EIWR.2 Comprehensive Assessment Report on WEFE nexus over the BNB upstream GERD

1. Introduction:

Natural resources are under enormous pressure due to population growth, economic development, increased energy and food needs. Common development needs have to be met in a sustainable manner, without compromising the functioning of ecosystems. Shortcomings in inter-sectoral coordination are a major challenge both on the national and transboundary levels, in developing as well as in developed countries. In a transboundary setting, the trade-offs and externalities may cause friction between the riparian countries and different interests. A nexus (or inter-sectoral) approach to managing the interlinked resources can enhance water, energy and food security by increasing efficiency, reducing trade-offs, building synergies and improving governance across sectors.

Upper Blue Nile Basin is one of the main source of Nile flow and a transboundary river. The current study assessed the water-energy-food-ecology (WEFE) nexus, including the implementation of a hydrological and water balance modelling framework, hydropower and agricultural water management over the BNB upstream GERD.

2. Objective:

Assessing Water-Energy-Food-Ecology (WEFE) nexus, including the implementation of a hydrological and water allocation framework, hydropower and agricultural water management over the Blue Nile Basin (BNB) upstream Grand Ethiopian Renaissance Dam (GERD).

3. Study area:

Blue Nile River is the main source of the water for hundreds of millions of people in Ethiopia, Sudan and Egypt in the Nile River basin with a drainage area of 324,530 km^2 (Peggy and Curtis, 1994) the. The Upper Blue basin is 176,000 km^2 in area (Conway, 2000) and it is the largest of Ethiopian basins in terms of volume of discharge. The primary tributaries in Ethiopia are the Besheilo, Welaka, Jemma, Muger, Guder, Finchaa, Anger, Didessa and Dabus on the left bank and the North Gojam, South Gojam, Wombera and Beles on the right bank (McCartney and Girma, 2012). The topography is dominated by an altitude ranging from 485 meters to more than 4257 meters.

The livelihood of the people in the basin is heavily dependent on rain-fed agriculture and small-scale irrigation schemes (Fenta et al. 2014). The basin is also characterized by poverty, rapid population growth, environmental degradation, and frequent natural disasters (Abtew and Melesse, 2014). The Blue Nile basin is increasingly experiencing multi-dimensional pressures including population growth, climate change and variability, deforestation, land/soil degradation, as well as increasing upstream-downstream tension on water use rights. Ethiopia has so far little utilized the water resources of the Basin although it contributes nearly 84% of the annual flows of the Nile (Block and Strzepek, 2010). Sustainability of the Nile River Basin water resources development is highly linked with a regular assessment and management of the level of interdependency and integration exists among Water - Energy - Food and Ecosystem (WEFE) nexus. These four sectors are so interlinked and complex that requires critical and in-depth analyses.

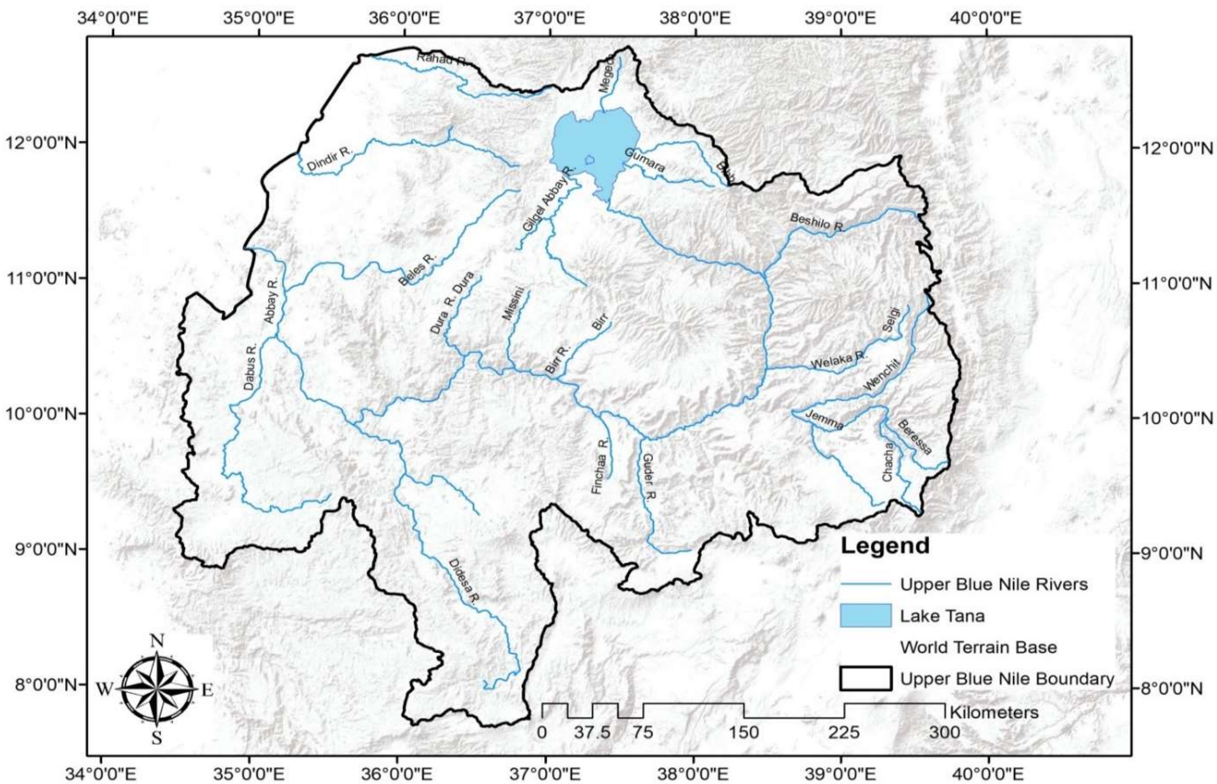

Figure 1. Upper Blue Nile

4. Materials and Method

For WEFE nexus assessment, MIKE Hydro water allocation model is implemented.

The following steps are followed in MIKE Hydro:

The upstream of GERD is divided into seven sub-catchments. The rainfall-runoff simulation using MIKE-NAM conceptual model at each sub-catchment using climate research unit time series (CRU TS v. 4.03) rainfall, temperatures and potential evapotranspiration data. The MIKE-NAM rainfall-runoff model is calibrated using observed stream flow at different sub-catchments. Streamflow estimation for ungauged catchment is implemented in order to calculate streamflow at the outlet of each sub-catchments (i.e., transferring the ratio of streamflow to rainfall at different gauging stations to the outlet of the sub-catchments). Once the river flow for each sub-catchment is estimated/established, reservoirs, irrigation water use and hydropower nodes were added. Monthly irrigation demand data from different irrigation scheme studies (feasibility studies) were considered for food security. Four reservoirs such as Lake Lana, Diddessa reservoir, Fincha reservoir and GERD are considered. Tana-Beles hydropower, Fincha hydropower and GERD were considered for energy security. The release from reservoirs were evaluated for ecological flow availability.

5. Results

Sub-catchment delineation of upper Blue Nile is indicated in figure 2 below. The rainfall-runoff simulation using MIKE-NAM conceptual hydrologic model and CRU TS4.03 rainfall and evapotranspiration data as an input did not work well even after calibration. As the result prediction of streamflow in ungauged catchment principle were applied in order to obtain river flow for each sub-catchment.

Estimated sub-basin river flows are indicated in Table 1. Streamflow observations at Lake Tana outlet and Kessie gauging stations are adopted directly while for other sub-catchments the flow is estimated using ungauged catchment procedure (by assuming constant runoff to rainfall ration for a sub-catchment). When the intermediate catchment has no gauging stations, then area weighted interpolation were implemented (for example for sub-catchment upstream of Fincha and upstream of Deddessa).

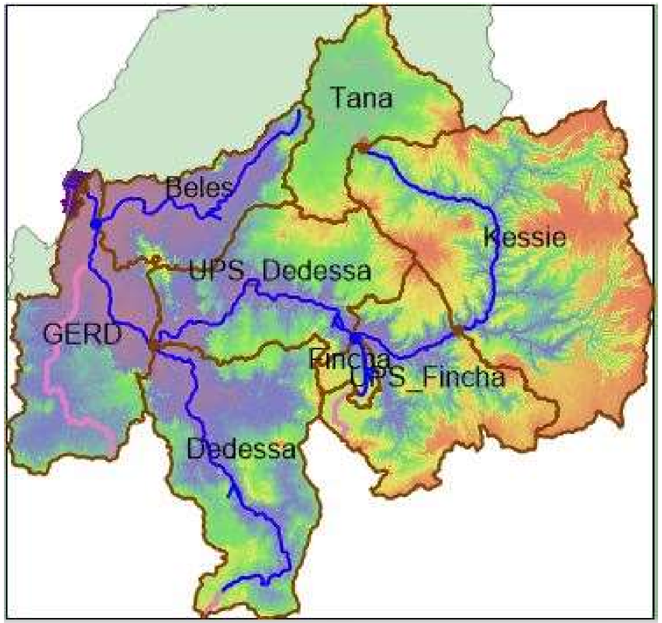

Figure 2. Sub-catchment delineation

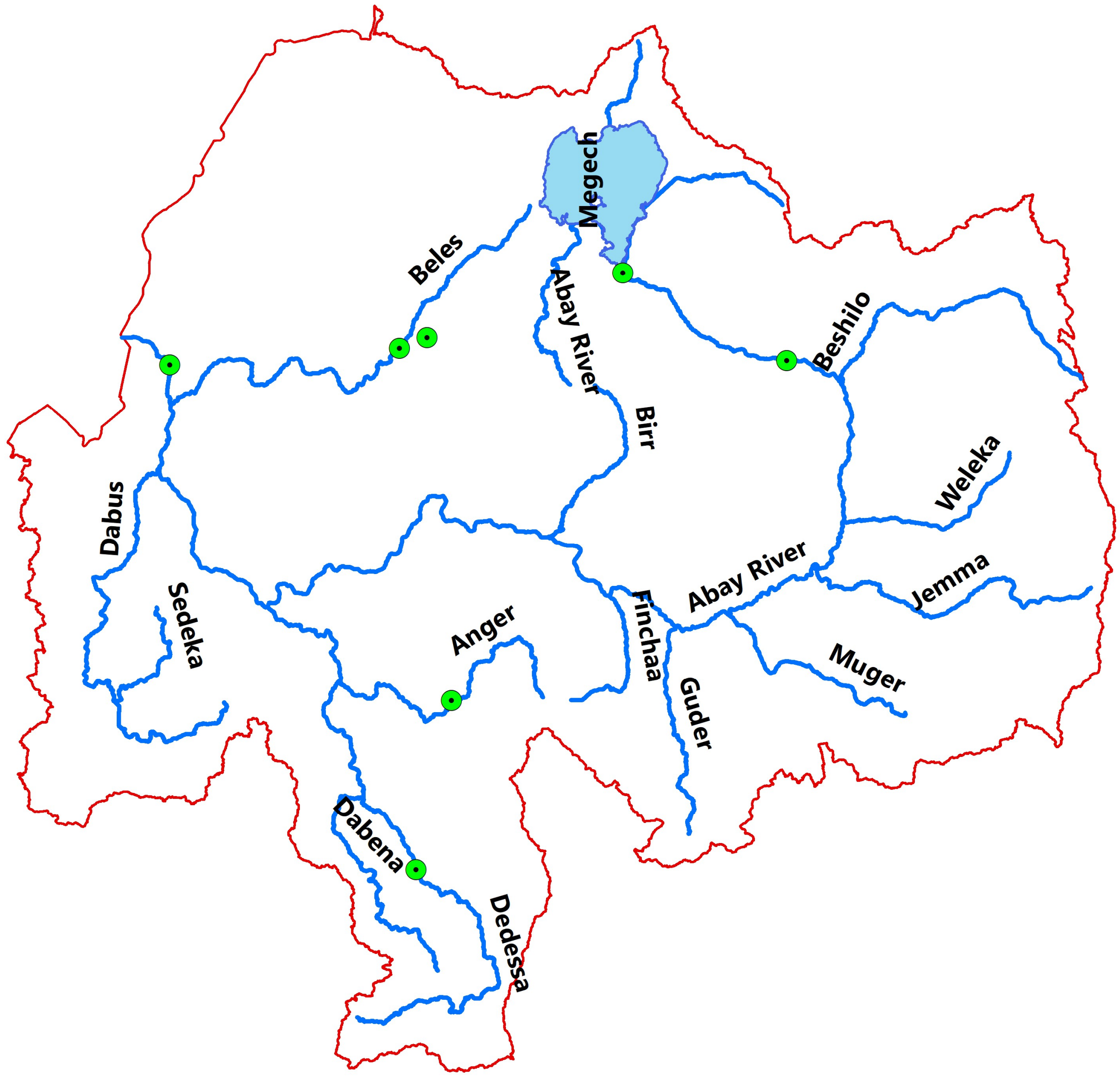

Figure 3. River flow gauging stations considered in the current study

Table 1. Catchment yield or river flow (m^3/sec)

Sub-catchment	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Tana	169.02	173.62	179.47	200.65	143.7	614.1	1600.6	2079.6	2011.6	709.3	398.4	356.76
Fincha	3.95	2.89	2.26	1.98	1.97	5.8	20.91	35.57	40.03	30.01	15.22	6.33
Deddessa	168.93	173.5	179.36	200.52	143.59	614	1600.52	1447.49	1353.33	742.71	385.3	370.43
GERD	213.16	208.69	183.41	182.69	283.75	1068.1	2420.15	2595.45	1487.2	677.31	332.59	358.07
Beles	23.16	15.51	13.72	12.89	31.41	185.28	545.02	981.82	641.35	369.42	133.11	42.88
Kessie	144.2	112.5	186.4	187.4	161.5	260.3	2015.1	3668.9	1232.2	661.7	393.1	267.5
US Deddessa	102.3	68	60.3	63.7	112.3	378.3	746.3	978.3	896.6	596.1	318.4	155.8

Lake Tana MIKE Hydro output is shown in Table 2. The Irrigation water demand is aggregated from feasibility study of different schemes in the Lake Tana sub-basin. Tana-Beles hydropower installed capacity is 450 MW. The actual operational data for hydropower generation is not found. Therefore, simple assumption such as percentage of installed capacity is considered as actual demand or operational power. As a result we can see irrigation water demand deficit and power deficit from MIKE Hydro simulation (Table 2).

Table 2. Tana Irrigation and Tana-Beles Hydropower simulation outputs

Month	Inflow to Tana (m^3/sec)	Total Release Tana (m^3/sec)	Tana water Level (m)	Irrigation Water Used (Mm^3)	Water demand Deficit (Mm^3)	Generated power (MW)	Power Deficit (MW)
January	169.02	573.63	1784.72	15.41	25.65	47.96	352.04
February	173.62	227.89	1784.37	11.41	28.02	44.70	355.30
March	179.47	165.04	1784.28	11.64	28.58	44.61	355.39
April	200.65	140.61	1784.21	2.18	5.38	44.65	355.35

May	143.7	137.32	1784.19	0.00	0.00	44.32	355.68
June	614.1	358.84	1784.19	2.14	3.56	44.17	355.83
July	1600.6	986.1	1784.33	0.00	0.00	46.37	353.63
August	2079.6	1371.45	1784.45	1.04	0.59	48.34	351.66
September	2011.6	1348.77	1784.52	6.84	3.88	50.12	349.88
October	709.3	722.56	1784.52	12.63	7.16	50.53	349.47
November	398.4	436.75	1784.54	5.33	6.21	50.63	349.37
December	356.76	326.21	1784.5	16.8	41.25	50.71	349.29

For Fincha Irrigation scheme actual irrigation water demand is obtained from master plan study. However, the streamflow at the confluence of Fincha River to Blue Nile River is estimated during master plan study, and hence adopted. Actual operational data were adopted form estimation of power deficit. MIKE Hydro output for Fincha sub-catchment is shown in Table 3. Table 3 indicated that there is no water demand deficit for the existing irrigation scheme as well as the hydropower generation.

Table 3. Fincha Irrigation and Tana-Beles Hydropower simulation outputs

Month	Inflow to Fincha (m^3/sec)	Total Release Fincha (m^3/sec)	Fencha Level (m)	Irrigation Water Used (Mm^3)	Water demand Deficit (Mm^3)	Generated power (MW)	Power Deficit (MW)
January	3.95	16.72	2220.96	16.84	0	1122499.6	0.00
February	2.89	16.68	2220.90	20.17	0	1111609.8	0.00
March	2.26	17.18	2220.84	21.41	0	1135867.3	0.00
April	1.98	16.07	2220.77	22.94	0	1052648.6	0.00
May	1.97	17.03	2220.70	20.27	0	1106369.2	0.00

June	5.8	17.23	2220.63	19.71	0	1109341.7	0.00
July	20.91	9.36	2220.58	2.70	0	598779.7	0.00
August	35.57	5.63	2220.64	2.70	0	362571.4	0.00
September	40.03	8.87	2220.80	16.04	0	444450.9	0.00
October	30.01	22.95	2220.95	17.65	0	550093.9	0.00
November	15.22	15.96	2220.99	15.96	0	1052030.5	0.00
December	6.33	16.09	2220.98	15.65	0	1083504.1	0.00

MIKE Hydro output for Deddessa sub-catchment is shown in Table 4. At Deddessa sub-catchment only irrigation demand is considered. Table 4 indicated that there is no water demand deficit for the existing irrigation scheme at Deddessa sub-catchment.

Table 4. Deddessa Irrigation water demand deficit using MIKE Hydro.

Month	Inflow to Deddessa (m^3/sec)	Total Release Deddessa (m^3/sec)	Irrigation Water Abstracted (Mm^3)	Irrigation Water Used (Mm^3)	Water demand Deficit (Mm^3)
January	168.93	293.80	7.34	7.3	0
February	112.92	217.02	9.25	9.2	0
March	99.56	193.76	4.99	4.9	0
April	111.15	221.50	0.76	0.7	0
May	142.39	284.78	0.01	0.0	0
June	512.28	1024.55	0.00	0.0	0
July	1107.98	2215.96	0.00	0.0	0
August	1447.79	2895.58	0.00	0.0	0

September	1353.33	2706.66	0.00	0.0	0
October	742.71	1485.42	0.00	0.0	0
November	398.30	791.96	4.64	4.6	0
December	248.32	491.73	4.91	4.9	0

MIKE Hydro output for GERD sub-catchment is shown in Table 5. Table 5 indicated that there is no power deficit at GERD hydropower scheme although actual power generation data is not yet exist as the Dam is not yet commissioned.

Table 5. GERD Hydropower Hydropower simulation outputs using MIKE Hydro.

Month	Inflow to GERD (m^3/sec)	Total Release GERD (m^3/sec)	Generated power (MW)	Power Deficit (MW)
January	213.16	1250.49	239.18	0.00
February	173.93	679.79	195.16	0.00
March	165.64	634.62	185.86	0.00
April	188.09	673.61	211.05	0.00
May	371.41	851.59	416.74	0.00
June	1086.11	2618.14	1218.69	0.00
July	2498.74	7492.37	2803.76	0.00
August	2897.20	10292.95	3250.86	0.00
September	1900.17	6965.17	2132.11	0.00
October	1056.53	4159.29	1185.50	0.00
November	526.79	2232.12	591.09	0.00
December	350.62	1355.14	393.42	0.00

Relevant data such as depth-area-volume, rainfall on the reservoir, evaporation loss from the reservoir were adopted from the relevant feasibility study report of the four reservoirs (Lake Tana, Fincha, Deddessa and GERD) (see figures 4 to 8).

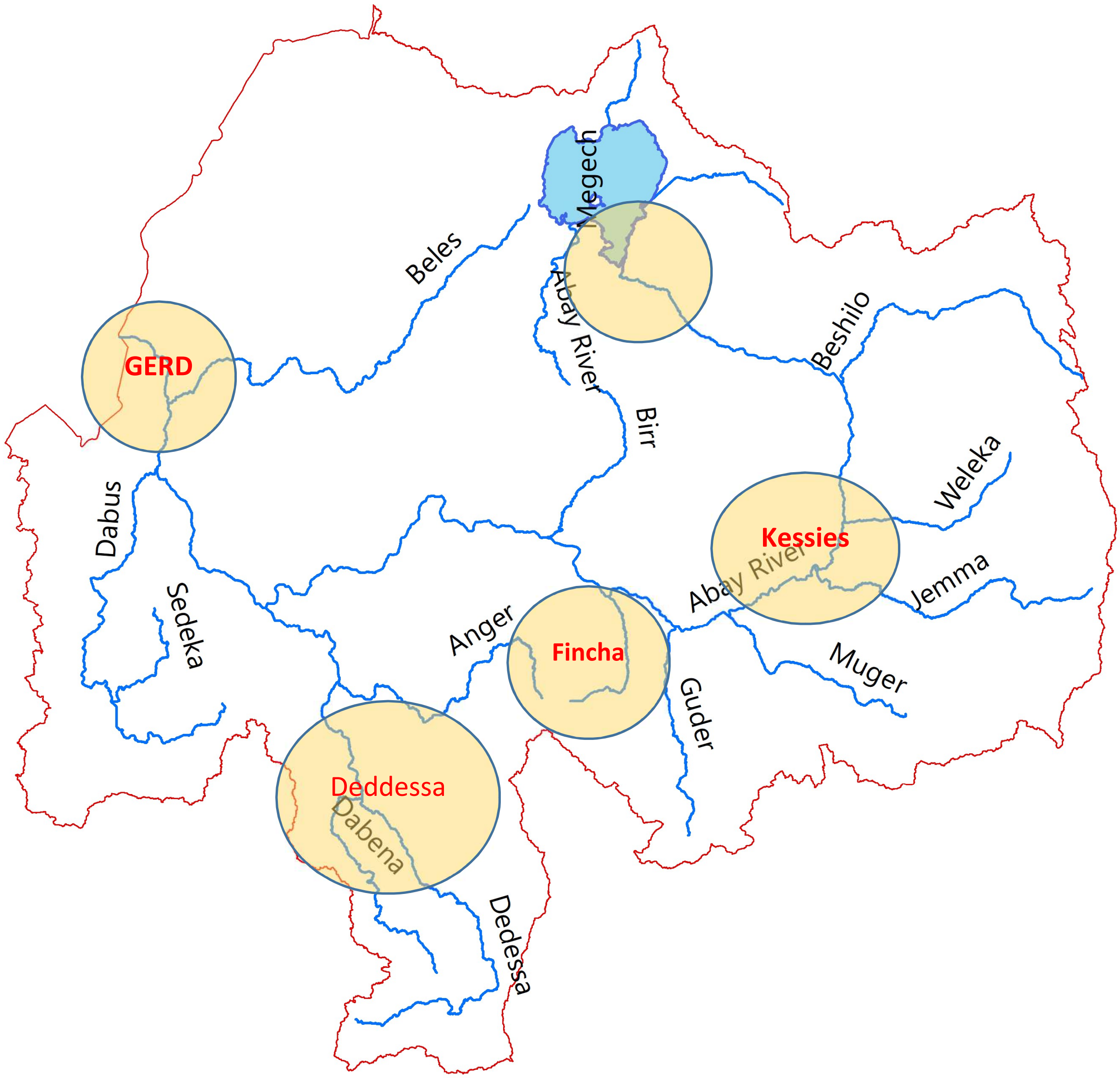

Figure 4. Selected study sub-catchments for WEFE nexus analysis

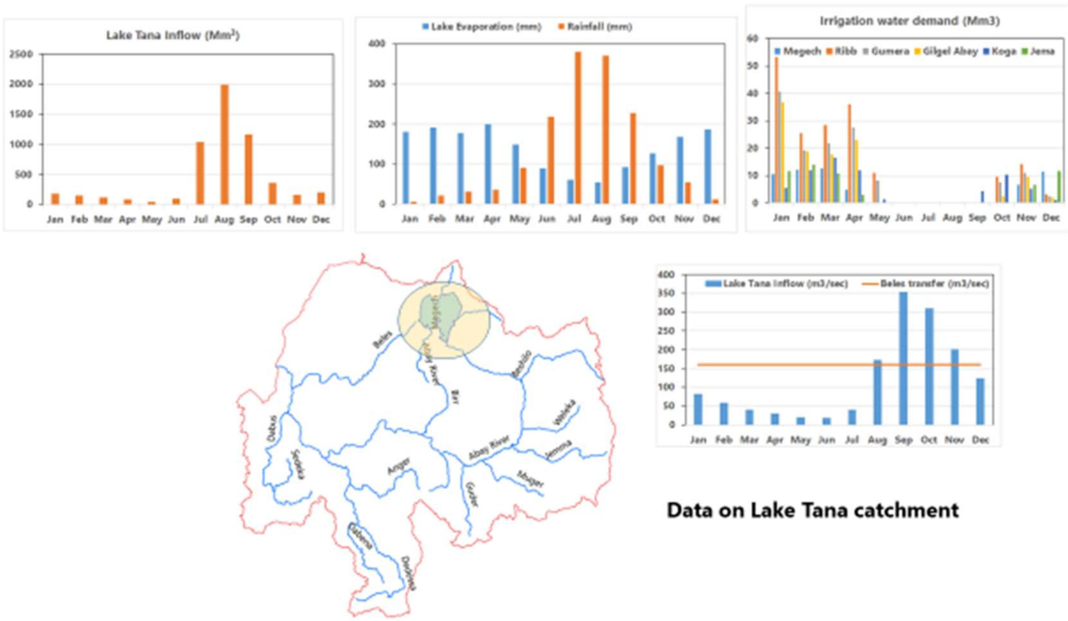

Figure 5. Input data at Lake Tana sub-catchment

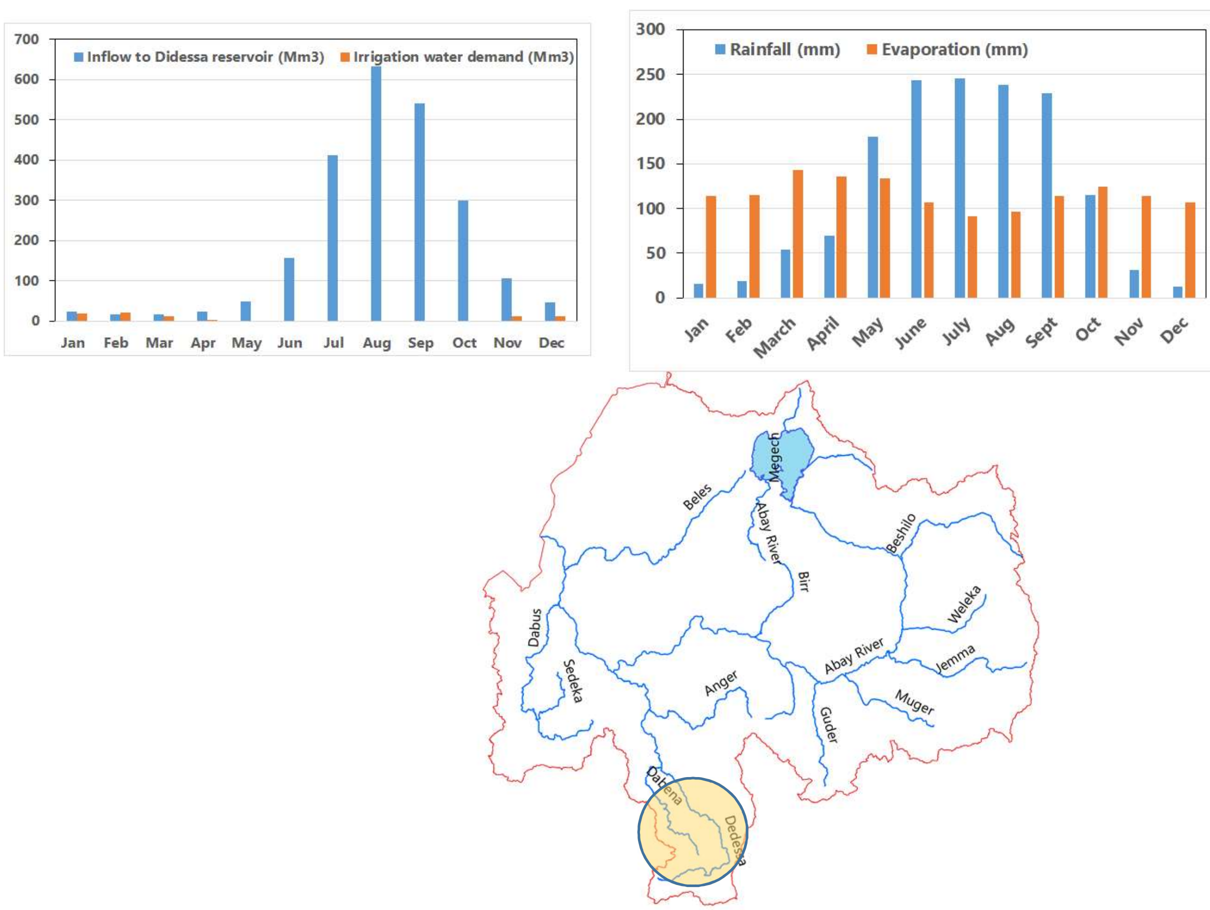

Figure 6. Input data for Deddessa sub-catchment

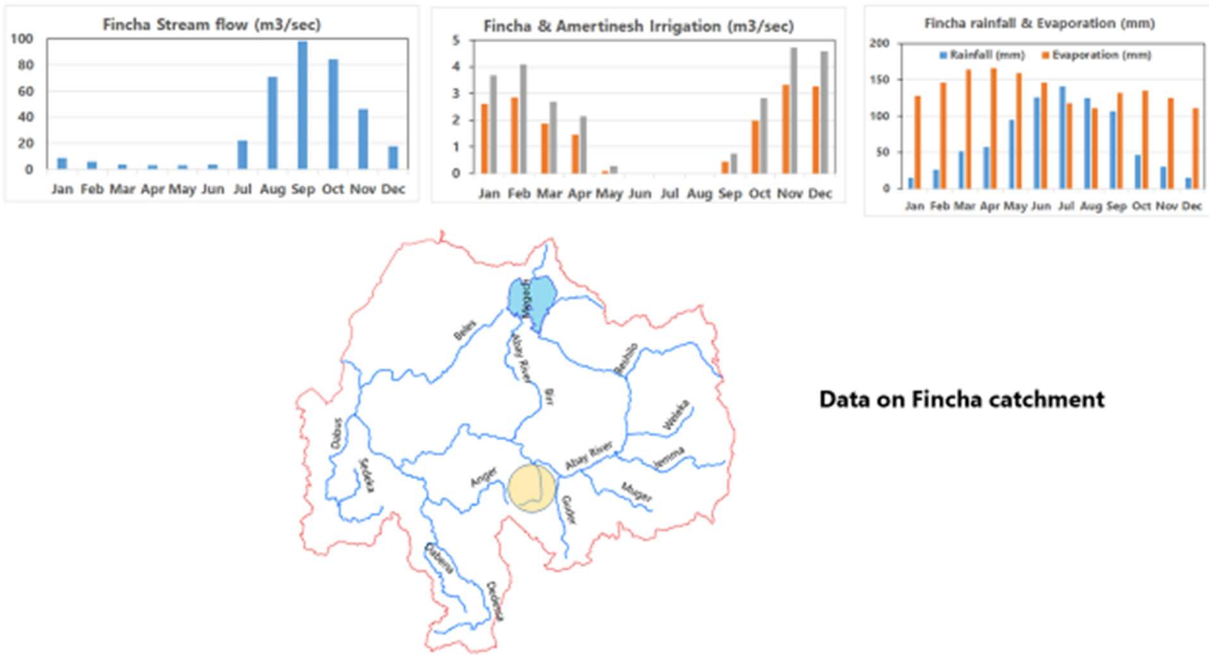

Figure 7. Input data for Fincha sub-catchment

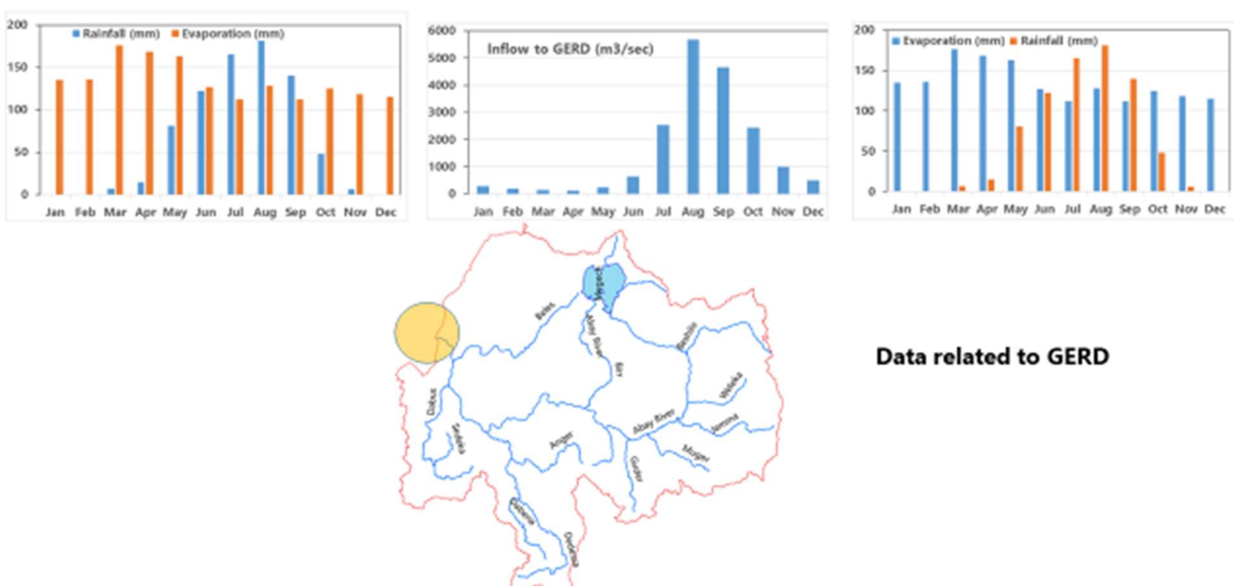

Figure 8. Input data for GERD sub-catchment

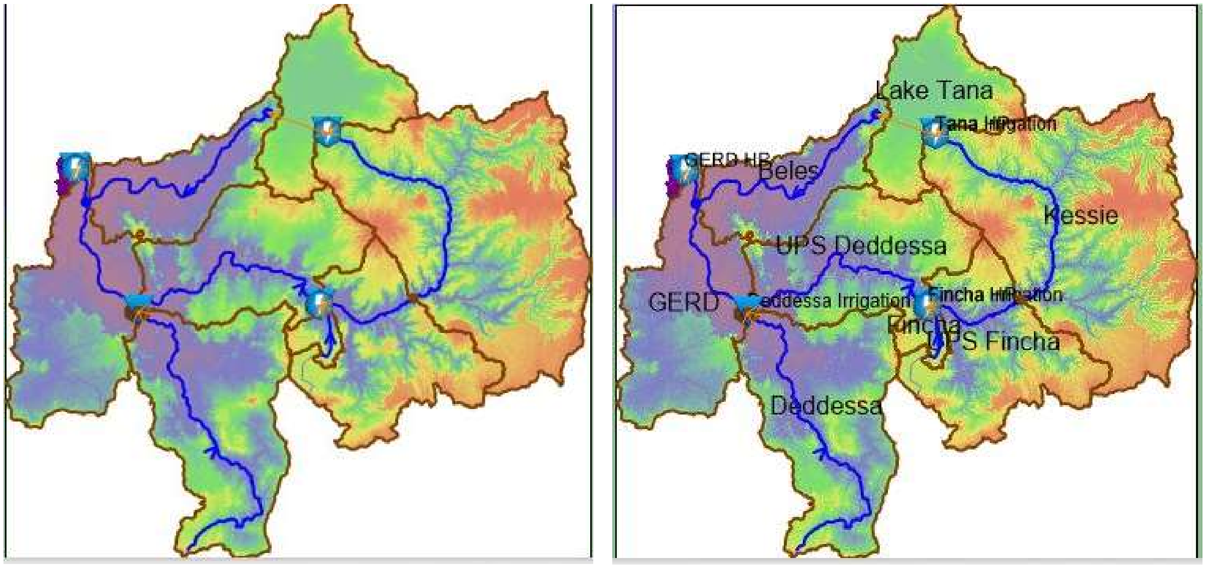

Figure 9. Hydropower, Reservoir and Irrigation nodes

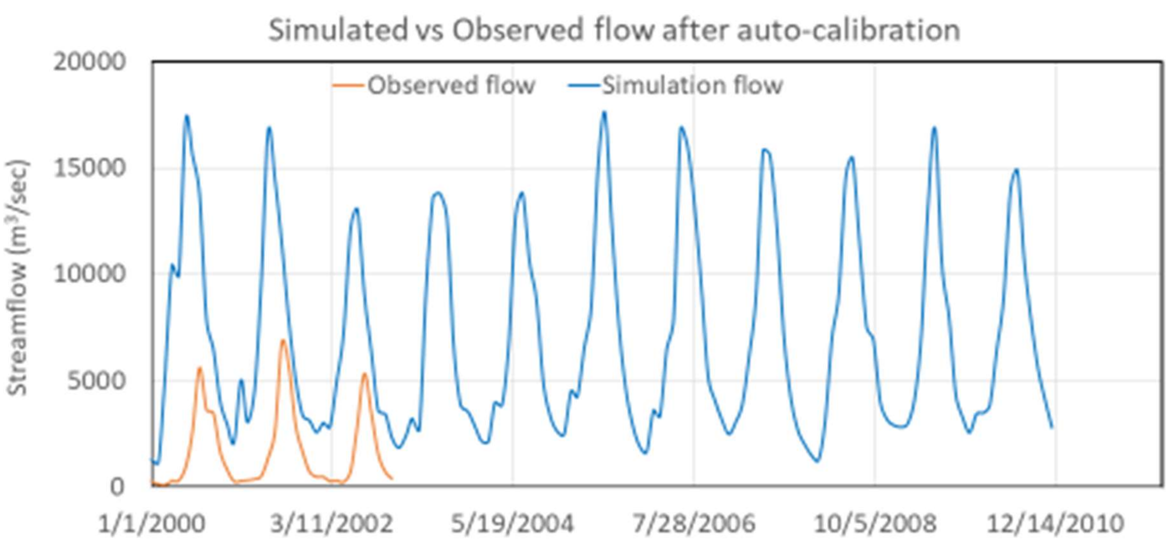

Figure. The simulated and observed streamflow is not matching even after auto-calibrating MIKE-NAM rainfall-runoff model at GERD.

Conclusions

Rainfall-runoff modeling using MIKE-NAM did not work. However, the streamflow for each sub-catchment were estimated using stream flow estimation for ungauged catchment principle.

The irrigation water demand for food security and hydropower deficit for energy security is satisfied for almost all schemes considered except Lake Tana basin. It is worth mentioning that most of the data inputs are assumption rather than actual power operations. Therefore, the outputs from this study might not be consumed directly. However, it could be considered as a modeling exercise.