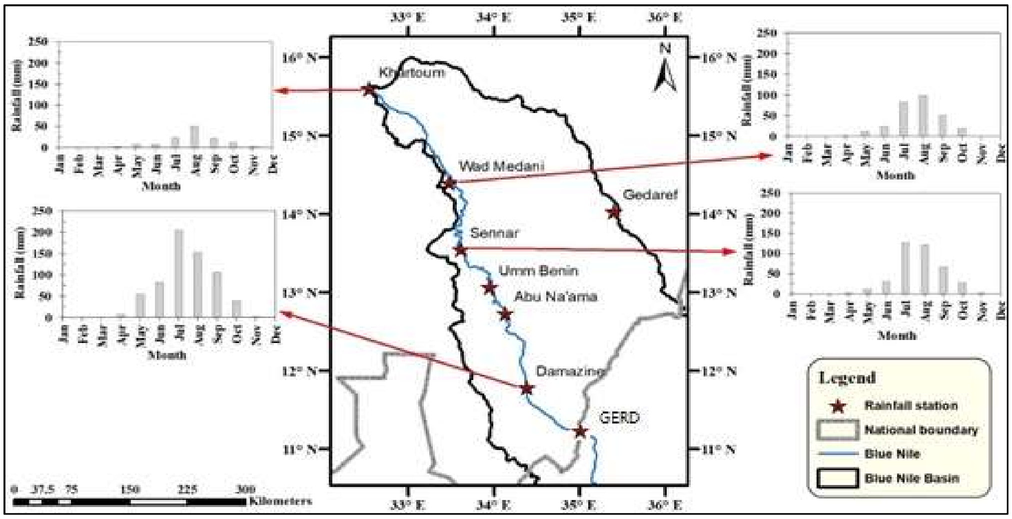

Figure 6 Rainfall gauges to be employed in this study an average monthly rainfall of some stations with available data Source: adapted from (Basheer et al., 2018)

4.5.4. **Climate change/variability data**

Future scenarios for the Blue Nile Basin that include the no-stationarity in climate will be acquired from ICPAC based on their study part on climate variability and change. The required information includes:

- Projections for the Blue Nile flow at the Ethiopian-Sudanese border and at some other points upstream the GERD.
- Projections for rainfall in the Blue Nile Basin.
- Projections for temperature and solar radiation in the Blue Nile Basin.

4.5.5. **Ecosystem data**

Ecosystem data is generally scarce in the study area. However, few investigations have been carried out in the study area from which information on fresh water ecosystem, land ecosystem, species of birds, animals, plants, etc. will be obtained. Based on this, environmental flow requirements will be estimated.

4.5.6. **Other data**

Soil data, land use and land cove data, socio-economic data, and demographic data will be obtained from public-domain data sources. Those sources include USGS Global Land Cover Characterization, FAO GeoNetwork, and Word Bank Open Data.

5. Work plan

Table 2 Schedule of core activities

Activity	Period
Assessment of local (i.e. in situ) data	Aug 2018
Acquisition and evaluation of satellite data and development of a scientific report based on the evaluation results	Sep to Oct 2018
Development of the study area database	Dec 2018 to Jan 2019
Development of the study area model	Jan 2019 to Feb 2019
Organizing a workshop to present the initial results and to come up with improvement measures	Feb 2019
Improving the study area model and assessing the WEFE nexus.	Mar 2019
Developing the final WEFE nexus report of the Study area in addition to scientific publications.	Apr 2019 to Jun 2019

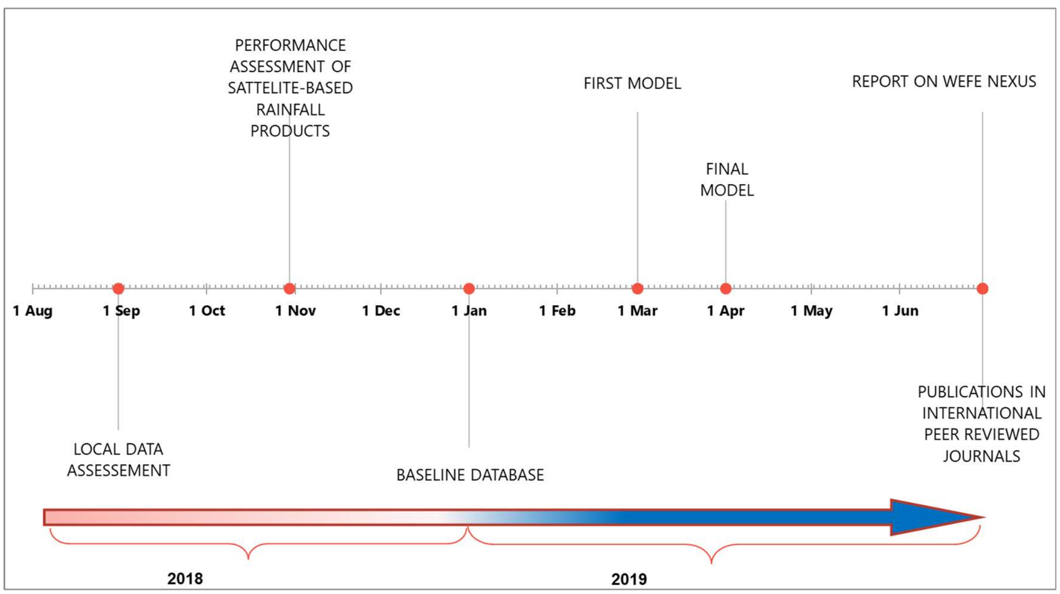

Figure 7 Project milestones

6. Risks and mitigations plan

Data represent the main risk in this study. The cost of obtaining the required gauge rainfall data amounts to around 80,000 SDG (approximately 2000 euros), which is quite high in view of the available resources. The WRC is currently negotiating with SMA the possibility of obtaining the data at a lower cost. In case of not being able to obtain the data, the WRC will rely on previous studies that have been conducted in regions near the Blue

Nile Basin to decide on which satellite-based rainfall product could be used in modeling rainfall-runoff of seasonal streams in the study area.

The operating policies of the GERD are still unknown for the WRC. The WEFE nexus in the study area is largely dependent on the operation of the GERD. The WRC will base the analysis of WEFE nexus downstream the GERD on hypothetical operation scenario. The development of those scenarios will possibly be in coordination with the modeling exercise of the Blue Nile Basin upstream the GERD, which will be conducted by the EiWR.

Investigating the impact of climate change and variability will be based on the analysis of ICPAC. The WRC already contacted ICPAC regarding these data. Additionally, the WRC would review the literature in developing some climate change/variability scenarios.

7. Deliverables

This project includes the following deliverables:

1. The present Inception report, which details the conceptual framework of the study, data availability and collection, the structure of the database, the overall planning of the work to be implemented, as well as issues, challenges and possible solutions, and the tentative table of contents of the final report.
2. Report describing the Baseline database on hydrology and water use. The database shall include periodic rainfall data (i.e. average monthly) from ground stations and from the best performing satellite-rainfall product, periodic river flow data (average daily), water users, periodic water abstractions per sector (average monthly), reservoir geometry and specifications, evapotranspiration data, and environmental flow requirements.
3. A Comprehensive assessment report on WEFE nexus (current and future scenario), including the design and implementation of a hydrological and water balance modeling framework and agricultural water management. The results of the scenario based analysis using water allocation model RiverWare, the hydrological model HEC-HMS and the irrigation water requirements model CropWat will be presented and discussed, taking into consideration planned water supply and irrigation schemes with different cropping patterns and optimized hydropower scenarios. Table 3 shows a tentative table of contents for the final report. Note that the contents of the final report are subject to minor changes based on the findings of the WEFE assessment.
4. Dissemination material in the form of presentations slides on the methodology and findings of the study including models setup and outcomes of the scenarios-based simulations

8. Structure of the database

Figure 8 shows different data that will be included in the database, which can be categorized as point data, geographic data, descriptive data, and spatially distributed data. Time series data will be analyzed and then added to the database as the WRC has no authority to distribute raw data.

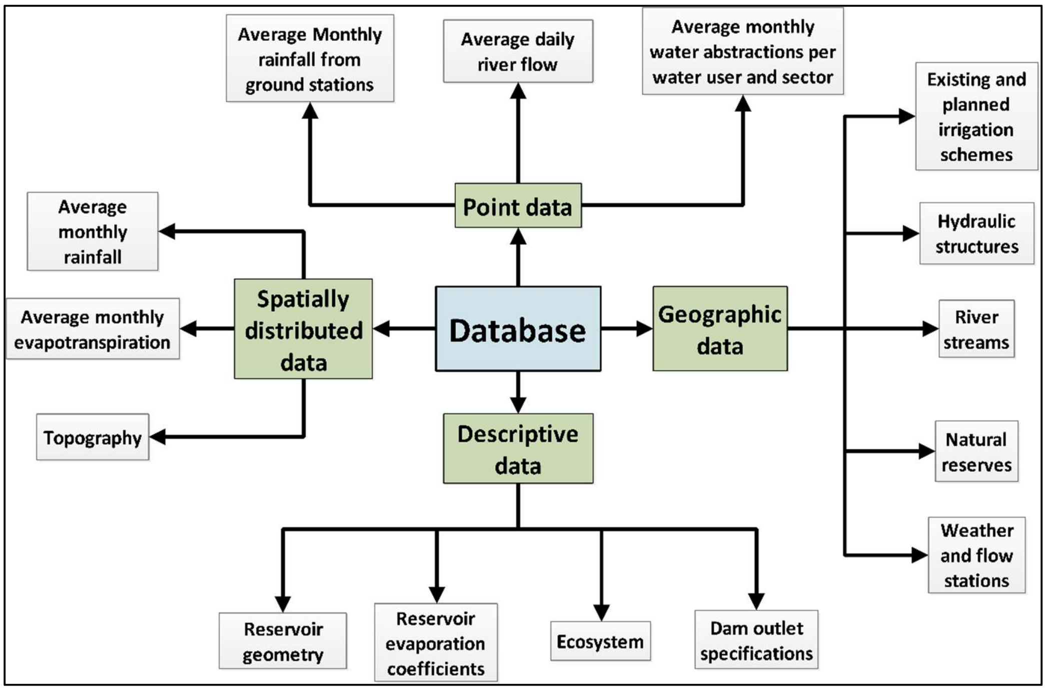

Figure 8 Architecture of the baseline database

9. Table of contents of the final report

The final report will tentatively contain an executive summary, 5 chapters and a list of the references consulted as shown in Table 3

Table 3 Tentative table of contents of the final report

Section	Subsection
Executive summary	-
1. Introduction	1.1 Background 1.2 Literature review 1.3 Scope
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	2.3 Irrigation schemes 2.4 Thermal power plants 2.5 Water rights 2.6 Ecosystem
3. Modeling	3.1 Model components 3.2 Modeling framework 3.3 Model performance 3.4 Simulation scenarios
4. Water-Energy-Food-Ecosystems nexus	4.1 Water-energy productivity 4.2 Risk of water supply shortages 4.3 Risk of dropping below environmental flows
5. Conclusions& Way Forward	5.1 Conclusions 5.2 Way Forward
6. References	-

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