WACONI

WAter and COoperation within the NIle River Basin Deliverable EIWR.1

Baseline database on hydrology and water use and related report in the Blue Nile upstream of GERD.

Deliverable EIWR.1

Contractor: Geremew Sahlu Gebrie: **Ethiopian Institute of Water Resources**

Contract Number : CT-EX2018D329228-101

Authors: Tekalegn Ayele, Azage G/ Yohannes, Yonas Girma, Dejene Sahlu, Tena Alamrew

Submission date: 07-02-2019

Outline

Baseline Hydrological Database on Blue Nile Base Water Use

1. INTRODUCTION

1.1. Description of the Blue Nile Basin

1.1.1. Background

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 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.

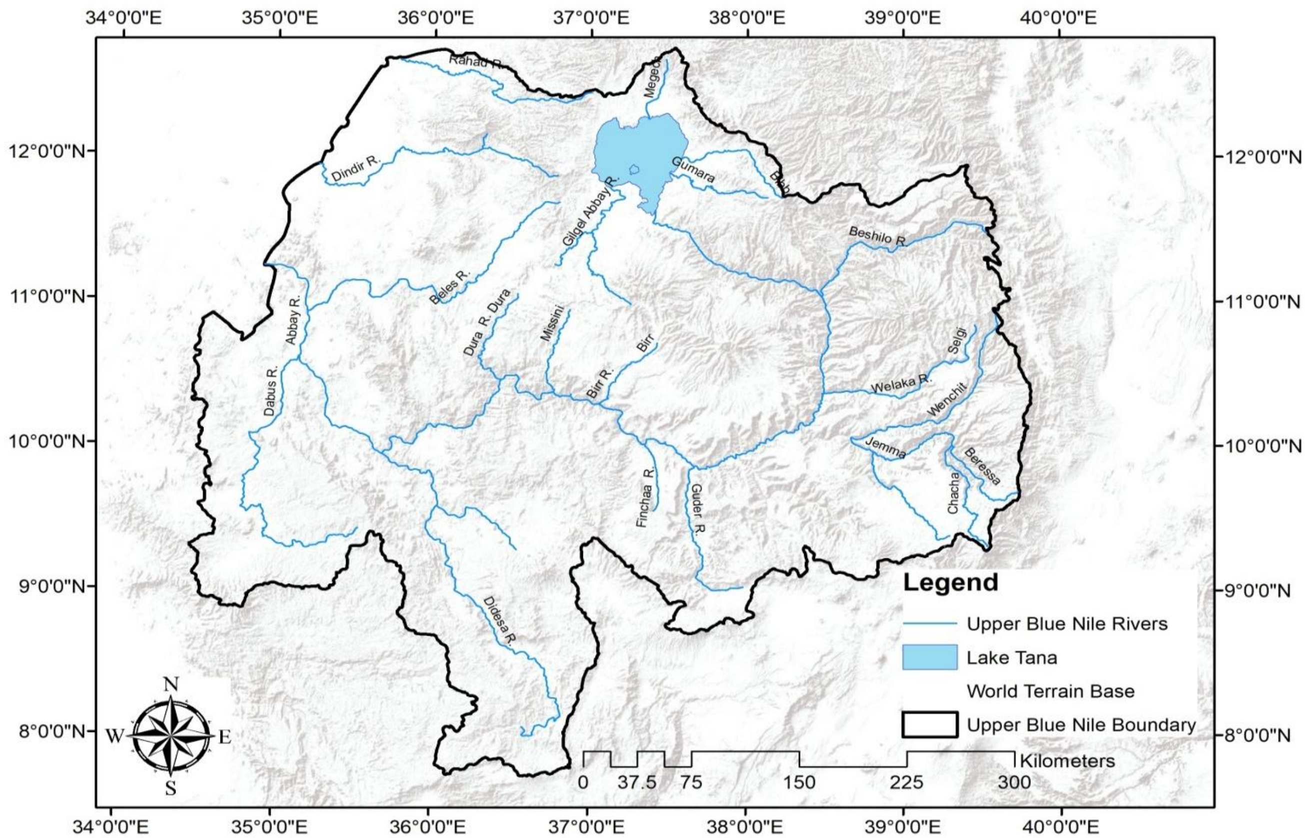

Figure 1. Blue Nile Basin

1.1.2. Climate

Within the basin, rainfall varies significantly with altitude and is to a large extent controlled by the movement of air masses associated with the Intertropical Convergence Zone (ITCZ). There is considerable inter-annual variability, annual rainfall over the basin decreases from the southwest (more than 2,000 mm) to the northeast (around 1,000 mm), with about 70% occurring between June and September (Conway, 2000). The basin June-September rainfall is positively correlated to the Southern Oscillation Index (SOI) and negatively correlated to the equatorial eastern pacific sea surface temperature (Seleshi and Zanke, 2004).

Potential evapotranspiration also varies considerably and, like rainfall, is highly correlated with altitude. Mean monthly flow also varies considerably. Typically, more than 80% of the flow occurs during the wet season (July to October) while only 4% of the flow occurs during the dry season (February to May) (Awulachew et al. 2008). The high variability in both rainfall and flow mean that water storage is a critical component of water resources development in the basin (McCartney and Girma, 2012). The Blue Nile River basin is one of the most sensitive basins to changing climate and water resources variability in the region (Kim and Kaluarachchi, 2009). In the Blue Nile River basin, El Niño years are likely to correspond to dry years and La Niña years to high rainfall and high flow years (Abtew et al. 2009). There is statistically significant correspondence between cumulative SST and annual Upper Blue Nile basin rainfall anomaly with rainfall deficit occurring during El Niño years and wet years occurring during La Niña years. Similar statistically significant correspondence is shown between the Blue Nile flow at Bahir Dar and cumulative Sea Surface Temperature (SST) (Abtew and Melesse, 2014). Seleshi and Zanke (2004) reported that June–September rainfall of the Ethiopian highlands is positively correlated to the SOI and negatively correlated to the equatorial eastern pacific SST.

1.1.3. Water Resources development

To date, Ethiopia has utilized very little of the Blue Nile water. While inaccessibility and the limited water resources infrastructures development on the river play an important role for the poor exploitation of this resource on the one hand, on the other hand locations of the major centers of population being outside of the basin paly decisive role.

Until recently only three, relatively minor, hydraulic structures have been constructed in the Ethiopian part of the catchment. The CharaChara weir and Finchaa Dam were built primarily to provide hydropower. They regulate flow from Lake Tana and the Finchaa River respectively. The combined capacity of the power stations they serve (218 MW) represented approximately 13% of the total installed generating capacity of the country in 2009 (i.e. 1618MW, of which 95% was hydropower) (EEPCo, 2010). In 2010, a new power station on the Beles River came on line, which utilizes water diverted into the Beles River from Lake Tana and has an installed capacity of 460MW. By April 2011, the total installed capacity within the country had increased to 2060 MW, of which 29% was within the Blue Nile basin.

Agriculture, which is the main occupation of the inhabitants in the basin, is primarily rain-fed with almost no irrigation. Although there is some informal small-scale irrigation, currently the only formal irrigation schemes in the Ethiopian part of the catchment are the Finchaa sugar-cane plantation (8145 ha), which utilizes water after it has passed through the Finchaa hydropower plant, and the Koga scheme (7200 ha), which uses water flowing into Lake Tana and was constructed in 2010" (McCartney and Girma, 2012).

The Ethiopian government contends that utilization of the Nile water resources both for irrigation and hydropower is essential for socio-economic development and poverty alleviation. Current planning is focused primarily on the Lake Tana and Beles River catchments, which have been identified by the government as an economic "growth corridor" (McCartney et al. 2010). However, additional projects are planned in nearly all the sub-catchments as well as along the main river. Possible irrigation projects have been investigated over a number of years (e.g. Lahmeyer Consulting Engineers 1962, USBR 1964, JICA 1977, WAPCOS 1990, BCEOM 1998) and the total potential irrigated area is estimated to be 815,581 ha, comprising 45,856 ha of small (<200 ha), 130,395 ha of medium (200–3000 ha) and 639,330 ha of large (>3000 ha) schemes. Of this, 461,000 ha are envisaged to be developed in the long-term (BCEOM 1998).The four largest schemes being considered are dams on the main stem of the Blue Nile River (i.e. Karadobi, Mendaya, Beko Abo and Border). Of these schemes, the furthest advanced was the Karadobi project, for which the pre-feasibility study was conducted in 2006 (Norconsult, 2006).

Ethiopia's morphology and physiographic setting is naturally suitable for a large amount of hydroelectric power energy generation, opportunity for electric power connectivity of the basin countries.The hydropower potential in the basin is estimated to be over 10,000 MW or 78,820 Gwh/year (Awulachew et al., 2007). There are four operational hydropower plants in the basin in the Ethiopian part; namely, Tana Beles (installed capacity of 460 MW), Tis Abay I (Installed capacity of 11.4 MW), Tis Abay II (installed capacity of 73 MW), and Fincha (installed capacity of 100 MW). More than 120 potential hydropower sites have been identified (WAPCOS 1990). Of these, 26 were investigated in detail during the preparation of the Abay River Basin Master Plan (BCEOM 1998).The 6000 MW capacity Border Dam, Renaissance Dam, is the first of this endeavor. In addition to the single-purpose hydropower schemes, it is anticipated that electricity generation will be added to several of the proposed irrigation projects where dams are being built. It is estimated that this could provide an additional 216 MW of capacity (BCEOM, 1998). Hence, the total generating capacity of all the hydropower schemes being considered in the Blue Nile may exceed 10,000 MW. Currently, it is anticipated that much of the electricity generated by these power stations will be sold to Sudan and possibly Egypt” (McCartney and Girma, 2012).Demand for fresh water supply in the entire Blue Nile River Basin is constantly increasing due to economic development and population growth. Increasing demand for food security in the future will certainly bring further pressure on the scarce water supply (Swain, Ashok, 2011).Unilateral developmental action by riparian countries is also another challenge on the management and utilization of scarce water resource in the basin.

Access to safe and adequate water supply, reliable energy source and improved food security are the bottom line for any development endeavor. These three sectors are so interlinked and complex that critical and in-depth analyses need to be done. The core of the matter is that we should avoid costly trade-offs and bad investments, protect the public from unintended side effects of uninformed decisions, use the opportunities properly, and can make the synergy of the three sectors more balanced and sustainable.

Rapidly growing populations in the UBN River basin are exceeding the existing domestic and non-domestic water supply sources in many locations throughout the region. Water sources that are found at great depths from the users perspective are becoming prohibitively expensive to develop. Water sources should also be developed so they do not exceed their regenerative capacity; otherwise a basic principle of sustainability, providing for succeeding generations, is violated.

1.1.4. Land use and environmental issues

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. It is the most degraded basin due to rapid population growth, poverty, poor watershed management, poor or absence of effective water use policy and frequent natural disasters (Melesse et al. 2011). The population pressure in the Blue Nile River part of the basin has led to serious land degradation and land conversion to agricultural areas. This has led to increased soil erosion, loss of soil fertility and reduction in dry season flows. Land degradation the upper Blue Nile takes place in the form of soil erosion, gully formation, soil fertility loss, and severe soil moisture stress, which is partly the result of loss in soil depth and organic matter (Hagos et al. 1999; Gessesse, 2014). The excessive dependence of the Ethiopian rural population on natural resources, particularly land, as a means of livelihood is an underlying cause for degradation of land and other natural resources (Bekele, 2008). Soil erosion, nutrient depletion, and deforestation are common environmental problems in the basin (Hagos et al. 1999). Over 2 million hectares of cultivated land in the highlands exhibits unsustainable soil erosion rates (Merrey and Gebreselassie, 2011). Studies at local scale identified diverse and locally specific patterns of land use change over the past decades; with the main trends being the creation of surface water bodies, deforestation, the conversion from grazing into farm land, as well as the establishment of (merely) eucalyptus plantations (Eguavoen, 2009). Although there is no a reliable basin wide systematic analysis of land use and land cover change, satellite images shows land cover changes in the upper Blue Nile River basin (Melesse et al. 2011).

1.1.5. Socio-economic condition

The population of the Ethiopian highlands had been increasing for centuries. Despite some out-migration, the result has been rising population densities, extension of cultivation into steeper lands and former forests leading to soil erosion and shortage of fuelwood, and reduction in fallow periods. Home of the second populous country of Africa, the upper Blue Nile basin is under continuous pressure to provide the water needs of the basin. The population pressure in the Blue Nile River part of the basin has led to serious land degradation and land conversion to agricultural areas.

1.1.6. Basin Development policy strategies

Transboundary water cooperation leads to the sustainable water resources development, peaceful management and efficient use of freshwater resources. However, the management of Transboundary River is complex by the fact that they cross political and administrative boundaries indiscriminately. Unilateral developmental action by riparian countries is also another challenge on the management and utilization of scarce water resource in the basin. However, multiple researches shows that collaborative works and joint development of a shared water resources can increase the sustainability of the resource, and help the needs and interests of all riparian countries involved.

One element of the national development strategy is the creation of growth corridors with a high potential to contribute to the Growth and Transformation Plan (GTP). Within the Blue Nile Basin, the Tana and Beles Growth Corridor (TBGC) has been identified as an area with a substantial potential for irrigation and hydropower development. In the upper Blue Nile sub-basins, dams are being planned or constructed. For instance in Tana sub-basin, dams are under construction or being planned on all major rivers-the Megech, Ribb, Gumara and GilgelAbay (Stein et al. 2014). The main purpose of the dams is irrigation, but most of them serve multiple purposes, including flood mitigation, water supply and the regulation of water levels for hydropower production. The Blue Nile River the natural outflow of Lake Tana, but since 2010 the Tana-Beles transfer is diverting water from Lake Tana the Beles sub-basin for hydropower production and irrigation. Lake Tana now acts as a natural reservoir for the 460-megawatt Tana Beles hydropower scheme. After passing through a cascade of turbines for electricity production, the water is planned to irrigate up to 140,000 hectares sugarcane in the upper and lower Beles sub-basin.

1.1.7. Challenges and opportunities in the basin

The hydro-politically active feature of the Nile is its water use. Perhapsit may be the only transboundary water basin where the upstream water suppliersof upper riparian countries use insignificant amount of water and the lower riparianwater recipients of the Nile use almost 100% of the total Nile flow and defend theirhydro-hegemonic rights from the grounds of historical and acquired rights. Ongoinguncooperative development in the basin will further complicate the water securityissue in the basin.

Deterioration of the ecosystems resulting in excessive erosion and soil loss upstream and flooding problems and silt accumulation in the downstream is increasing. Unilateral development and management activities causing impediment by one party or another are seen to be among the challenges in the basin.

Socioeconomic activities located in highly sensitive hydrological regimes are generally vulnerable to small changes in the climate change as witnessed from the extremely vulnerability of rain-fed agriculture in the Ethiopian highlands. Retarding runoff and enhancing infiltration capacity of the soil improve the hydrological condition for socioeconomic activity in largely vulnerable areas of rain-fed agriculture (Moges and Gebremichael, 2014).

As the water resources of the Nile decline, the demand on the other hand is continuously increasing along with per capita demand and population increase. The need for more consumptive water resources development projects by the basin countries is putting the scarce and limited resource under pressure, requiring new thinking and collaboration for efficient use and sharing of the water equitably. Lack of legal and adequate institutional arrangements to harmonize upstream-downstream water utilization interests at sub-basin or basin levels adds to the challenges.

Despite these challenges, various opportunities exist in the basin. Hydro power generation which is a non-consumptive use of water in the system is one of the major direct economic benefits that can be achieved from cooperation on the Blue Nile River basin. Growing interests for collaboration by the riparian countries can also be seen as opportunities.

2. Objectives

To acquire and document baseline database on hydrology and water use and related report in the Blue Nile upstream of GERD.

2.1. Specific objectives:

i. To acquire and document spatial and temporal rainfall in the Upper Blue Nile Basin
ii. To acquire and document stream flow of major tributaries in Upper Blue Nile
iii. To acquire and document irrigation demand of major irrigation schemes in Upper Blue Nile

3. Methodology

Observed rainfall and stream flow data from existing feasibility and design reports in the upper Blue Nile Basin were collected and screened. Spatial and temporal patterns of the collected data was developed. Irrigation water demand, irrigation scheme area, and dominant crop from their respective design and/or feasibility reports were identified.

4. Results and discussions

Both observed rainfall and streamflow data were considered on the supply side of available water in the upper Blue Nile basin.

4.1. Rainfall

Selected and screened meteorological stations and their geographical locations are indicated in Table 1. Seasonal and annual total rainfalls for 100 meteorological stations were interpolated using kriging method (see Figures 2 to 4).

Table 1: Rainfall stations used for spatial interpolation of seasonal and annual rainfall at upper Blue Nile subbasin

No.	Station Name	Latitude, N	Longitude, E	No.	Station Name	Latitude, N	Longitude, E
1	Abasina Jogir	8.54	36.10	12	Arb Gebeya	9.27	36.75
2	Abay Sheleko	10.12	38.13	13	Arjo	8.75	36.45
3	Addis Alem	9.04	39.38	14	Asosa	10.20	34.58
4	Addis Zemen	12.12	37.87	15	Aykel	12.53	37.05
5	Adet	11.27	37.47	16	Bahir Dar (Met)	11.60	37.42
6	Alem Ketema	10.03	39.03	17	Bako	9.12	37.08
7	Alibo	9.90	37.07	18	Bambesi	9.72	34.72
8	Amba Giorgis	12.77	37.60	19	Bedele	8.45	36.28
9	Amba Mariam	11.02	39.22	20	Bulen	10.68	36.10
10	Ambo	8.97	37.87	21	Chagni	10.95	36.50
11	Anger Gutin	9.57	36.57	22	Chancho	9.32	38.75

No.	Station Name	Latitude, N	Longitude, E
23	Chewhahit	12.34	37.23
24	Dabat	12.98	37.75
25	Dangela	11.25	36.83
26	Debark	13.16	37.90
27	Debre Birhan	9.63	39.58
28	Debre Elias	10.30	37.47
29	Debre Markos	10.33	37.67
30	Debre Tabor	11.88	38.03
31	Debre Work	10.73	38.13
32	Delgi	12.19	37.06
33	Dembecha	10.57	37.47
34	Dera Hamusit	11.46	37.23
35	Derba	9.43	38.63
36	Ebinat	12.13	38.05
37	Enchini	9.32	38.37
38	Enewari	9.90	39.15
39	Enfranz	12.18	37.68
40	Enjabara	10.97	36.90
41	Felege Birhan	10.75	38.07
42	Feres Bet	10.90	37.58
43	Fiche	9.80	38.70
44	Gebre Guracha	9.82	38.42
45	Gedo	9.05	37.43
46	Gida Ayana	9.87	36.93
47	Gimbi	9.02	35.78
48	Gimjabet Mariam	10.75	36.60
49	Gondar Synoptic	12.55	37.42
50	Gorgora	12.25	37.30
51	Gundil	10.86	37.10
52	Gundo Woin	10.93	38.08
53	Haro	9.90	36.45
54	Jarso	9.45	35.32
55	Jeldu	9.27	39.07
56	Jimma	7.07	36.08
57	Kachise (RS)	9.61	37.86
58	Kelala	11.18	39.52
59	Kelem Meda	10.59	39.00
60	Kessa	10.90	36.97
61	Kidamaja	11.00	36.68
62	Kora	9.07	40.32
63	Kunzila	12.17	36.17
64	Lalibela	12.03	39.02

No.	Station Name	Latitude, N	Longitude, E
65	Lay Birr	10.59	37.17
66	Limu Genet	8.07	36.95
67	Maksegnit	12.37	37.55
68	Mehal Meda	10.23	39.68
69	Mekane Selam	10.74	38.76
70	Mendi	9.78	35.10
71	Menge	10.33	34.73
72	Merawi	11.42	37.15
73	Mertule Mariam	10.88	38.27
74	Meshenti	11.47	37.29
75	Metema	12.97	36.02
76	Molale	10.07	39.39
77	Mota	11.08	37.87
78	Muke Turi	9.55	38.87
79	Nefas Mewucha	11.73	36.45
80	Nejo	9.50	35.45
81	Nekemte	9.08	36.50
82	Pawe	11.31	36.41
83	Sekela	10.99	37.21
84	Shahura	11.93	36.87
85	Shambu	9.57	37.12
86	Shandi	10.64	36.95
87	Sheno	9.33	39.30
88	Sholla Gebeya	9.05	38.77
89	Sirinka	11.55	39.62
90	Teji	8.83	38.37
91	Tilili	10.85	37.05
92	Tis Abay	11.50	37.58
93	Wanzaye	11.78	37.68
95	Wereta	11.92	37.68
96	Wetet Abay	11.37	37.03
97	Yechereka	10.60	37.42
98	Yejube	10.15	37.75
99	Yetmen	10.33	38.13
100	Yifag	12.07	37.72
101	Zege	11.68	37.32

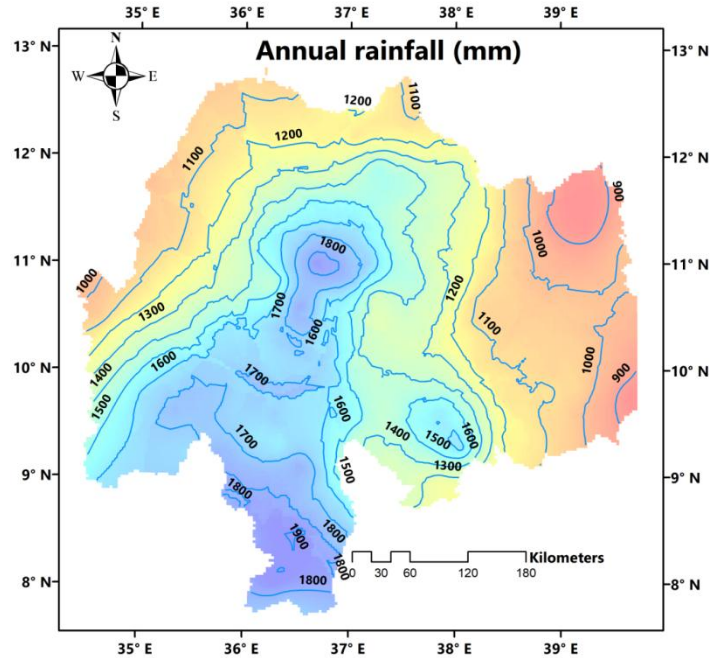

Figure 2: Spatial distribution of annual total rainfall at upper Blue Nile Basin

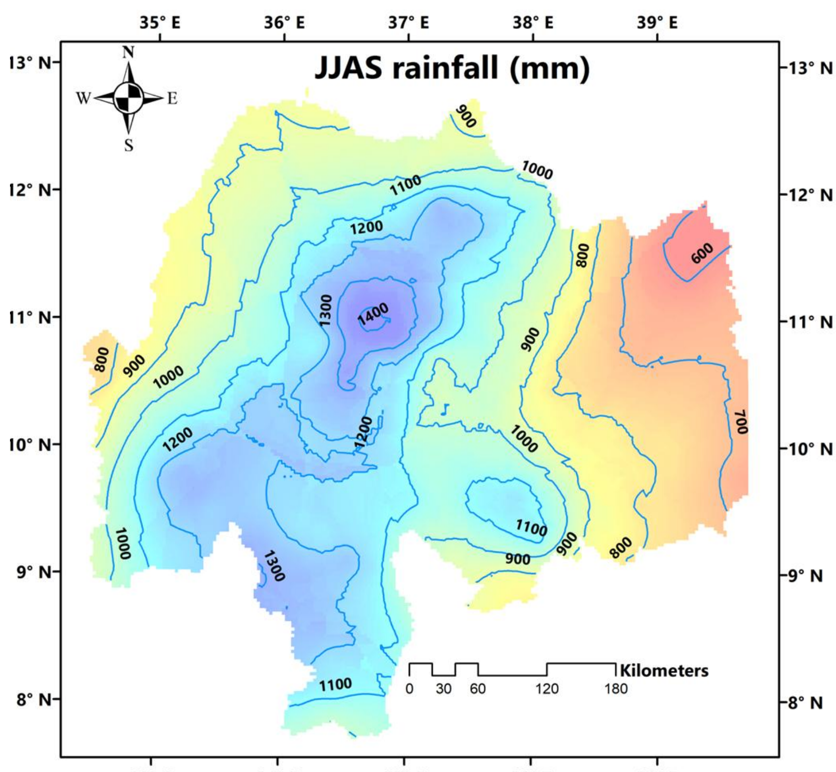

Figure 3. Spatial distribution of main rainy season (JJAS) total rainfall at upper Blue Nile Basin

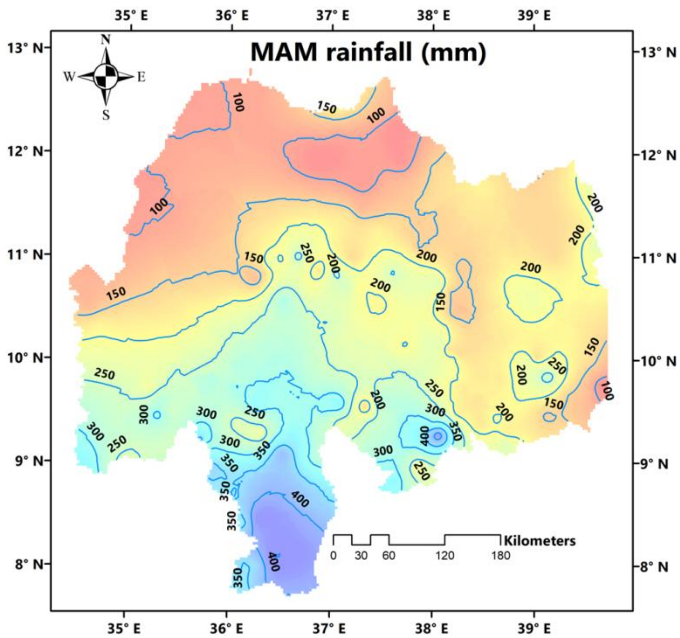

Figure 4. Spatial distribution of small rainy season (MAM) total rainfall at upper Blue Nile Basin

4.2. Streamflow

Long-term average monthly streamflow data were acquired at different gauging stations (Figure 5).

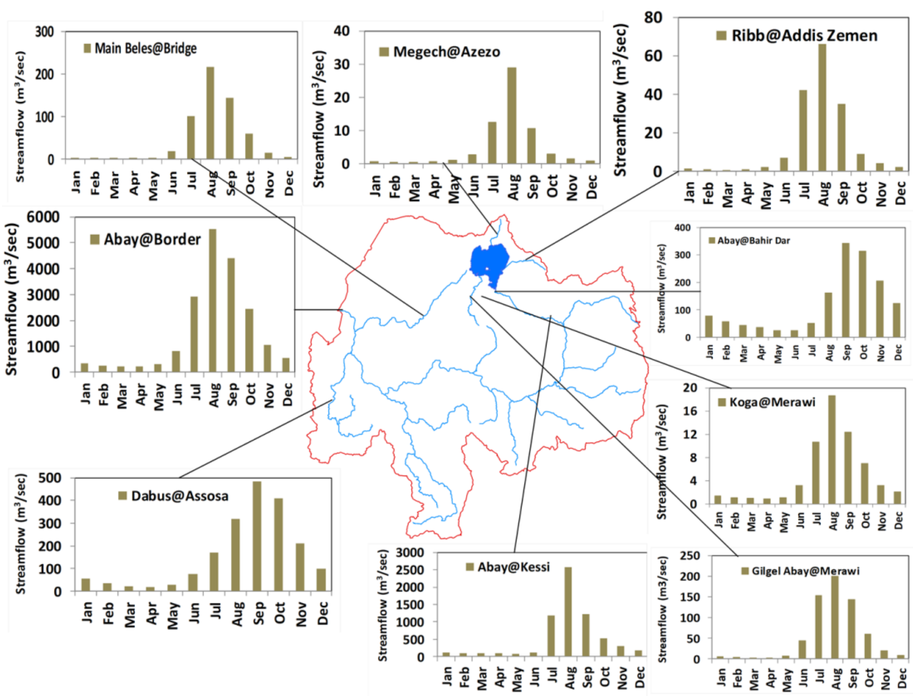

Figure 5. Streamflow at different gauging stations

4.3.Irrigation water demand

Irrigation water is the only water use considered on the demand side. Existing and ongoing irrigation schemes, their areal extent and dominant crop are indicated in Table 2. Monthly irrigation water demands at different irrigation scheme are indicated in Figures 5 and 6.

Irrigation scheme	Water demand (MCM)	Irrigation area (ha)	Dominant crops
Rib Irrigation	197.6	19900	Pulses
Megech Irrigation	56.57	31800	Pulses
Gummera Irrigation	77.24	13980	Pulses
Koga Irrigation	97.76	7004	Pulses
Jemma Irrigation	89.08	7800	Pulses
Gilgel Abay Irrigation	174.14	12850	Pulses
Lake Tana Pumping	58.15	6720	Pulses
Upper Beles	529.44	53700	Sugarcane
Upper Dinder	98.11	10000	Sugarcane
Lower Beles	851.18	85000	Cotton/Sugarcane
Upper Dabus	69.41	9661	Cotton/Sugarcane
Arjo-Dedessa Irrigation	169.63	13665	Sugarcane
Nekemte Irrigation	71.47	11220	Sugarcane
Anger Irrigation	92.05	14450	Sugarcane
Neshe Irrigation	54.37	27217	Sugarcane
Fincha Multi-purpose	183.94		
Lower Guder	27.31	4100	Pulses
Upper Guder	33.45	4896	Pulses
Didessa	769.4	54058	Sugarcane

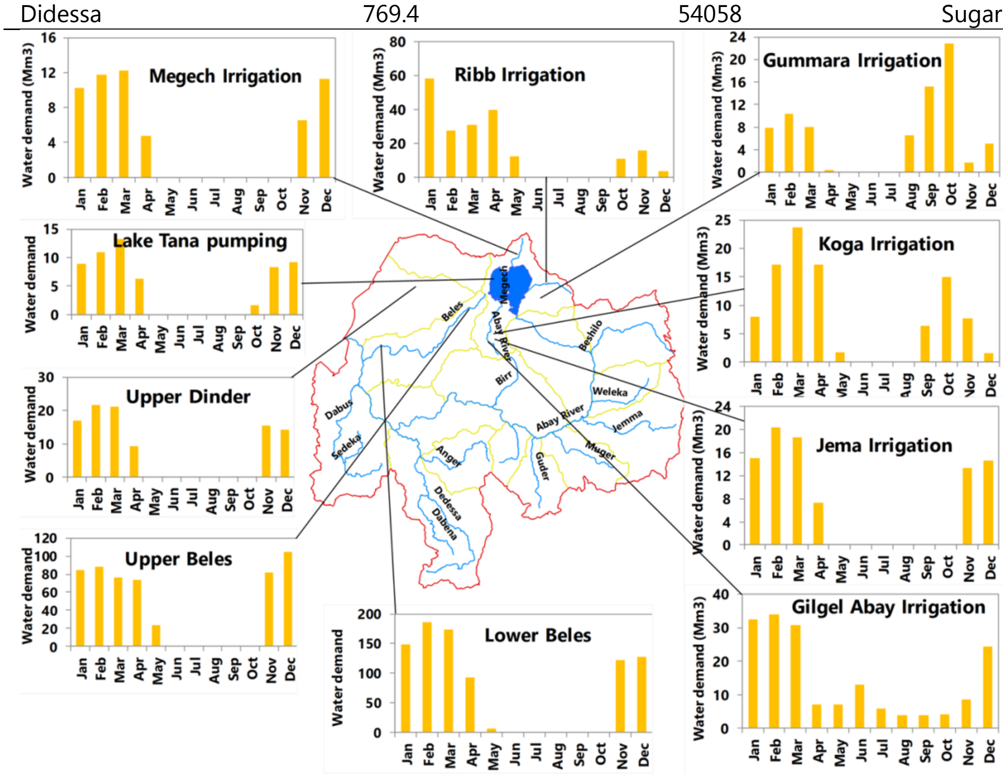

Figure 6. Monthly Irrigation water demand (MCM)

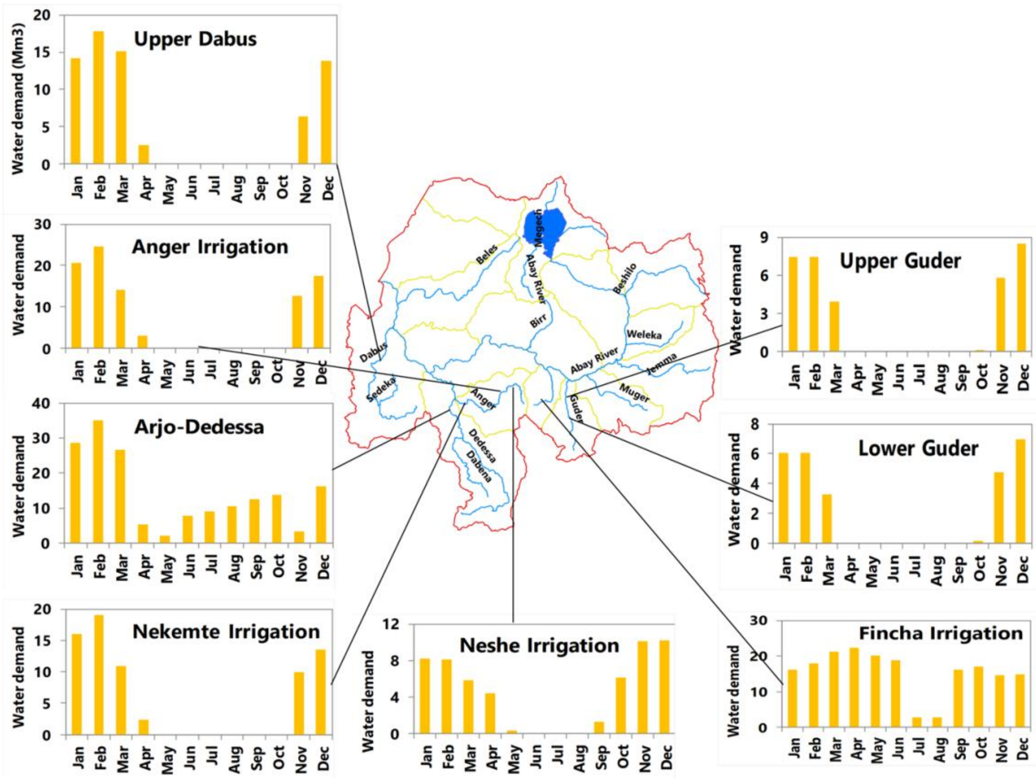

Figure 7: Monthly Irrigation water demand (MCM)

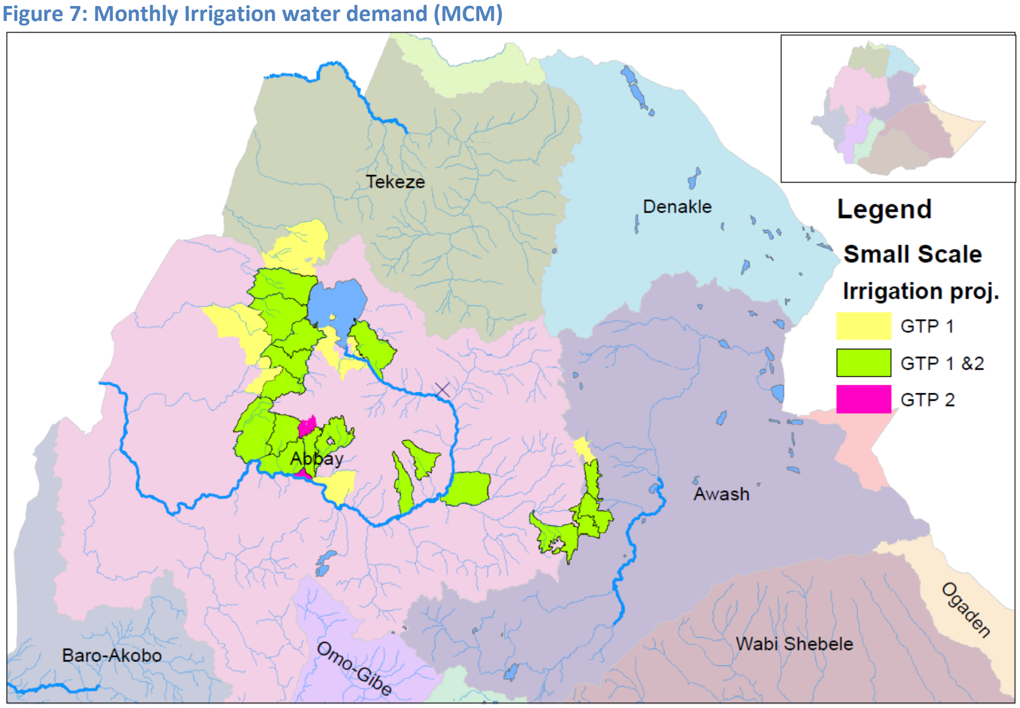

Figure 8. Small Scale Irrigation Projects Distribution (GTP 1 and 2)

5. Conclusions

Spatial and temporal rainfall data are collected for annual, seasonal and monthly scales though the distribution of rainfall stations is less for downstream region of the upper Blue Nile Basin. Streamflow data are also documented for annual, seasonal and monthly scales. Only irrigation water demand for different irrigation schemes are considered as water use in the upper Blue Nile basin. Domestic and industrial water demands are not considered due to insufficient data.

Ministry of water Irrigation and Electric city developed a basin information system for surface water and groundwater availability, use and quality for two sub-basins through Abay Basin Authority https://www.cuahsi.org/data-models/for-developers/. However, availability – Access and sharing hydro-meteorological data is limited due to data restriction policy from relevant ministries and agencies.

6. References

Abtew and Melessa, 2014.WossenuAbtew and Assefa M. Melesse, 2014.Climate Teleconnections and Water Management. In A. M. Melesse et al. (eds.), Nile River Basin, Ecohydrological Challenges, Climate Change and Hydro politics. Switzerland: Springer International Publishing. DOI 10.1007/978-3-319-02720-3_2,7.

Abtew and Melesse, 2014.WossenuAbtew and Assefa M. Melesse, 2014.The Nile River Basin. In A. M. Melesse et al. (eds.), Nile River Basin, Ecohydrological Challenges, Climate Change and Hydro politics. Switzerland: Springer International Publishing. DOI 10.1007/978-3-319-02720-3_2,7.

Abtew W, Melesse A, Desallegne T (2009) Spatial, inter and intra-annual variability of the upper Blue Nile basin rainfall. Hydrol Process 23:3075–3082

Assefa M. Melesse, Seleshi Bekele, and P. McCornick, 2011. Introduction: Hydrology of the Niles in the Face of Climate and Land-Use Dynamics. In Assefa M. Melesse. Nile River Basin: Hydrology, Climate and Water Use.

Available from: http://www.eepco.gov.et

Awulachew SB, McCartney M, Steenhuis TS, Ahmed AA (2008) A review of hydrology, sediment and water resource use in the Blue Nile Basin.Working Paper 131, IWMI.

BCEOM, 1998.Abbay river basin integrated development master plan, section II, volume V: Water resources development. Part 1: Irrigation and drainage. Addis Ababa, Ethiopia: Ministry of Water Resources.

Bekele M, 2008. Ethiopia's environmental policies, strategies and program. pp 337–370

Conway D, 2000.The climate hydrology of the upper Blue Nile River.Geogra J 166(1):49–62

EEPCo, 2010. Total power production from water [online]. Ethiopian Electric Power Corporation.

Fenta AA, Rientjes T, Haile AT, Reggiani P, 2014. Satellite Rainfall Products and Their Reliability in the Blue Nile Basin. In Melesse et al. (eds.), Nile River Basin, DOI 10.1007/978-3-319-02720-3_4, Gizaw Desta Gessesse, 2014. Assessment of Soil Erosion in the Blue Nile Basin. In A. M. Melesse et al. (eds.), Nile River Basin, Ecohydrological Challenges, Climate Change and Hydro politics. Switzerland: Springer International Publishing. DOI 10.1007/978-3-319-02720-3_2,7.

Hagos F, Pender J, Gebreselassie N (1999) Land degradation and strategies for sustainable land management in the Ethiopian highlands: Tigray region. Socio-economic and Policy Research Working Paper, 25, International Livestock Research Institute, Nairobi, Kenya

IritEguavoen, 2009. The Acquisition of Water Storage Facilities in the Abay River Basin, Ethiopia.ZEF Working paper series 38.

JICA, 1977.Feasibility report on power development at Lake Tana Region. Tokyo: Japan International Cooperation Agency.

Kim U, Kaluarachchi JJ (2009) Climate change impacts on water resources in the Upper Blue Nile River Basin. J Am Water ResourAsso (JAWRA) 45(6):1361–1378. doi:101111 j17521688200900369x.

Lahmeyer Consulting Engineers, 1962.GilgelAbay scheme. Addis Ababa:Ministry of PublicWorks, Imperial Ethiopian Government.

Maurice, s., & L. Alan, W. (2002). Regional Cooperation, and tthe Role Of International Organizations and Regional Integration. World Bank Policy Research Working Paper 2872 .

McCartney and Girma, 2012. Matthew P. McCartney & Michael Menker Girma (2012): Evaluating the downstream implications of planned water resource development in the Ethiopian portion of the Blue Nile River, Water International, 37:4, 362-379. http://dx.doi.org/10.1080/02508060.2012.706384

McCartney et al. 2010 McCartney, M.P., et al., 2010.Evaluation of current and future water resources development in the Lake Tana Basin, Ethiopia. IWMI Research Report 134. Colombo, Sri Lanka: International Water Management Institute.

Merrey and Gebreselassie, 2011. Promoting improved rainwater and land management in the Blue Nile (Abay) basin of Ethiopia Nile Basin Development Challenge Technical Report 1. Douglas J. Merrey and TadeleGebreselassie, 2011.

Michago, W. S. (2015). Dividends of Cooperation: The Case of Nile River.

Moges and Gebremichael, 2014.Semu A. Moges and MekonnenGebremichael, 2014.Climate Change Impacts and Development-Based Adaptation Pathway to the Nile River Basin. In A. M. Melesse et al. (eds.), Nile River Basin, Ecohydrological Challenges, Climate Change and Hydro politics. Switzerland: Springer International Publishing. DOI 10.1007/978-3-319-02720-3_2,7.

MoWR.(2002). Water Sector Development Program 2002-20016, Irrigation Development Program, Main Report. Addis Ababa, Ethiopia: Minister of Water Resource (MoWR).

Nigussie et al. 2014.TewodrosAssefaNigussie, Abebe Fanta, Assefa M. Melesse and ShoebQuraishi, 2014. Modeling Rainfall ErosivityFrom Daily Rainfall Events, Upper Blue Nile Basin, Ethiopia. In A. M. Melesse et al. (eds.), Nile River Basin, Ecohydrological Challenges, Climate Change and Hydro politics. Switzerland: Springer International Publishing. DOI 10.1007/978-3-319-02720-3_2,7.

Norconsult, 2006.Karadobi multipurpose project, pre-feasibility study. Report to the Ministry of Water Resources, The Federal Republic of Ethiopia. Addis Ababa, Ethiopia

Peggy AJ, Curtis D (1994) Water balance of Blue Nile basin in Ethiopia. Journal of Irrigation and Drainage Engineering 120(3):573–590

Rawia, T. (2016). The Grand Ethiopian Renaissance Dam: a benefit sharing project in the Eastern Nile? Water International, 41:4, 574-592, .

Seleshi Y, Zanke U (2004) Recent changes in rainfall and rainy days in Ethiopia. Int J Climatol 24:973–983

Stein et al. 2014. Stein C, Barron J, Nigussie L, Gedif B, Amsalu T, Langan S. 2014. Advancing the water-energy-food nexus: social networks and institutional interplay in the Blue Nile. Colombo Sir Lanka: International Water Management Institute (IWMI). CGIAR Research Program on Water, Land and Ecosystems (WLE), 24p.(WLE Research for Development (R4D) Learning Series 2). doi:10.5337/2014.223

Swain, Ashok. (2011). Challanges for water sharing in the Nile basin: changing geo-Politicsand Changing climate. Hydrological Sciences journal , 4, 687-702.

USBR, 1964.Land and water resources of the Blue Nile basin, Ethiopia.Main report. Washington, DC: United States Bureau of Reclamation.

WAPCOS, 1990.Preliminary water resources development master plan for Ethiopia.Final report.Prepared for EVDSA. Addis Ababa.