



NILE-SEC
NILE BASIN INITIATIVE
INITIATIVE DU BASSIN DU NIL

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Current and projected demand and water use in the Nile Basin: Phase 1 synthesis report

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Executive Summary.....	iii
1. Introduction	5
1.1 Overview	5
1.2 Background	6
2. Baseline Water Availability	8
2.1 The Nile Basin baseline model	8
2.2 Basin yield	9
2.3 Spatial and temporal variability of yield	10
3. Current water demand for major uses	17
3.1 Existing hydraulic infrastructure in the Nile Basin	17
3.2 Estimated current water demand and use	18
4. The Nile Basin water balance.....	21
5. Preliminary results of demand projections.....	21
5.1 Growth in water resources infrastructure	21
5.2 Preliminary scenarios for future water demands estimation.....	24
5.3 Projection of water demand and potential shortfalls under historical climate	25
6. Preliminary identification of measures for addressing potential future water shortfalls.....	28
7. Conclusions and Way forward	29

Executive Summary

Sustainable river basin management requires balancing water demands with available water supply across water use sectors in all countries that share a river basin. In its 23rd meeting in June 2015, the Nile Council of Ministers (Nile-COM¹) gave the directive to the NBI Secretariat to carry out assessment of current and projected future water demands and availability in the Nile Basin. The Nile-Sec completed the first phase of its assessment of water supply and demand and hereby presents the results.

Basin water availability: The average annual flow of the Nile at the entrance to the High Aswan Dam (HAD) is estimated at 73 BCM. Under naturalized conditions of no man-made abstraction, the annual yield of the basin would be approximately 94 BCM. The balance 21 BCM comprises of abstractions upstream of the HAD, which is close to 16 BCM per year and net evaporation from man-made reservoirs (without including the HAD), which is approximately 5 BCM per year on the average. The average annual evaporation from the HAD is approximately 13 BCM. Together with the evaporation from the HAD, the total average annual evaporation loss from all dams is 18 BCM.

Water demand: Approximately 5.4 million hectares of land was under irrigation as of 2014. Most irrigation schemes in Egypt grow more than one crop per year, i.e. they have a cropping intensity greater than 1. As a result, the actual cultivated area is close to 6.5 million hectares. The total irrigation water demand stands at 83.2 BCM per year. This demand is met from the Nile with some supplement from groundwater and recycled drainage water in Egypt. Overall, the deficits in meeting the total irrigation demand is negligible (approximately 1.4 percent of the demand not met). The total supplement from groundwater and recycled drainage water is estimated to be approximately 10 percent of the aggregate demand. The net municipal and industrial water demand including the demands in Egypt is approximately 2.5 BCM. Due to lack of data water demands for livestock, rural water supply and mining have not been estimated.

Hydropower generation: The total installed capacity of hydropower plants in the basin is 5,600 MW from which approximately 25,525 GWH energy is generated annually.

Projected growth in water demand: Based on national plans, total increase of irrigation areas is estimated to be 3.7 million hectares by 2050. Thus, by 2050, approximately 8.7 million hectares of land is projected to be under irrigation. A number of new storage dams are planned that will raise the total storage capacity basin-wide by approximately 200 BCM. New hydropower plant are planned that will have a total installed capacity of 21000 MW. The total projected irrigation water demand is approximately 160 percent of current demand. If irrigation remains dependent on surface water and current irrigation efficiencies remain the same, which for many schemes are low, the basin is likely to face a water shortfall of approximately 40 – 45 BCM per year. This shortfall is expected to happen gradually over the coming 3 to 4 decades and, hence, measures are need for addressing the shortages before they become critical.

Strategies for addressing growing water shortage: A number of strategies have been identified as part of the strategic analysis. These strategies cover measures for enhancing water supply, such as increasing basin water yield, and increasing groundwater use; demand side management measures, such as improving water use efficiencies, such as limiting growing water intensive crops areas with high evaporation; and basin system management measures that focus on optimization of reservoir option to reduce losses.

¹ The Nile Basin Initiative is a partnership of the 10 Nile riparian states: Burundi, DR Congo, Egypt, Ethiopia, Kenya, Rwanda, South Sudan, Sudan, Tanzania and Uganda. Eritrea participates as observer. The Nile-COM is the highest decision making body of NBI.

Subsequent phases of the strategic analysis will deal with quantification of the contribution of the options in addressing the water shortfalls.

1. Introduction

1.1 Overview

This document presents the results of the strategic water resources analysis carried out by the Nile-Sec under its water resources management program. The strategic water resources analysis is the first step taken by Nile-Sec towards addressing water resources issues raised by members of the Nile-TAC in the consultative meeting carried out in March 2013 and implementation of the directive of the Nile Council of Ministers (Nile-COM) for projection of water supply and demand in the Nile Basin (*Nile-COM Min 6.2.6, 5 June 2015, Dodoma, Tanzania*). The analysis has been carried out in close collaboration with a National Experts Group (NEG) comprising one Nile-TAC member and two experts from each NBI member

Note on process of the strategic analysis

The strategic analysis was conducted through the participation of the NBI member states. Due to its freezing of participation in NBI activities, Egypt, though invited to take part in the analysis, didn't participate. All other NBI member states participated in the entire process by providing data, reviewing results and taking part in the consultation workshops.

The strategic analysis is aimed at assessing water demands and water availability to support inter-riparian dialogue for sustainable development and management of the Nile Basin water resources. In this regard, the participating member states decided that the analysis should cover the entire Nile Basin. Without considering the entire Nile Basin, it wouldn't be possible to identify the challenges the Nile Basin countries would be facing in meeting the growing water demands that should also take into account the water scarce downstream countries. All data and results of the analysis have been reviewed and vetted by NBI member states (except Egypt).

No data has been provided from Egypt for the analysis. All data used for the analysis for the part of the Nile Basin in Egypt was taken from project studies carried out by ENTRO when Egypt was still participating in NBI activities and from global data sources, such as the FAO Aquastat.

state.

The document presents a synthesis of basin yield, current and projected future water demand and estimated water use under historical climate. The basin yield, current water demand and use constitute the baseline condition in the Basin.

Baseline basin yield is estimated based on the model estimated flow for the period 1950 – 2014 using historical climate data. Basin yield estimates are provided for major sub-basins and selected catchments within these sub-basins. They are provided as average annual river flows with monthly statistics provided for selected sub-basins.

The baseline water demands are computed based on characteristics of the water use systems (water infrastructure for irrigation, hydropower and urban water supply) existing in the Nile Basin as of 2014. As water demands vary from year to year in response to growing demands and variation in climate (especially for irrigation water demands), the baseline water demand provided are average values for a the period 1955 – 2014.

Detailed documentation of methodology and approach, data, models used, and analysis results are to be found in four technical notes listed below:

1. Technical Note I: Baseline Hydrologic Modeling Results
2. Technical Note II: Baseline on hydraulic infrastructure in the Nile Basin
3. Technical Note III: Current water supply, demand and estimated water use
4. Technical Note IV: Preliminary scenarios of future water supply and demand in the Nile Basin

The results presented herein and in the Technical Notes are based on analysis of data provided by NBI member states and modeling using Nile Basin DSS.

Recommendations on options for addressing the growing water demands in the Nile Basin in a sustainable manner are given at the end of this document. These recommendations were drawn by the National Experts Group in its second meeting 27 – 28 April 2015 in Addis Ababa and further elaborated by the Nile-Sec. They form the basis for subsequent phases of the strategic analysis.

1.2 Background

The Nile Basin, with an area of over 3.2 million square kilometers, is source of livelihoods to over 250 million people residing within the basin boundary. The basin area stretches over 11 countries and, thus, making the Nile one of the most shared river basins in the world; it is one of the world's five rivers that are shared by 9 to 11 countries. The Nile Basin, compared to other large river basins, has relatively low runoff coefficient. Moreover, in the Nile Basin, most of the runoff (hence river flow) is generated from less than a third of the basin area, which is prone to seasonal and, at times, strong inter-annual variability.

Most of the 11 riparian countries of the basin are grappling with the task of meeting their population's basic needs. Based on data from FAO (world hunger statistics)², a substantial proportion of the population in five Nile riparian states is undernourished. Access to electricity is very low in all countries except Egypt. Access to clean drinking water has improved as a result of the efforts to meet the Millennium Development Goals (MDGs) (UNECA 2015, UN 2015) but many countries still need to catch up with others in ensuring full coverage in terms of access to drinking water and proper sanitation. The challenge is compounded by the rapid rise of the population of the basin countries; over the period 1960 to 2010, the population of the basin countries grew fourfold thereby resulting in declining per capita water availability.

² <http://www.fao.org/hunger/en/> (accessed on 11 June 2016); no data for Burundi, South Sudan and Sudan

The arid/semi-desert downstream parts of the basin have large irrigation schemes that fully rely on the Nile river flow while the upstream parts still rely on traditional, subsistence level rain-fed agriculture. Population increase and economic growth in the basin countries necessitates expansion of food and energy production systems, largely in upstream countries. The Nile Basin, particularly the upstream parts, is endowed with substantial yet untapped water resources potential. This potential can be developed to address the hugely unmet water, food and energy demands of the population of the countries and their growing economies. In this regard, more and larger scale development of irrigated agriculture, construction of storage dams for water supply, and construction hydropower plants is expected in the basin.

The Nile is a transboundary river and, therefore, its sustainable development and management requires balancing demands and water availability across the basin in all riparian countries. This requires understanding the current levels of water availability and variability; estimation of water demands and actual water uses; projections of water demands and water availability; quantifying any potential imbalances between current and future water demands and supply and working out strategies for addressing the imbalances. Without a basin-wide water supply and demand analysis, there is a risk the Nile Basin countries could possibly run into conflicts as more and more uncoordinated water resources developments can lead to water shortages somewhere in the basin. The potential risk in not meeting all water demands in the basin through ‘business as usual’ un-coordinated water resources development has been felt by NBI member states as demonstrated by the Nile-COM’s directive to the Nile-SEC to carry out water demand and supply projections for the Nile Basin. The issue of potential imbalances between water supply and demands was also identified by Nile-TAC as one of strategic water resources issues that need to be explored and addressed through NBI’s analytic work – many of which focus on the challenge of meeting the growing water demands in the basin.

In response to the felt needs and instructions from the Nile-COM, the Nile-SEC has carried out the first stage of its analysis in the period July 2015 – June 2016. The analysis focused on the following three themes:

- Estimation of baseline water supply, demands and water uses based on ground observation and model-based analysis
- Projection of future water demand based on national plans
- Compilation of preliminary list of strategies/options for addressing anticipated imbalances between water supply and demand

The analysis has been carried out in close collaboration with a National Experts Group (NEG) drawn from NBI member countries. The NEG is composed of one Nile-TAC member and two experts from each country. Names of NEG members are given in Annex 1. Most data obtained from NBI member states comprise river flow time series, data on irrigation areas (size, main crops, sources of water), characteristics of dams and hydropower plants and water demands for Municipal and Industrial use. Irrigation water abstraction data has been obtained from Burundi and Sudan and this has been used for calibrating the model. In addition, actual energy generation from hydropower plants in Ethiopia and

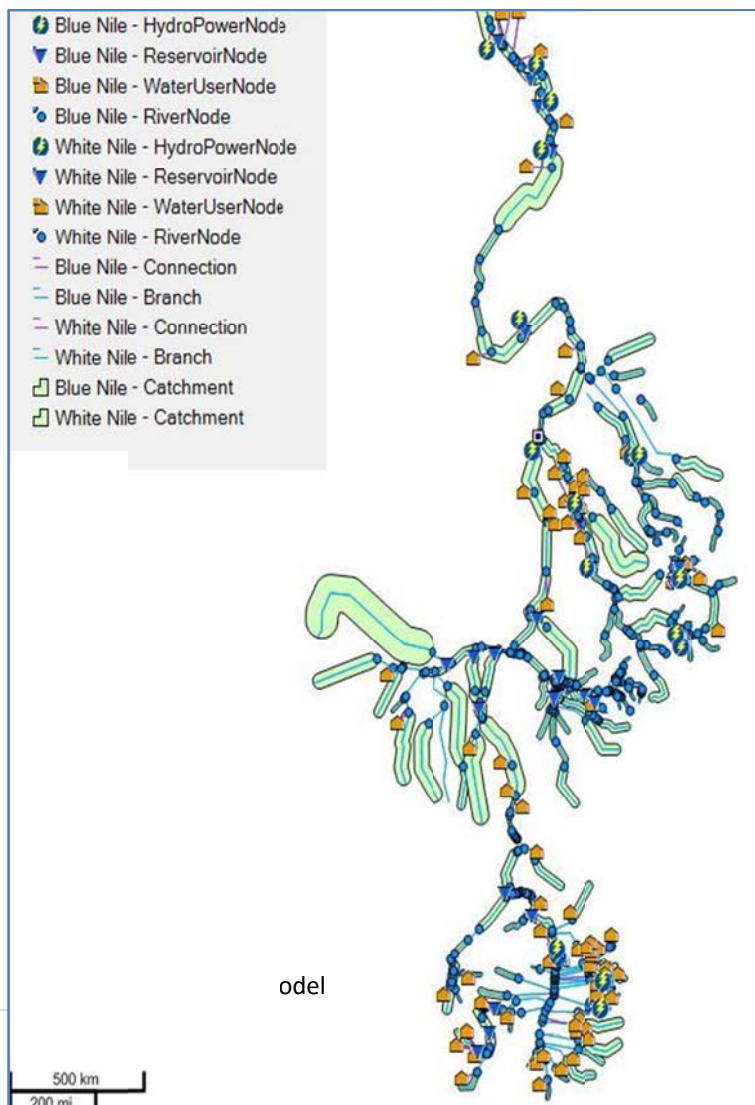
Sudan have been obtained, which was also sued to calibrate the model with respect to water release for power generation and reservoir levels.

Egypt did not participate in the analysis and no data has been supplied by Egypt. Therefore, the study has made use of data from previous work by the Eastern Nile Technical Regional Office (ENTRO). Data from the Eastern Nile Irrigation and Drainage study and the Eastern Nile Power Trade Program study carried out by ENTRO have been used. These two studies were conducted by ENTRO with the participation of Egypt. Further, literature available in the public domain have been reviewed to supplement data that were not available in the two studies. The data and analysis results have been reviewed and found acceptable by other participating NBI member states but this was not the case for data and analysis results for part of the Nile in Egypt.

2. Baseline Water Availability

2.1 The Nile Basin baseline model

The strategic analysis has been conducted using the Nile Basin Decision Support System (NB DSS) with data obtained from Nile Basin Initiative member states. A model of the Nile has been built in the DSS



representing the baseline (as of 2014) conditions with respect to hydraulic infrastructure, water demands and their characteristics. Further scenarios were built in the DSS that integrate water resources development projects, climate change and scenarios of irrigation efficiency improvements. A schematic of the baseline model in the DSS is shown in Figure 1. Further details on the model is provided in Technical Note I.

2.2 Basin yield

In any river basin planning and management exercise, one of the key questions to be answered is the question of how much water is available in the river basin. Often, river flow under natural conditions, i.e. without human interventions in the river basin which alter the quantity and temporal distribution of the flow, is needed in planning exercises. Estimation of naturalized flows (or flow under natural conditions) in a river basin with appreciable changes due to man-made structures for storage, abstraction and diversion is challenging due to lack of accurate data on, for instance, water abstractions and reservoir releases. In order to make such estimations, one needs a time series of actual abstractions of water from the river system at the various locations in the river network, data on how dams/reservoirs are actually operated (not just the planned operation rules) and their release time series and other actual water use data. When such data are available, one estimates flow in natural conditions by reconstructing the river flow sequence by eliminating the effects of abstractions, storages in dams, diversions and other human induced changes based on the observed data on these changes. In many river basins, finding such water use related data is very difficult if not impossible.

Box 1: Basin water supply - key messages

- *At current levels of water use, the average annual flow of Main Nile measured at entrance to the High Awan Dam (HAD) for the period 1955 – 2014 is approximately 72.7 BCM.*
- *If all water abstractions and evaporation from man-made reservoirs are neglected, the estimated naturalized yield of the Nile for the period 1955 – 2014 is approximately 94 BCM when the river enters Egypt*
- *The Blue Nile river system supplies approximately 60 percent of the flow at Dongola under naturalized condition*
- *Annual flow of the Blue Nile in the last 2 decades shows a rising pattern with more number of years showing flow that is above long term average. This is common to major rivers originating in the Eastern Nile highlands.*
- *Due to inadequate monitoring infrastructure, the hydrology of the Bahr el Jebel and Bahr el Gazal basins remain the least understood.*
- *Rivers originating in Ethiopian highlands show strong seasonality. For the Blue Nile river, approximately 82 percent of the average annual flow occurs in just four months (July – October)*

In the case of the Nile, major share of hydraulic infrastructures and flow alterations occur in Sudan and Egypt. In the Ethiopian highlands and in the White Nile system upstream of Malakal town in South Sudan, to date, the total aggregate water abstraction is relatively very low. In this study, estimation of available water in the Nile at various locations was made using a calibrated rainfall-runoff and river system model of the Nile. Estimates of river flow are compared with observed flows where available. The basin yield under current condition in the Nile Basin is described used model generated river flows at a number of locations in the basin. No assessment of groundwater resources has been made in this study due to lack of data.

The yields of all sub-basins of the Nile have been at the locations of White Nile near Malakal town, Blue Nile at Khartoum station, and Atbara river system at the confluence with the Main Nile.

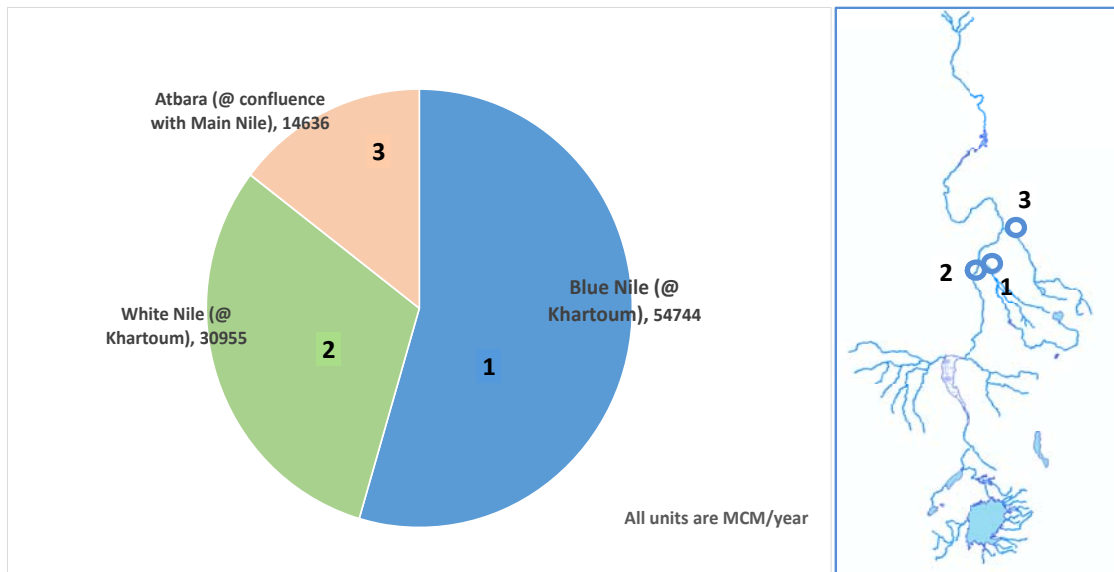


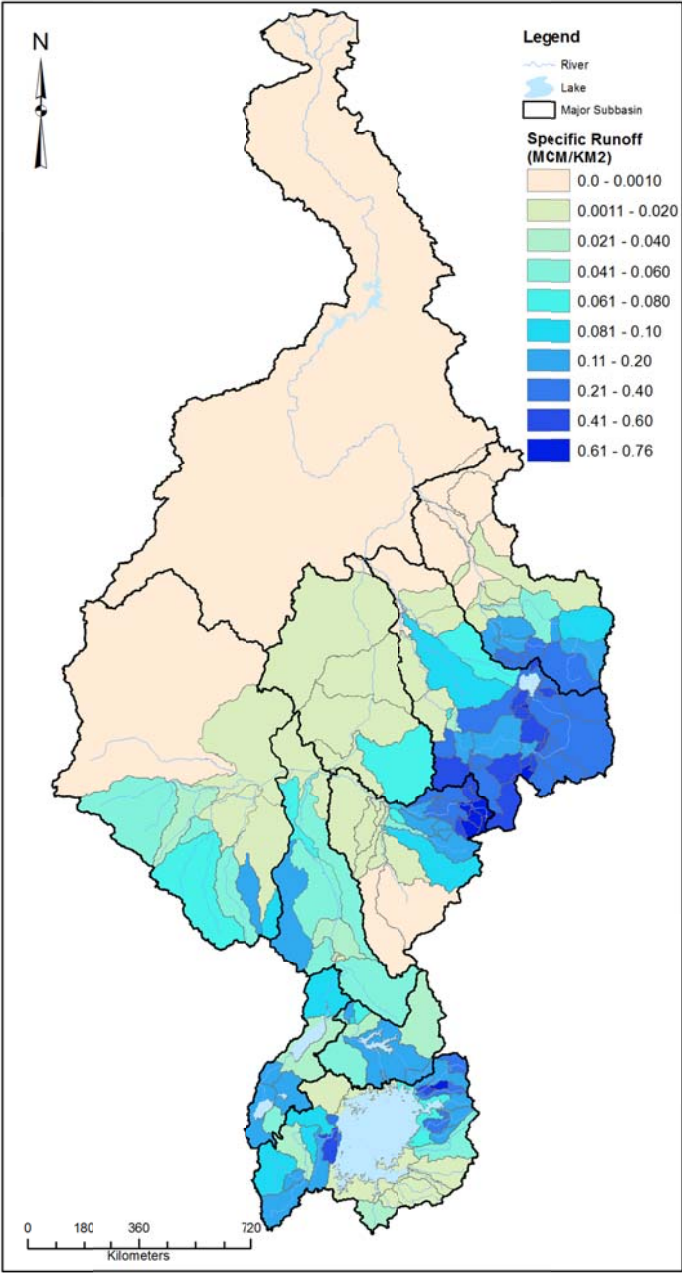
Figure 2: Estimated average naturalized annual yield of main sub-basins (1955 – 2014)

The naturalized yield of the Nile Basin has been estimated using the model by setting all man-made abstractions and evaporation from man-made reservoirs to zero. Data on estimated channel losses, such as due to evaporation and deep percolation from floodplains and net groundwater recharge from the river system have been obtained from Sudan³. Accordingly, the total estimated average annual flow at entrance to the HAD under natural condition is estimated at 94.7 BCM for the period 1955 – 2014. This estimate of naturalized flow need to be understood as approximate. Under natural condition, the actual channel losses could be higher. This is because inundation of floodplains, which is a key factor for channel losses, is a function of river stage. Under natural conditions, due to higher river stage, relatively more frequent and spatially large inundations are expected to occur resulting in proportionately higher channel losses.

2.3 Spatial and temporal variability of yield

³ Data on approximate channel losses in Sudan obtained from Ministry of Water Resources and Electricity – Sudan; no data available on possible transmission losses

The **spatial variability** of yield has been presented in the form of a map of specific runoff⁴ at catchment level, Figure 2. The values of the estimated water balance components for the sub-basin of the Nile are



shown in Table 2.

Figure 2: Specific runoff distribution

⁴ The average specific runoff is defined as the runoff generated per square meter of area per year

Table 2:

ID	Catchment	Inflow	Precip	Actual ET - Catch	Runoff	Lakes (P - E)	Dam (P - E)	Withdrawal	Channel Losses	Outflow
1	Lake Victoria basin (up to Jinja)	0	222815.31	202591.80	20818.74	12702.23	0.00	569.55	0.00	32339.40
1	Victoria Nile	32339	98443.55	92449.65	5919.09	0.00	0.00	242.04	0.00	37222.23
1	Albert Nile	37222	78303.86	72127.39	6117.64	-2115.99	0.00	16.72	0.00	41204.10
1	Bahr el Gazal at outflow to the bahr el jebel	0	460047.90	449981.72	10261.69	-9549.95	0.00	3.16	0.00	819.40
1	Bahr el Jebel (including the Sudd)	42024	179455.85	168845.08	10355.96	-3130.72	0.00	4.44	3238.31	18129.78
2	Sobat up to its confluence to white Nile	0	221517.06	194400.84	20562.12	-4610.94	-1.60	108.28	0.00	15804.93
2	Blue Nile up to Khartoum	0	315237.05	255283.81	59217.14	-1754.71	-864.40	11146.83	2956.14	42732.68
2	Atbara up to confluence to Main Nile	0	351743.55	325994.66	15176.72	0.00	-369.87	1532.51	487.74	12733.33
3	White Nile (from malakal to Khartoum)	33935	146101.07	141764.03	4151.69	-5021.27	-2442.90	1266.07	2735.47	26299.94
4	Main Nile till Atbara confluence	69033	1.00	2.00	0.00	0.00	0.00	348.74	1014.13	68012.61
4	Main Nile d/s of confluence with Atbara up to HAD	80746	0.00	0.00	0.00	0.00	-1448.78	765.89	5306.05	72711.57
			2073666.20	1903440.97	152580.78	-41481.35	-5127.55	16004.21	15737.83	72711.57

From Table 2, certain features of the various watersheds of the Nile Basin can be noted. The Bahr el Gazal sub-basin with an area double that of the Blue Nile has runoff that is 1/100th that of the Blue Nile. The outflow from Bahr el Gazal is less than 10 percent of the surface runoff generated in the sub-basin, which is the least among all sub-basins followed by the Bahr el Jebel.

The **temporal variability** of river flow is presented in term of seasonal variation as well as annual patterns. Most of the tributaries of the Nile show seasonal variation in their flow. The strongest seasonality is exhibited by the rivers Blue Nile, Tekeze – Setit and Atbara Rivers. For the Blue Nile (at Diem station), on the average, 82 percent of the annual flow occurs in just four months of July to October whereas for Setit river 80 percent of the flow occurs in just three months. The strong seasonality of these rivers is mainly due to the rainfall patters in the Ethiopian Highlands where most of the runoff for these rivers is generated. The strong seasonality has substantial impacts on water resources management measures that can be profitably employed to harness the river and exploit their full potential. Monthly average flows for major tributaries of the Nile are shown in Figures 3a and 3b.

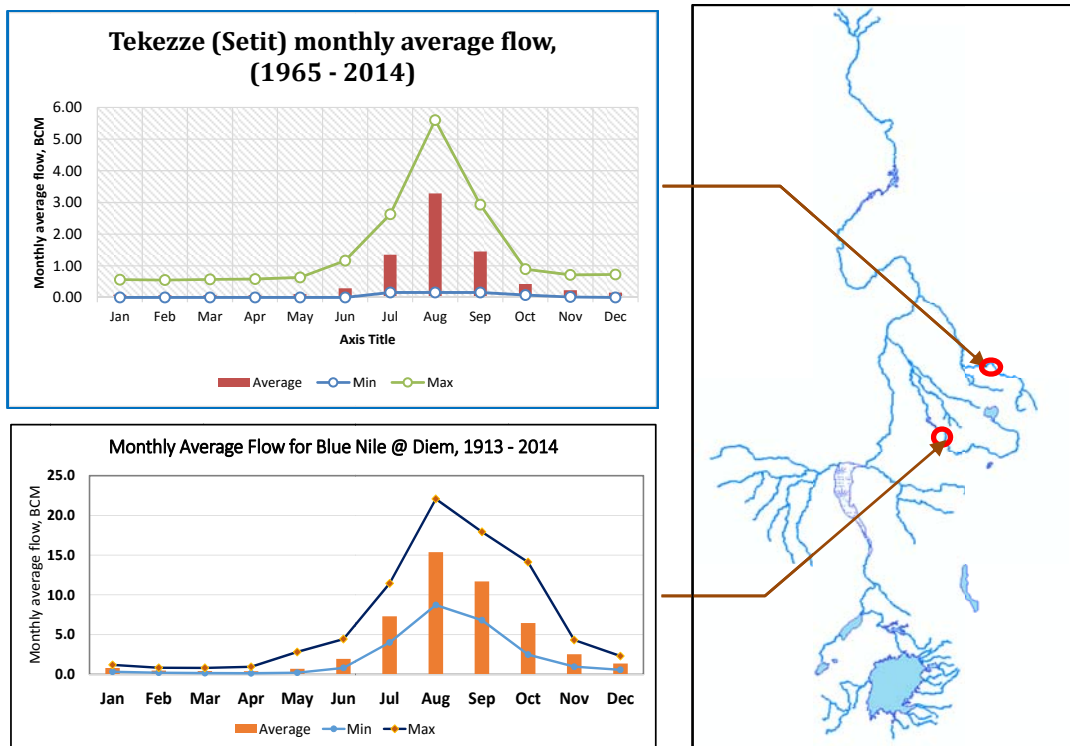


Fig.3a : Monthly river flow statistics for Blue Nile (Diem station) and Tekezze – Setit River

In contrast the White Nile River shows very small seasonal variation. This is partly due to the rainfall distribution in the catchments contributing to the flow of the White Nile, which is more spread over longer number of months in the year, and the regulation effects of natural lakes and swamps/wetlands in the Equatorial Lakes regional where the headwaters of the White Nile lie. The effect of the Sudd the largest freshwater swamp in the Nile Basin is effectively to reduce the inflow by nearly half as the Bahr el Jebel leaves the Sudd and then is joined by Sobat. However, the hydrology of the Bahr el Jebel is one of the least understood in the Nile Sub-basins.

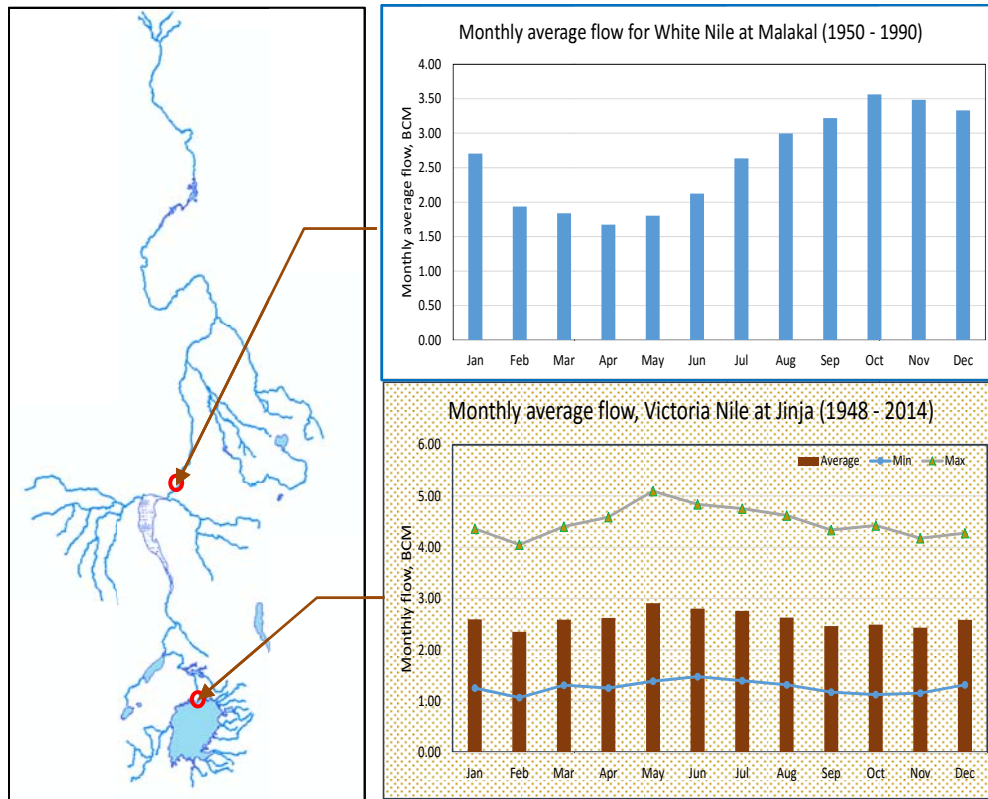
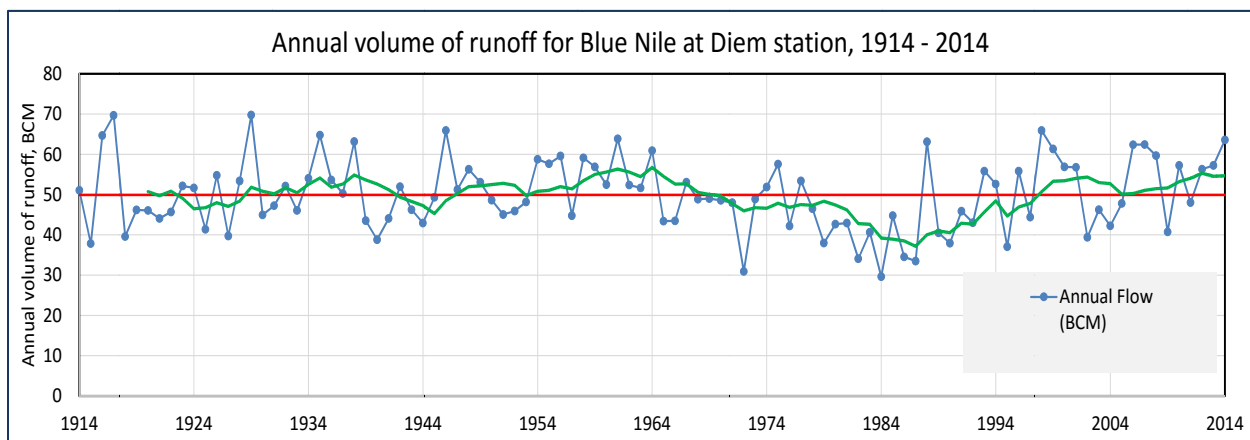


Fig.3b: Monthly river flow statistics for Victoria Nile at Jinja and White Nile at Malakal

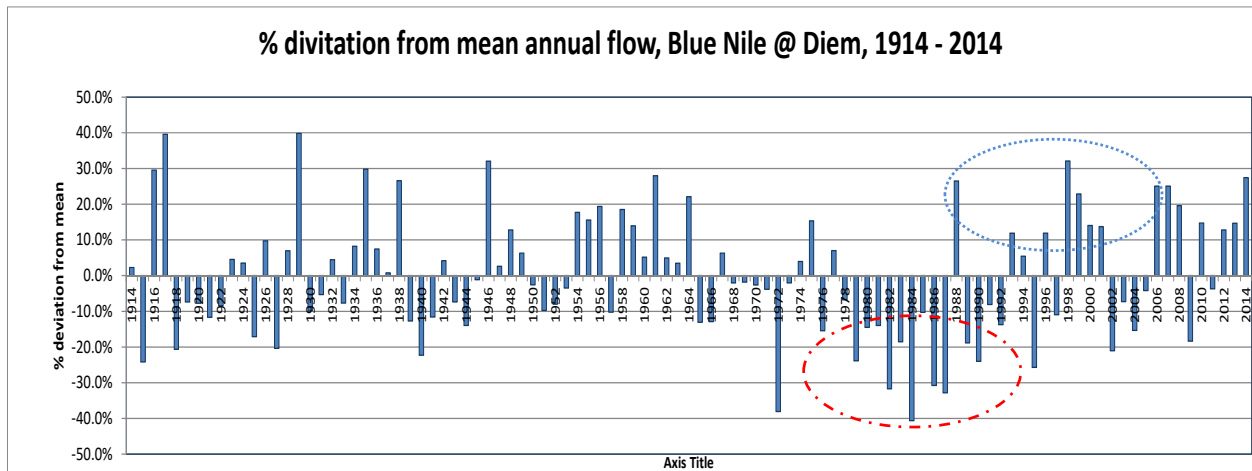
The inter-annual variability of river flow is also high in the rivers originating in the Eastern Nile, Figure 4. From the Figure, the low flow periods of the mid-1980s are clearly visible. There is a visible upward trend in annual volume of the Blue Nile after the low flow periods of the 1980s. Figure 4 also shows a 7-year moving average to reduce the 'noise' in the raw data and depict the pattern of changes in the



underlying process.

Fig. 4: Long-term time series of annual runoff volume for Blue Nile measured at Diem Station

The deviations of annual runoff volume from the long-term mean of the Blue Nile, Tekezze – Setit and Upper Atbara rivers are shown in Figures 5a and 5b. From the figure, it can be observed that the Blue Nile is not new to consecutive high and low flow years. However, the 1980s exhibit the longest consecutive low flow periods in the last 100 years. It is also observed that since the 1990s, the deviation from the long term mean annual flow has been more on the positive side. Such relatively long

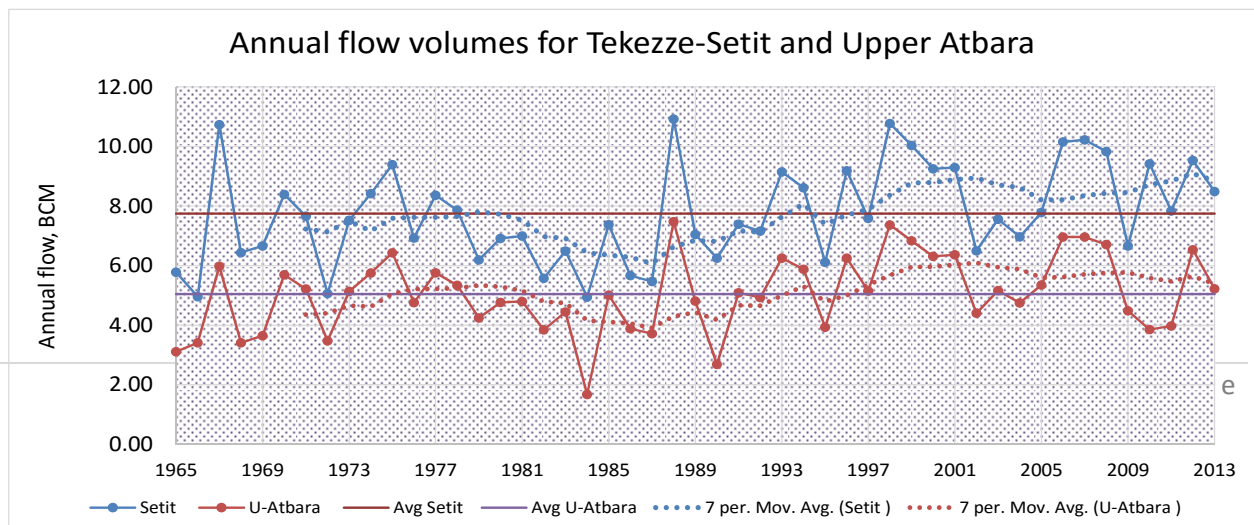


consecutive dry and wet years are important parameters for design water storage dams on such rivers.

Fig. 5a: Time series of deviations from the long-term mean runoff for Blue Nile measured at Diem Station

Fig. 5b: Time series of deviations from the long-term mean runoff for Tekezze – Setit and Upper Atbara Rivers

The flow pattern of White Nile recorded at Malakal in South Sudan has interesting features. Following the hike in flows observed in the Equatorial Lakes region – approximately from 1962 – 1972- the White Nile seems to have an average that is higher than the one before the hike. There is a difference of about 3 BCM in the average annual flows before and after the hike of the 1960s.



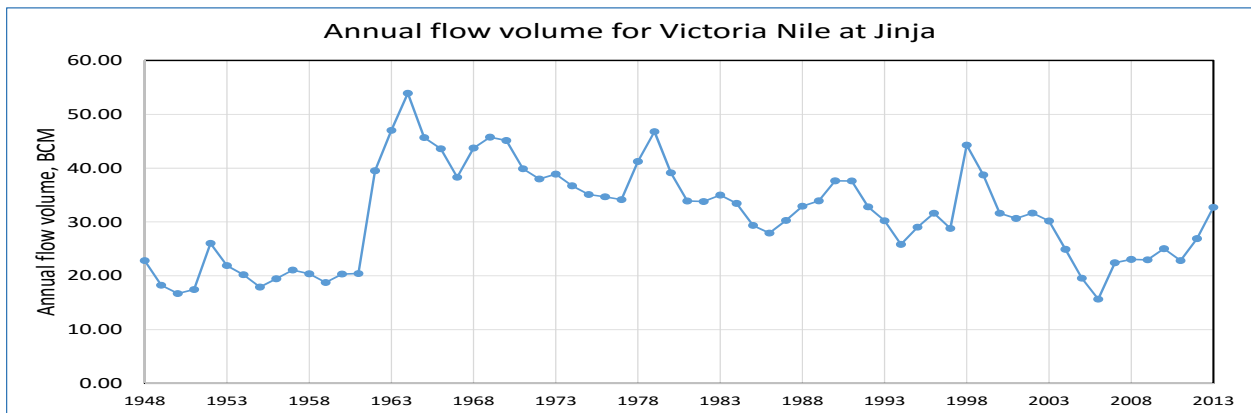
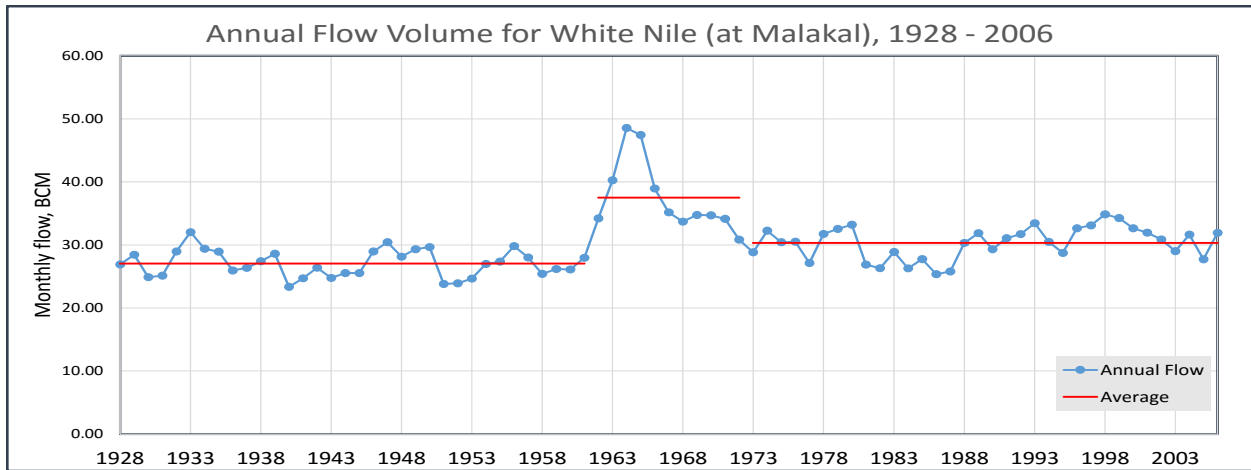
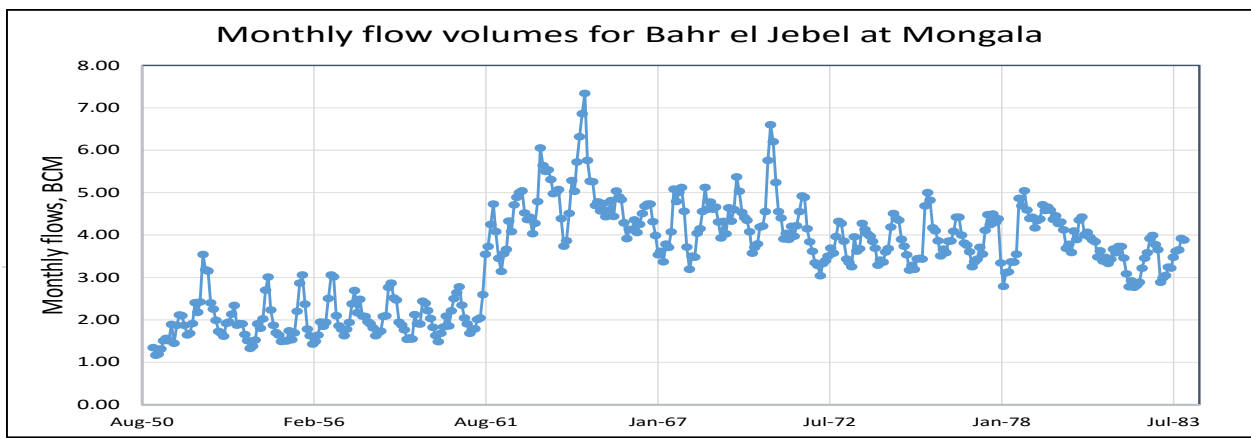


Fig. 6: Time series of annual river flow volume for White Nile at Malakal

Fig. 7: Time series of Annual River flow volume for Victoria Nile at Jinja

Fig. 8: Time series of monthly flow volume for Bahr el Jebel at Mongala

In summary, the yield of the Nile Basin under naturalized condition has been estimated as 94.7 BCM at the current location of the HAD. Due to abstractions and losses from man-made reservoirs, the estimated current yield is approximately 72.7 BCM per year. The rivers originating in the Ethiopian highlands, which provide more than 80 percent of the average flow, show high seasonal and inter-annual variability. For the period considered in the study, no long-term trend in annual flows have been observed.

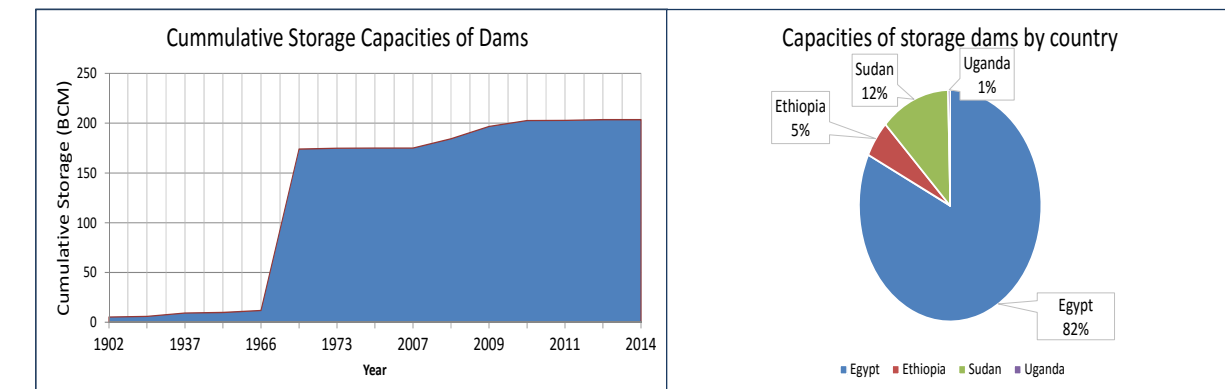


3. Current water demand for major uses

3.1 Existing hydraulic infrastructure in the Nile Basin

This section provides an overview of existing storage dams, hydropower plants and irrigated areas in the Nile Basin. Data obtained from Nile Basin Initiative member states show that as of 2014, there are 14 storage dams basin-wide with a total storage capacity of about 203 BCM. In addition, the Owens Fall (Nalubalee) dam built at the outlet of Lake Victoria in Uganda provides an additional 200 BCM of live storage to the Lake. Details on these dams are given in Technical Note II.

The growth in aggregate storage capacities of all dams in the basin is shown in Figure 10. It is interesting to note that, after a period of four decades of near stagnation in dam construction during 1968 – 2007, the basin is witnessing more and more storage dams added to the system as shown in Figure 9. The chart doesn't include the additional storage to Lake Victoria through construction of the Owens Fall



dam.

Fig. 9: Growth in cumulative storage capacities of dams and cumulative storage capacity by country

With an aggregate basin-wide storage capacity of just over 200 BCM, most of the Nile Basin countries have the least per capita water storage by world standard. In a region with severe seasonal and intra-annual variability and anticipated climate change, absence of adequate storage capacity means more vulnerability to impacts of climate shocks.

Hydropower is one of the main purposes for most dams. The aggregate installed capacities of 22 hydropower plants basin-wide is 5,660 MW.

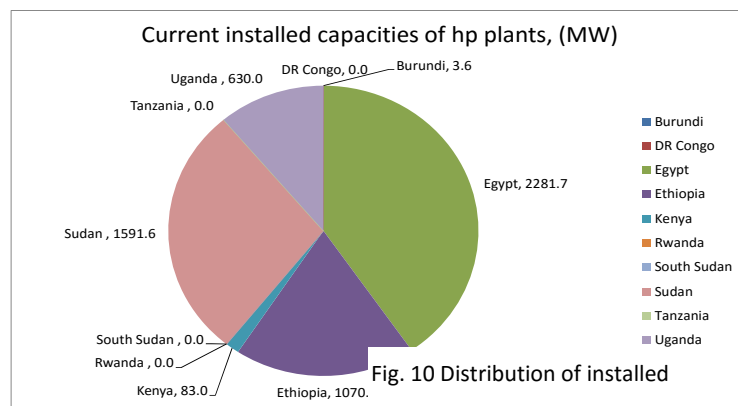


Fig. 10 Distribution of installed

Approximately 5.4 Million hectares are equipped for irrigation in the Nile Basin in all countries. The distribution of the areas among the Nile Basin countries is given in Table 3. The table also provides estimated average cropped area per country.

Country	Equipped Area ('000 ha)	Cropped Area ('000 ha)
Burundi	14.96	8.74
Dr Congo	-	-
Egypt	3447	5021
Ethiopia	91	134
Kenya	47.8	20
Rwanda	7	7
South Sudan	0.5	0.15
Sudan	1764.63	1146.7
Tanzania	19.753	6
Uganda	9.7	9.7
Total	5,402	6,354

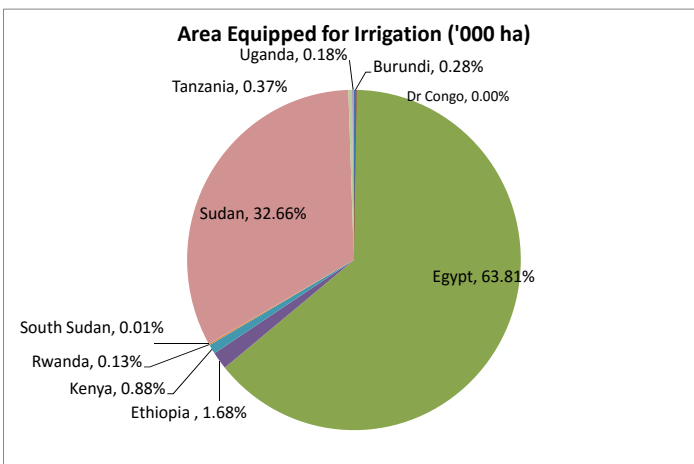


Table 3: Current irrigation areas

In Table 3, 'equipped area' represents the area that has been equipped with the necessary infrastructure for irrigation but not all area might be cultivated in any given year or growing season. The 'cropped area' refers to the area that is actually under cultivation. In most basin states, the cultivated area is less than the equipped area. In few countries, mainly in Egypt, more than one crop is cultivated per year and, therefore, the cropped area is bigger than the equipped area.

Most of the irrigation systems in the Nile Basin are assumed to use surface gravity method of water application. With the exception of Egypt, Ethiopia (one scheme with sprinkler technology), Kenya, Sudan, and Uganda, in other countries surface gravity method is the irrigation method used. Canals are assumed to be not lined and hence result in loss of water through seepage.

3.2 Estimated current water demand and use

Water use includes consumptive as well as non-consumptive uses. The water use sectors that have been included in the analysis are:

- Irrigated agriculture
- Hydropower,
- Municipal and Industrial (M and I) uses for large urban centers.
- Evaporation from dams has also be considered as water use.

Water demands for other uses, such as fisheries, mining, and navigation have not been included for lack of data.

Water demand estimates have been based on observed climate condition in the Nile Basin for the period 1950 – 2014. The selection of this period has been dictated by availability of climate data used for driving the model. The estimates, thus, provide average values of water demand, water supply (to meet these demands) and any gap between demand and supply for the observed climatic condition of the period 1950 – 2014.

The total water demand for Municipal and Industrial uses has been estimated at 12900 MCM per year for the whole Nile Basin. Nearly 97 percent of this demand occurs in Egypt.

The total irrigation water demand was estimated based on assumed cropped area for each irrigation scheme or district, Table 4.

Country	Crop water Requirement[MCM]	Irrigation Water Demand [MCM]	Extracted water from River (MCM)	Extracted from GW or Reused (MCM)	Actual Withdrawal [MCM]	Unmet Demand [MCM]
Burundi	28.89	28.9	28.7	0	28.7	0.13
DRC	0.00	0.0	0.00	0.00	0.0	0.00
Egypt	49185.42	66551.5	57417	8637	66054.0	499.38
Ethiopia	1035.50	2018.2	1501	0.00	1500.9	517.34
Kenya	180.01	367.4	307.50	0.00	307.5	59.87
South Sudan	1.69	3.4	3.16	0.00	3.2	0.00
Rwanda	28.71	58.6	57.38	0.00	57.4	0.85
Sudan	10249.86	13959.8	13303	0.00	13921.6	38.26
Tanzania	50.10	102.2	63.42	0.00	63.4	38.82
Uganda	127.58	260.4	260.32	0.00	260.3	0.05
Total	60887.76	83350.45	72941.55	8636.59	82196.95	1154.71

Table 4: Irrigation water demand, abstraction and estimated unmet demand by Country

In Table 4, ‘Total Supply Requirement’ refers to the volume of water that must be withdrawn from the source (surface or groundwater) to meet the crop water requirement and the losses in the conveyance and distribution systems. The losses are modeled using conveyance and field application efficiency factors that take into account percentage of water lost in the delivery and field application. Details on how the losses have been estimated are provided in Technical Note III. The figures indicated in Table 4 **Error! Reference source not found.** under ‘Actual Withdrawal’ and ‘Unmet Demand’ columns show the amount of actual water abstracted from the river system to deliver water to irrigation fields and the deficit due to shortage from supply side respectively. The total unmet demand in the system is about 1.2 BCM. For the system in Egypt, the model has been configured to estimate re-use of drainage water and groundwater supplement to surface water resources for meeting the irrigation demands. Since no ground observation data has been obtained from Egypt, the estimated groundwater contribution needs further refinement as more data are obtained.

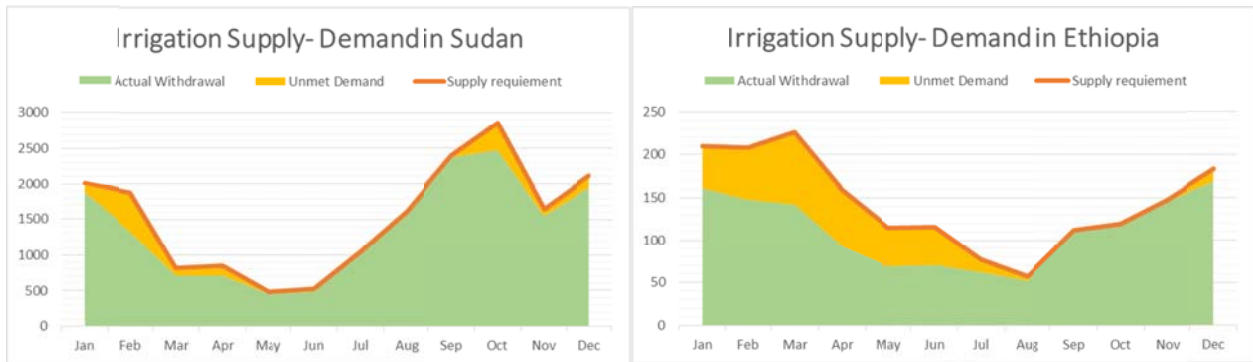


Fig. 11: Monthly patterns of Supply and Demand for irrigation water in Sudan and Ethiopia

For Ethiopia most of the deficit in water occurs from November to June, as indicated in Figure 11, with minimum to no deficit from July to October. In the case of Sudan, most of the deficits occur during September to March. Minimum deficit is observed in July and August. This pattern corresponds to the rainy season of Ethiopian highlands in Blue Nile and Tekeze river basins since the majority of river flow originates from this part of the sub-basin. The deficits are mainly due to lack of adequate storage facilities than shortage of water.

The total estimated net evaporation loss from dams in the Nile Basin has been estimated as 18 BCM per year. Due to the size of the reservoir surface area and the climate, the evaporation from the High Aswan Dam is the biggest. Distribution of the evaporation losses are shown in Figure 12.

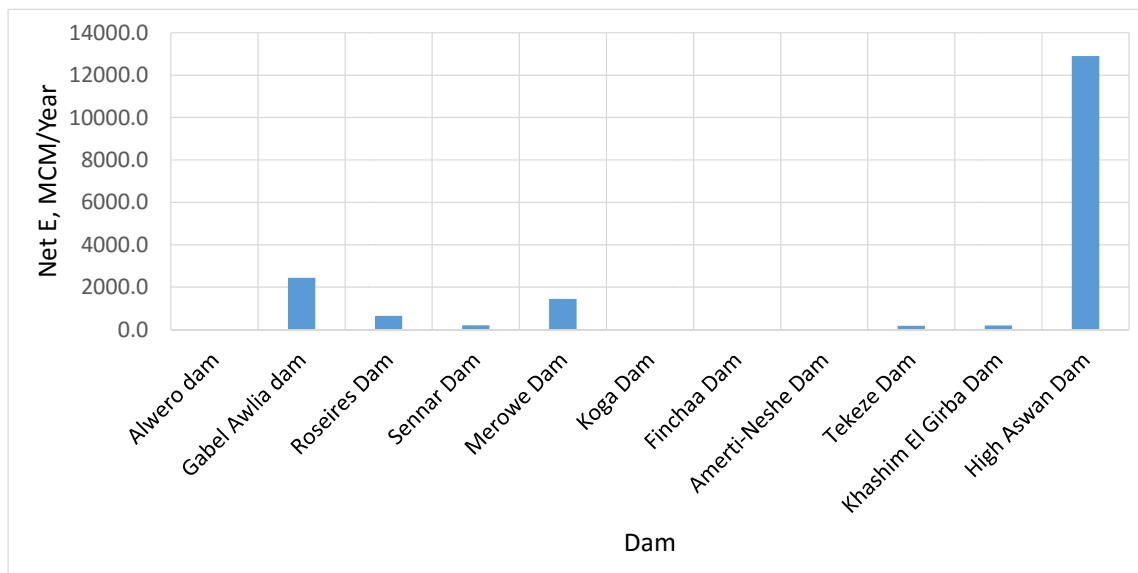


Fig. 12: Evaporation from dams

4. The Nile Basin water balance

The water balance of the basin, taking into account all river flow, system losses (from river course), water abstractions and evaporation from lakes and reservoirs has been documented as a schematic. This schematic provides annual water balance at key locations and for major dams and irrigation schemes. The values are based on the model outputs from the period 1950 – 2014. This schematic is prepared in excel as a simplified schematic of the model in the Nile Basin DSS. A snapshot of the schematic is given in Figure 13. The schematic is best viewed in Excel where users can choose the years for which they want to view estimates of river flow, abstractions and other components of the water balance. The excel based schematic is provided together with this report.

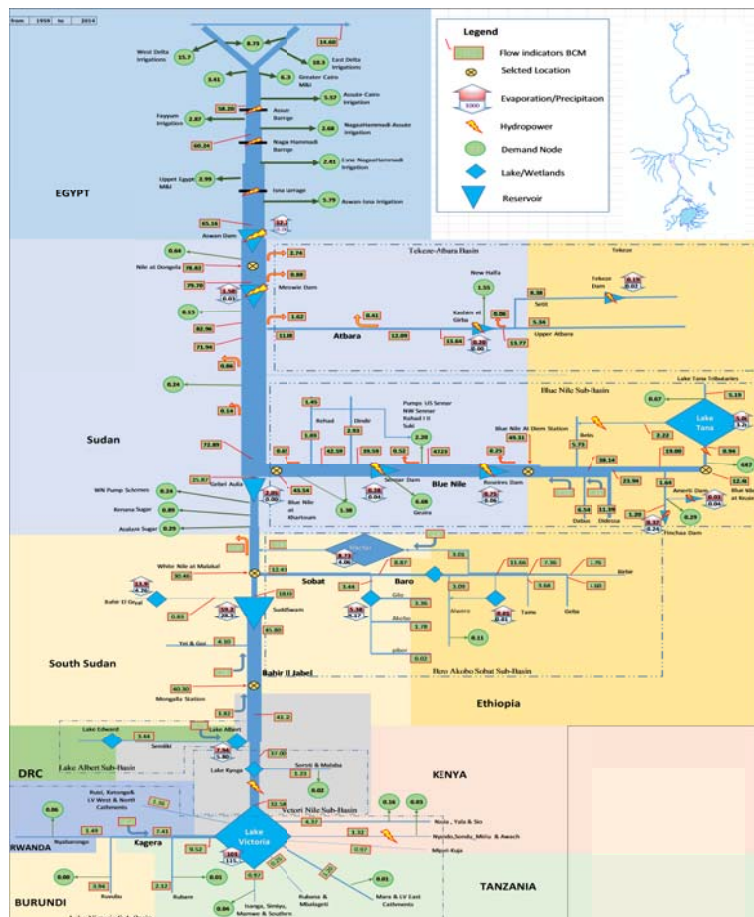


Fig. 13: A snapshot of the Nile Basin water balance schematic

5. Preliminary results of demand projections

5.1 Growth in water resources infrastructure

Estimates of basin-wide water demands for the sectors considered in the analysis has been prepared. The estimates are based on planned water resource development projects in the Nile Basin countries.

Data on future projects have been supplied by Nile Basin Initiative member states as part of this analysis. The projection of water demand has been made for the time horizon of 2050, i.e. included water resources projects that are expected to be implemented in the coming three-and-half decades. The projection has assumed that these projects will be implemented as planned – both in scope and implementation date. Further, the water demand projection assumes that those projects will be implemented unilaterally by member states. Therefore, the key driver of water demand in the basin is the growth in water resources infrastructure for food (irrigated agriculture) and energy production.

Planned expansion of irrigation areas: as shown in section 5, most of the existing irrigated area falls within Egypt and Sudan as many of the Nile countries depend on rain-fed agriculture and recession agriculture with little irrigation. However, this is expected to change as other countries also implement their plans to develop irrigation schemes such as in Ethiopia, Kenya, and Tanzania. The planned growth in irrigation areas is shown in Table 5 with Figure 14 showing distribution of the planned areas by country.

Table 5: Expected growth in irrigation area

Country	Baseline ('000 ha)	Planned Additions ('000 ha)	Expected total area by 2050 ('000 ha)
Burundi	8.74	0	8.74
Dr Congo	0.00	0.00	0.00
Egypt	3447.00	444.00	3891.00
Ethiopia	91.00	1420.06	1511.06
Kenya	47.80	63.25	111.05
Rwanda	7.00	4.45	11.45
South Sudan	0.50	273.13	273.63
Sudan	1764.63	1146.60	2911.23
Tanzania	19.75	0.00	19.75
Uganda	9.70	0.00	9.70
Total	5,396.12	3,351	8,748

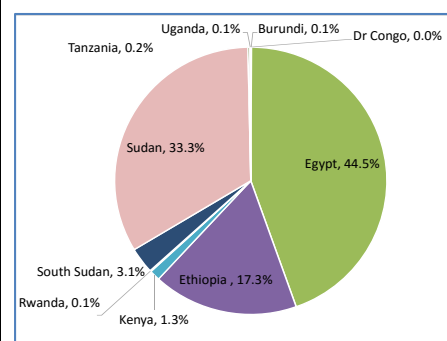
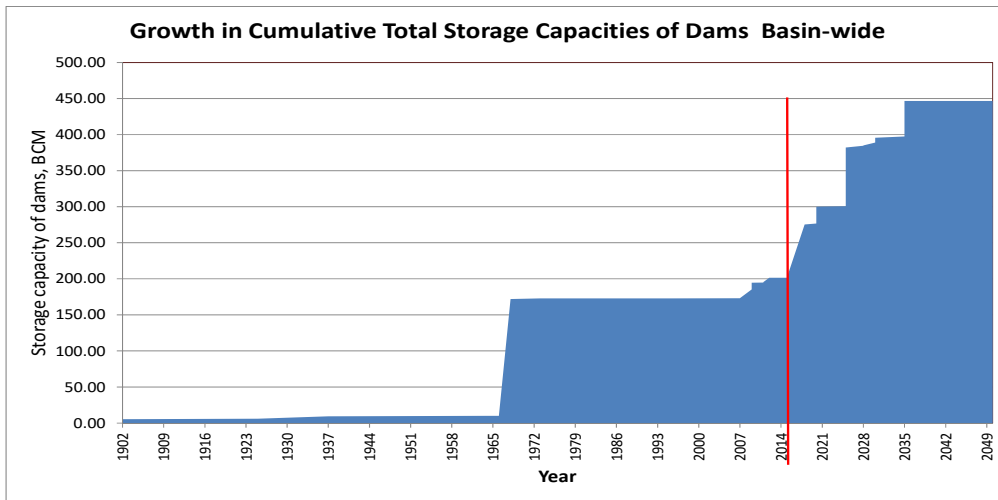


Fig.14: Distribution of future irrigation areas by country

Table 5 shows the planned expansion in areas equipped for irrigation. If the current level of cropping intensity is applied, the total cropped area will be approximately 10 million hectares. It is likely that the cropping intensity can grow and the cropped area will be higher than this figure. Irrigation water demand is determined by the cropped area rather than the equipped area. Therefore, one expects a substantial increase in irrigation water demand. The above projection of irrigation areas is based on existing national plans in riparian states.

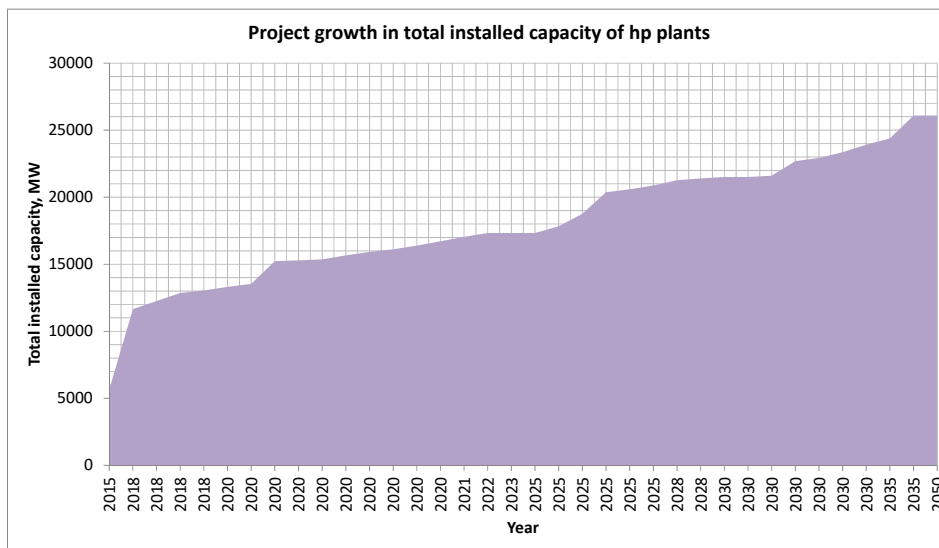
Planned growth in dam storage capacity: a number of new dams are planned to be constructed in the coming decades. These dams, most of them upstream, are planned as multi-purpose dams providing water for irrigation, hydropower and other purposes, such as flood control. The projected growth in total storage capacity indicates that, based on existing plans, the total storage capacity that will be available in the basin will reach to approximately 445 BCM. Most of the new storage dams are planned to be built in the Eastern Nile. With the increasing number of dams, the basin will have more storage capacity and, hence, reduce vulnerability to climate shocks. At the same time, the total evaporation



from these dams will grow.

Fig. 15: Projected growth in total storage capacity of dams basin-wide

Projected growth in hydropower capacity: the Nile Basin has considerable hydropower potential that is not yet fully tapped. Data availed to the Nile-Sec by Nile Basin Initiative member states indicate that the total installed capacities of hydropower plants in the basin is expected to reach 26,000 MW, that is an



increase of about 21,000 MW; Figure 16.

Fig. 16: Projected growth in total installed capacities of hydropower plants

5.2 Preliminary scenarios for future water demands estimation

A first estimate of growth in water demand has been made using the model calibrated as part of the baseline analysis and using the data on planned water resources infrastructures. Though the data on planned growth in water resources infrastructure have been collected from national plans, there is some room for uncertainty as to when exactly and how many of the planned projects will be implemented within the time frame considered for this analysis. Therefore, in order to provide a realistic picture on how the water demand might grow, a few scenarios have been constructed that attempt to capture variations in expected expansion of water resources infrastructure. The factors that have been taken into account to generate the scenarios are given in Table 6.

Table 6: Factors considered for scenario construction

Factor	Description	Variants considered
<i>Growth in irrigation areas</i>	Irrigation is the biggest consumer of water. Therefore, the growth in water demand in the Nile Basin largely depends on expansion of irrigated agriculture	<ul style="list-style-type: none"> - Full (planned) Development (FD) - 25 % of the Full Development - 50 % of Full Development - 75 % of Full Development
<i>Improvements in irrigation efficiency</i>	A substantial proportion of the irrigation expansion is planned by upstream countries, where current levels of irrigation infrastructure is low. Therefore there is a great opportunity to employ water saving technology in new irrigation expansions to reduce to potential increase in irrigation water demand. There is also some room for increasing efficiencies of existing schemes.	<ul style="list-style-type: none"> - Existing irrigation efficiency levels - 50 % improvements in irrigation efficiencies of new schemes (compared to current levels) - 50 % improvements in efficiencies for all irrigation areas (old and new); <i>this variant is only possible where existing efficiencies are low.</i>

Based on the factors given in Table 5, a set of 6 scenarios has been defined; Table 7. All scenarios assume full development of planned storage dams. No provision has been made on possible cooperative arrangement between member states that might alter the currently existing plans. The infrastructure scenarios are purely based on national plans. This set of scenarios is planned to be refined in the second stage of the strategic water resources analysis.

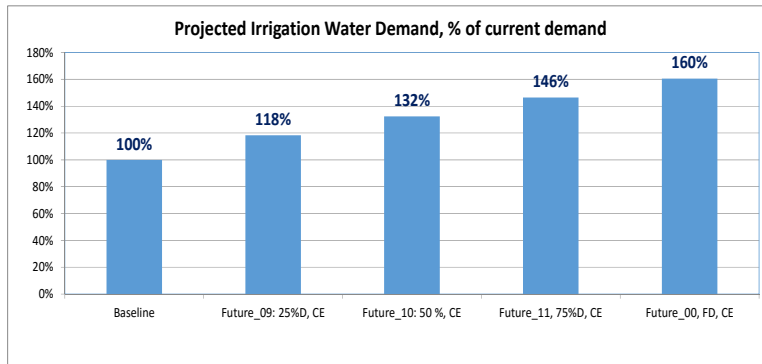
Table 7: Scenario definition

Ser No	Climate/Hydrology	Irrigation expansion	Irrigation efficiency	Scenrio ID
1	Historical	Full development	Current level	future_00
2	Historical	Full development	Current for existing + 50% New System	future_01
3	Historical	Full development	Increased level 50% for all	future_02
4	Historical	25% development	Current level	future_09
5	Historical	50% development	Current level	future_10
6	Historical	75% development	Current level	future_11

The above set of scenarios have been configured in the Nile Basin DSS and simulated.

5.3 Projection of water demand and potential shortfalls under historical climate

The total irrigation water demand for all schemes under scenarios of irrigation expansion and assuming

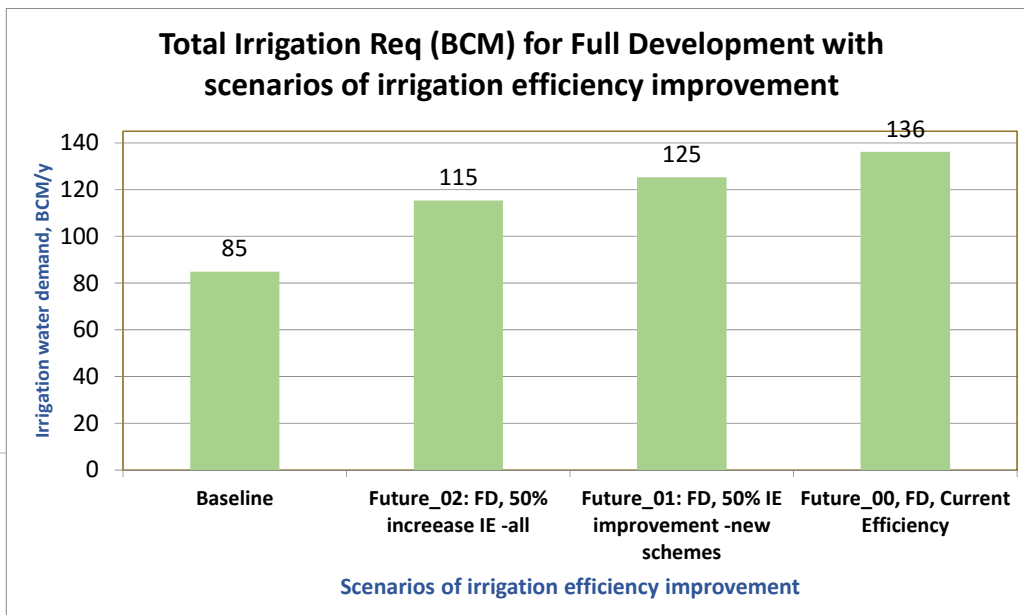


current/historical climate are shown in Figure 17a and 17b.

Fig. 17a: Expected growth in irrigation water demand for scenarios of irrigation expansion levels

Fig. 17b: Expected growth in irrigation water demand for scenarios of irrigation expansion levels

Improvements in irrigation efficiencies have a visible impact in reducing the total irrigation water demand. The scenarios of irrigation efficiencies under the scenario of Full Development have been used



to explore potential contribution of irrigation efficiency improvement towards alleviating the stress on the river system. Figure 18 shows the growth in irrigation water demand for the scenarios of irrigation efficiency improvements considered.

Fig. 18 Projected irrigation water demand under scenarios of irrigation efficiency improvement for Full Development

From Figure 18, it can be observed that improving the efficiencies by 50 percent of current levels for all newly planned irrigation areas can save approximately 11 BCM of water (difference between Future_00 and Future_01 Scenarios).

Potential future deficits in meeting the growing water demands basin-wide (here referred to as 'shortfalls') have been estimated using the model and estimated water demands shown above. The shortfalls are shown in Figures 19a and 19b. Figure 19a shows the shortfalls for scenarios of irrigation expansion assuming current levels of irrigation efficiencies while Figure 19b shows the potential shortfalls for Full (planned) Development scenarios for the two cases of irrigation efficiency improvements.

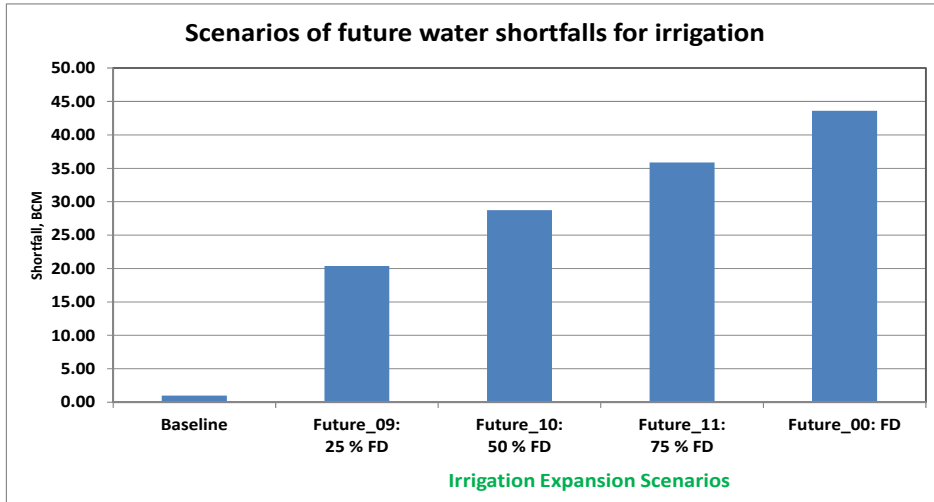


Fig. 19a: Projected water shortfalls for scenarios of irrigation expansion

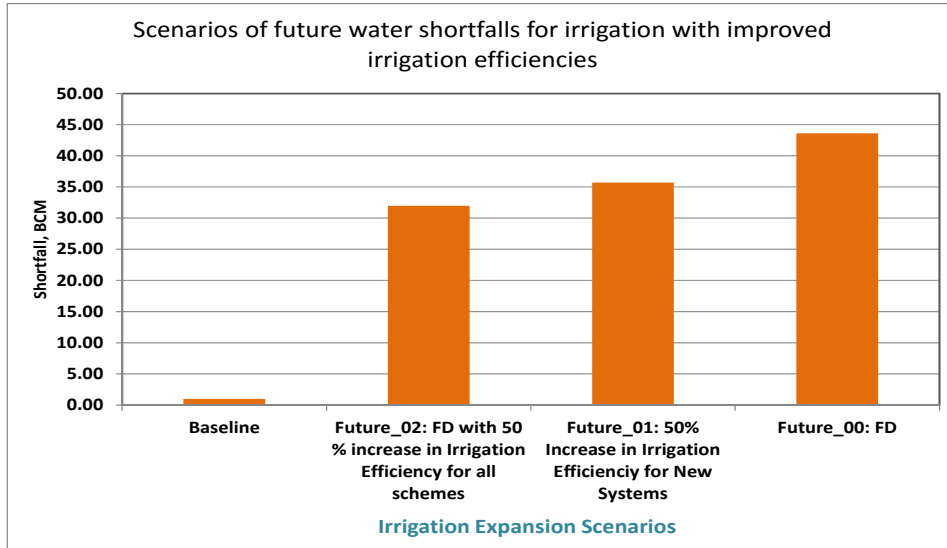


Fig.19b: Projected water shortfalls for scenarios of irrigation efficiency improvements

The above results are preliminary and will be further refined in the second stage of the analyses. However, they provide indicative values on how the basin water demands will evolve and the likely challenges the Riparian States might be facing to meet the growing water demands.

6. Preliminary identification of measures for addressing potential future water shortfalls

The results of the baseline analysis presented earlier in this document show that the Nile Basin currently supplying water for various uses without appreciable shortfalls. However, as data compiled from national plans and projected future water supply and demand show, there is a high likelihood that water demand in basin will outstrip the available water resources. This is expected to occur if the basin evolves under purely unilateral development, relying mainly on surface water (current use of groundwater for irrigation is very small) and with no appreciable improvements in irrigation technologies. However, there are a number of opportunities available to the riparian states that can be taken advantage of to address likely future water shortfalls. The purpose of the strategic analysis is to quantify such risks and explore options for addressing potential shortfalls in water. Based on the preliminary results presented earlier, the National Experts Group representing the NBI member states identified a number of options that subsequent stages of the strategic (shown in Box 2) for addressing potential future imbalances.

Box 2: preliminary list of options identified by the National Experts Group.

Water Supply Enhancement

1. Conjunctive (groundwater – surface water) use,
2. Recycling and reuse of waste water (Municipal, Industrial, agricultural)
3. Desalination;
4. Water harvesting;
5. Expanding water storage and cascading facilities,
6. Expanding basin-wide rainfall effective use in agriculture.

Demand side Management

7. Improving water use efficiencies, Basin-wide water use efficiency guidelines, policies on water use and regulations (permits)
8. Water pricing, awareness creation, population control,
9. Increasing basin water yield
10. Identification of alternative (less water reliance) uses
11. Optimization of system wide water use, such as selection of crops to limit growing highly water intensive crops in areas with high potential evaporation
12. Improved wetlands management
13. Incentives to reduce water consuming uses (pricing or taxation)
14. Treating polluted water and watershed management

Basin System Management for Optimal water resources utilization

1. Optimize location of reservoirs
2. Coordinated reservoir operations

Others

3. Economic integration
4. Joint planning and cooperation

Capacity development and awareness raising should be a cross-cutting theme

Subsequent stages of the analysis will explore and quantify the contribution of each option towards reducing potential shortfalls.

The list of options in Box 2 is preliminary. The effectiveness of each option in addressing potential future imbalance between water supply and demand need to be quantified and the feasibility of implementing any of the options need to be studied from technical and economic perspectives. This will then be used to develop portfolio of strategies that will be mainstreamed for implementation through NBI's investment programs and national water resources development plans. In this regard, one of the first activities in second stage of the strategic analysis starting August 2016 will be to work with the National Expert Group in further elaborating and prioritizing the options, which will then be characterized and quantified.

7. Conclusions and Way forward

The results of the first stage of strategic water resources analysis carried out by NBI are presented in this document. The results show that currently the Nile Basin supports the existing water demands without appreciable shortfalls. This, however, is likely to change as the demand for water is growing for meeting water supply, food and energy requirements of a rapidly growing population and economies.

Preliminary projection of water demand shows that if the basin water resources are developed as per plans by riparian states without any appreciable coordination, there is a risk that the growing water demand outpaces the available water resources. Therefore, in order to develop and manage the shared water resources of the Nile on which the livelihoods of millions of people depend, timely exploration of options for addressing the likely water shortfalls is necessary.

The strategic water resources analysis is one of the efforts being made by NBI in close collaboration with its member states to address the challenge. The National Expert Group identified a range of options for further study to address potential future imbalances between water supply and demand. These options cover measures for enhancing water supply, managing demands, optimizing water resources use and capacity development as cross-cutting theme.

Subsequent phases of the strategic analysis are planned to focus on analysis of some of the key options (many of them listed in Box 2), quantify the extent to which each option contributes towards addressing the challenge, prioritize those options with possible 'high and quick' return, and support mainstreaming them in national as well as sub-basin/basin development plans.

Subsequent stages of the analysis will integrate analytic work, consultation, policy dialogues, experience exchange with other basins and training.

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