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# Assessments of water demands for the Juba and Shabelle Rivers in Somalia

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Abstract: Fresh water is one of the most challenging current and future natural resources issues in the most regions of Somalia. In addition, the twenty and more years of civil war in Somalia have destroyed most of the irrigation schemes, as well as institutional structures. But, the Somali national economy, social, environmental well-being and the food security mainly depend on Juba and Shabelle Rivers. These rivers are the only perennial and transboundary rivers in Somalia but two-thirds of the river basins are located outside Somalia, mostly in Ethiopia, with a part of the Juba basin in Kenya.

The main objectives of this study are estimating the current utilization of rivers in the region and scenario development for different water user from these rivers. The study deals with a characterization of the water users and demands along the Juba and Shabelle Rivers were modelled using a WEAP model. During model application for the basins, there are a lot of data sources limitations and gaps.

Results show that the long-term mean annual flow volume at entering points from Ethiopia to Somalia (Luuq and Belet Weyne runoff stations) were 5,638 and 3,499 mcm/yr in the Juba and Shabelle Rivers, respectively. The current annual water use rate for irrigation estimates in Juba and Shabelle River basins are 11,428 $m^3$/ha and 11,829 $m^3$/ha, respectively. The irrigation annual water demand was along Juba 173.1 mcm and Shabelle 597.4 mcm and the domestic demand depends on the Juba and Shabelle Rivers were 14.5 and 5.5 mcm, respectively. If maintaining the existing irrigation infrastructure along the rivers, irrigation water demands for the year 2035 are 3% and 63% of the current annual flow volume at the Juba and Shabelle Rivers, respectively.

*Keywords: Juba River, Shabelle River, water demand, WEAP model*

## Introduction

Somalia is located at the Horn of Africa and bordered by Ethiopia to the west, Djibouti to the northwest, the Gulf of Aden to the north, the Indian Ocean to the east and Kenya to the Southwest. Somalia's total land area is 637,600 km$^2$, of which 45% is classified as rangelands suitable for livestock grazing, 30% is classified as desert land, 14% is covered by forest and 11% is arable land (Houghton-Carr *et al.*, 2011). The Juba and Shabelle River basins are international river basins at the Horn of Africa drained through Ethiopia, Kenya and Somalia and the only perennial rivers flowing through Somalia.

Almost all the Somalia's surface water resources exist in these rivers, whereas runoff contribution in Somalia is normally minimal or almost insignificant. The Shabelle River basin is larger in size and is longer than the Juba River, but Shabelle River is low in annual runoff compared with Juba River due to climatic and geological conditions in the catchment (Basnyat and Gadain, 2009). The rivers feed associated groundwater aquifers in the region and together these water sources sustain the extended agricultural as well as pastoralist activities, livestock, ecosystems and local settlements (Basnyat, 2007).

In terms of use of the rivers, Abdullahi Elmi (2002) assessed the significant impact in two transboundary rivers on the survival of the Somali national economy, social, environmental well-being and security of the nation. This study includes a section about several development projects like the Bardheere Dam Project (BDP), which is the largest dam ever planned in Somalia, but it is unimplemented due to Somalia's internal problems. Almost all water infrastructures that have been constructed in Somalia for irrigation were destroyed during the civil war. Basnyat (2007) reported that based on current infrastructure the irrigated area is actually larger along the Shabelle (77%) than along the Juba River (23%).

Markakis (1998) stated that southern Somalia is strongly dependent on the two rivers. Water resources in the two rivers are used to the survival of the Somali national economy, social and environmental well-being. The abstractions for different water resources development activites on the two rivers in Ethiopia are insignificant (Awulachew *et al.*, 2007).

Abdullahi Elmi (2002) stated that the Juba and Shabelle Rivers are international river basins in the Horn of African region. Ethiopia and Somalia have no past agreements on common utilization of the water resources in these two rivers and this may cause conflicts on water use in the future and influence the hydropolitics in the Horn of Africa. In this study area, the main economical activity mainly depends on agricultural productivity is highly influenced by the erratic and low rainfall. The abstractions and low flow seasons from the Shabelle River highly influence the swampy environment at downstream wetlands (Anderson *et al.*, 2006). The sustainable flow of a river is considered as a target of 90% of the flow duration curve used to sustain environmental flows (Richter *et al.*, 2003).

WEAP allows for the integration of demand and supply-based information together with hydrological simulation capabilities to facilitate integrative analysis of a user-defined range of issues and uncertainties, including those related to climate, changing human and ecosystem water demands, and infrastructure development. The user-defined demand structure and water allocation priority and supply preference designations drive the linear programming allocation algorithm for the water balance.

The WEAP model supports the planner in forecasting demand and supply structures under various assumptions and management practices and helps in developing water resource management policies to meet future water demand and solve water allocation problems (Yates *et al.*, 2005). WEAP can address a wide range of questions, for example such as: what if population growth and what if irrigation and crop patterns are changed, what if various demand management strategies are implemented, etc (Lévite *et al.*, 2003; Akivaga *et al.*, 2010).

Twenty and more years of civil war in Somalia have destroyed most of the irrigation schemes, as well as the data collected in the past on all natural resources of the nation. Institutional structures and capacity for water affairs and infrastructures are totally absent and destroyed during these periods (Abdullahi Elmi, 2002). The war also caused to neglect and abandonment of data collection and failure of monitoring of water resources on Juba and Shabelle River basins. In general, this study used the hydrometeorological data and other related works documented by the FAO-SWALIM project to forecast demand and supply in the Juba and Shabelle Rivers.

## Materials and methods

### *Area description*

The Juba and Shabelle River basins are located between the longitudes 41°53' and 46°09' east and between the latitudes 0°16' south and 5°04' north inside Somalia. Figure1 shows the area of the Juba and Shabelle Rivers basins are 218,114 $km^2$ (to Jamame, excluding Shabelle basin) and 296,972 $km^2$ (to the Juba confluence), respectively (Basnyat and Gadain, 2009).

The climate conditions for the Juba and Shabelle River basins can be described as mainly arid and semi-arid, and the climate is influenced by the north and south-easterly air flows of the Intertropical Convergence Zone (ITCZ). The north and south-easterly air masses meet at the Intertropical Front (ITF) and raise air upwards to form rain (Muchiri P.W., 2007a). Somalia has a bimodal rainfall distribution, with two rainy seasons (Gu and Deyr). The Gu season dominates over the Deyr in quantity and reliability of rainfall and as such it is treated as the primary rainy season. The mean monthly temperatures ranging between 25°- 30°C, with a maximum temperature of 41.3°C in March and a minimum temperature of 17°C in January. In areas near the rivers the relative humidity is high; ranging from about 75-80%, but further inland away from the rivers the air is much drier. Relative humidity is higher in the coastal areas, where it usually exceeds 80% (FAO SWALIM, 2010). The highest potential evapotranspiration occurs in the northern areas of Gedo, Bakool and Hiraan regions where it exceeds 2100 mm/yr; in the rest of the area it is between 1500 and 2000 mm/yr (Houghton-Carr, *et al.*, 2011).

The geology of two river basins has been developed due to the outcropping of the metamorphic basement complex, made up of migmatite and granite. Sedimentary rocks such as limestone, sandstone, and gypsiferous limestone are present, as well as an extensive, wide system of coastal sand dunes (Paron and Vargas, 2007). The river basins are characterized by three morphologic regions. The upper region can be described as high mountains, steep slopes and rugged features, mountain peaks and high plateaus with monsoon winds and rainfall, whereas in the middle region, gentle slopes and reliefs occur and transport and deposition is dominating (FAO SWALIM, 2010). The land covers in the basins consist mostly of natural vegetation and crop fields, urban areas, dunes and bare lands, and natural water bodies. The vegetation consists of bush lands, grasslands and riparian forest. The long term mean annual river flows of Juba and Shabelle have been quantified as 186 $m^3/s$ and 81 $m^3/s$ at Luuq and Belet Weyne runoff stations respectively (Sebaht and Wenninger, 2014).


*Figure 1 - Map of the Juba and Shabelle River basins.*

## Methodology

### *WEAP Model setup*

The WEAP system has been used to consolidate water-related data and to simulate current and future management and allocation rules for the Juba and Shebelle River basin, as provided by the local project partners. WEAP is a water resources modeling and planning tool, which in its simplest form is similar in structure to other water allocation decision support tools.Daily flow data from 2005-2011 was used from FAO-SWALIM database for ten Juba and Shabelle River runoff stations to simulate the model. These observed measurements considered at this validation are located at Juba River are Luuq, Bardheere, Kaitoi, Mareere and Jamame runoff stations, whereas at Shabelle River are Belet Weyne, Bulo Burti, Mahadey Weyne, Afgoi and Awdgele runoff stations. The initial scenario development start from 2005 since the population, the irrigation coverage and other basic data are available. The water uses and inflow data were used as the basis from which all scenarios are developed.

### *Description of the WEAP21 Model*

The Water Evaluation and Planning (WEAP) model has a long history of development and use in the water planning arena (Yates *et al.*, 2005). It was developed by the Stockholm Environment Institute (SEI). WEAP is an integrated hydrology / water resource system, mainly destined for policy makers, having to deal with the complex dynamics of water system. The system is GIS-based, and operates on the basic principle of water balance accounting.

Depending on the objectives of the user, WEAP can either be used as a database, as a forecasting tool or as a policy analysis tool. It can be applied at a local level up to very complex river basin system. Operating on the basic principle of water balance accounting, WEAP21 can account for hydrologic processes within a watershed system can capture the propagating and nonlinear effects of water withdrawals for different uses (Yates *et al.*, 2005). The latest version of the model, WEAP21 incorporates a range of physical hydrology processes in a watershed with the management of demands and installed infrastructure in a seamless and coherent manner.

Therefore, it allows for climate change and other changing anthropogenic stressors, such as land use variations, changes in water demand, alternative operating rules and others. This innovation provides WEAP21 as a robust analysis of future climate scenarios assert themselves onto the natural watershed, leading to associated hydrologic responses, all in the context of potential adaptation at a decisions level relevant to local water managers (Yates *et al.*, 2005). Fig. 2 below shows the schematic view of the Juba and Shabelle River basins using WEAP Model.

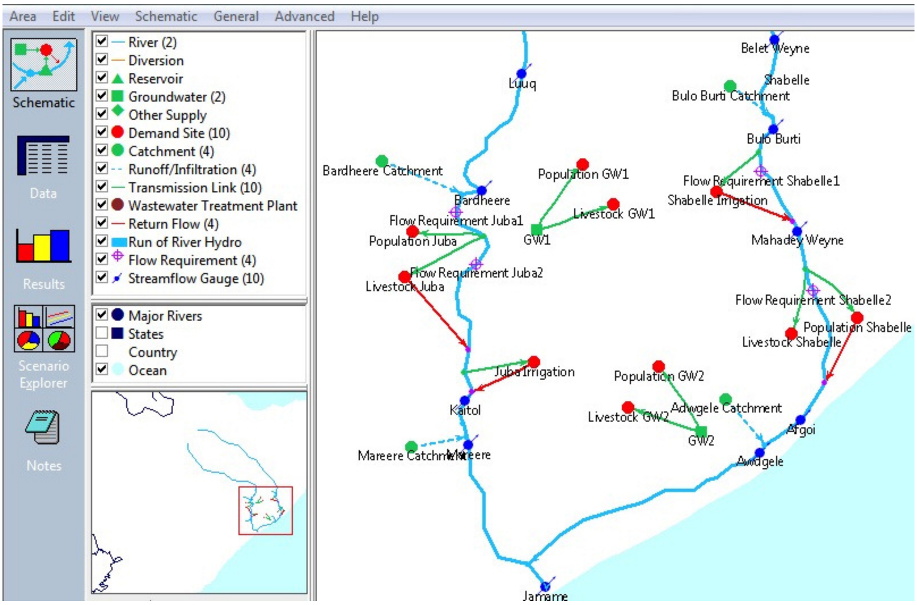


*Figure 2 - WEAP Model schematic view of the Juba and Shabelle River basins.*

## Results and discussion

The accuracy of the model is assessed by observing the simulated and observed streamflow data. From fig. 3 and 4 below it can be observed that the simulated and measured flows at different location along the river courses for both Juba and Shabelle Rivers.

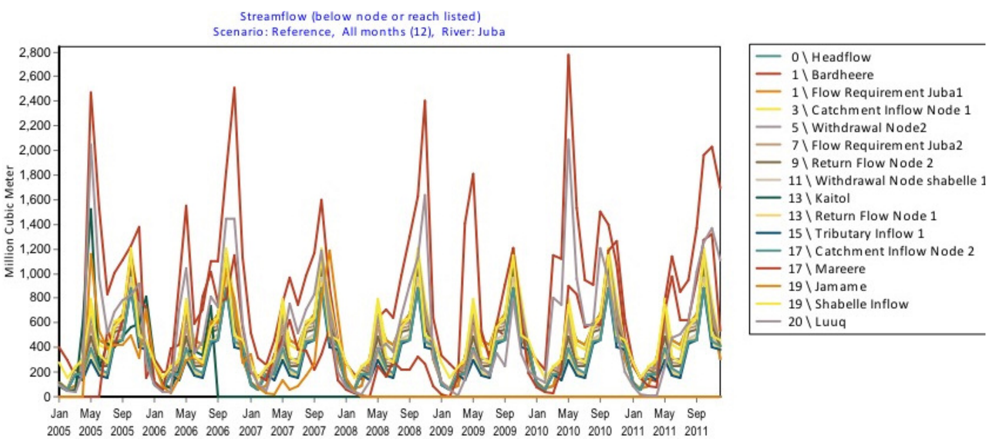


*Figure 3 - Measured and simulated stream flow at different location along the Juba River.*

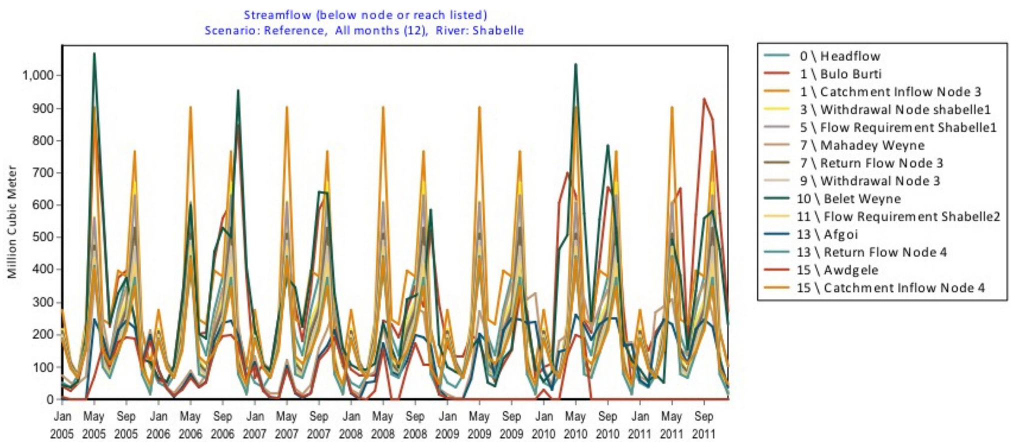


*Figure 4 - Measured and simulated stream flow at different location along the Shabelle River.*

Only Bardheere runoff station at Juba River showed an exception for simulated flow values during peak flow periods. Further analysis on this inconsistency should be done in a future study; this discrepancy occurred maybe due to the reason of questionable rating curves at the station,but the overall simulation in the two rivers is fitting well. Whereas, both fig. 3 and 4 indicate that the runoff stations and abstraction sites in both rivers well represent the observed and simulated stream flow.

***Scenario development***

In this study, the model was used to simulate five scenarios by considering the availability of irrigable land and infrastructure extension and population growth in the Juba and Shabelle River basins. The water uses from the two rivers are irrigation, domestic and livestock. Since, there is no reliable data sources for projection for livestock numbers, the water demands for the future were assumed to be similar with the present condition.

***Scenario 1 - Current water demand***

Figure 5 indicates the current scenario develop by using the current water irrigation coverage until 2035 in the basin. The current irrigation practice in the Shabelle and Juba River basins was 50,000 ha and 15,000 ha, respectively. Annual water use rate for irrigation in Juba and Shabelle River basins are 11 ,428 $m^3$/ha and 11,829 $m^3$/ha, respectively. A national population growth rate of 2.7% (UNEP, 2005) was used and combined with assumptions of the water demand per person. Based on Basnyat

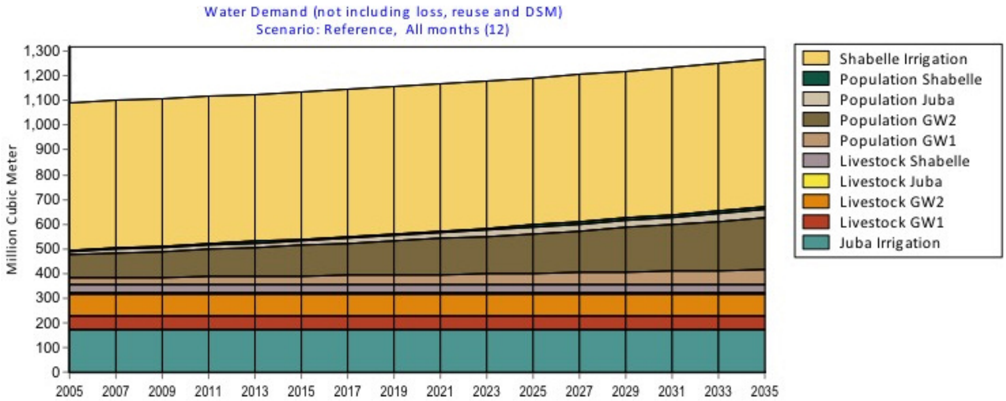


*Figure 5 - Current Water Demand.*

(2007) a per capita water demand of 20 l/d for the rural and 50 l/d for the urban population are assumed.

The irrigation annual water demand was along Juba 173.1 mcm and Shabelle 597.4 mcm and the domestic demand depends on the Juba and Shabelle Rivers were 14.5 and 5.5 mcm, respectively. The domestic demand abstracted from groundwater at location one (GW1) was 27.6 mcm and groundwater at location two (GW2) was 94.8 mcm. The livestock water demand was not predicated for the future since there is no data available for future projection.

***Scenario 2 - Existent schemes demand***

This scenario considers the water uses at different location in the river courses for irrigation in the constructed irrigation schemes from the rivers to irrigate 135,000 ha and 25,000 ha in the Shabelle and Juba River basins, respectively. The Juba River has much more irrigation potential along its basin and greater flow than the Shabelle River. In general, the irrigation infrastructure is much less constructed along the Juba River basin as compare to Shabelle River and this causes the irrigated area much lower than its potential as compare to its annual water discharge. There is much amount of water abstraction from the Shabelle River along its basin for irrigation uses (Figure 6).

If maintaining the existing irrigation infrastructure along the Juba and Shabelle Rivers, the irrigation water demands may increase to 337.6 mcm from the Juba River and 2,195.3 mcm in the Shabelle River during 2035. But, domestic demand will be same as scenario 2, 3 and 4 at both rivers.

***Scenario 3 - Water Demand during Minimum Flow***

Juba River flow during dry season is higher than in the Shabelle River. During this season it is possible to irrigate up to 17,000 ha at Shabelle River basin while 50,000

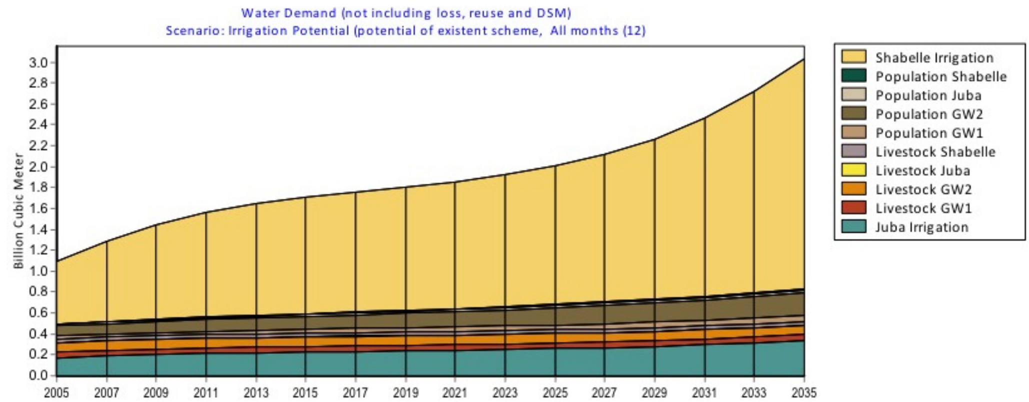


*Figure 6 - Water demand for irrigation if the constructed schemes fully operated*

ha along the Juba River. The irrigation water demand for 2035, along the Juba and Shabelle are 764.7 and 53.8 mcm, respectively. Irrigation coverage decreases more along Shabelle River as compare to Juba River since the river flow volume decreases (Figure 7).

***Scenario 4 - Water demand during maximum flow***

According to Basnyat and Gadain (2009), the maximum area that could be irrigated in the Juba and Shabelle River basins is 250,000 ha if irrigation extensions are made and the rivers flow is high. This scenario takes into account the proposed irrigation infrastructural extensions schemes are made, the basins can irrigate 80,000 ha in the Shabelle River basin and 170,000 ha along the Juba River during the wet

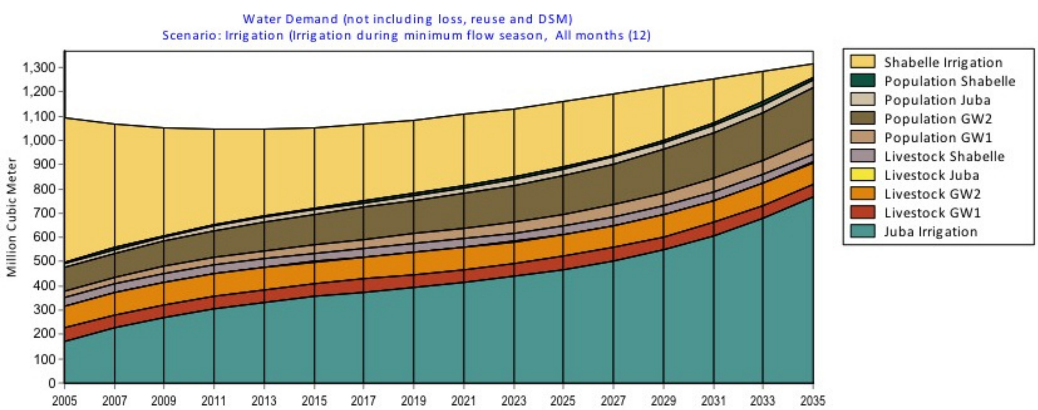


*Figure 7 - Demand during minimum flow.*

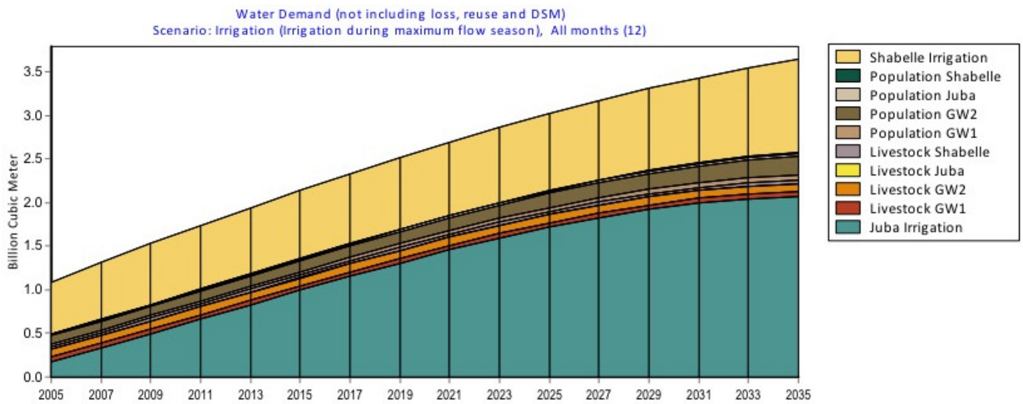


*Figure 8 - Demand during maximum flow.*

season. Irrigation annual water demand during 2035 will be 2,077.6 mcm and 1,075.3 mcm along the Juba and Shabelle Rivers, respectively (Figure 8).

***Scenario 5 - High population growth demand***

This scenario covers the future annual demand for a projected annual population growth rate of 3% until 2035 for domestic water demand scenarios. This assumes that future increase in water demand is proportional to the rate of population growth in the basin. Domestic water demand during 2035 will be 35.2 and 13.3 mcm in the Juba and Shabelle Rivers, respectively and at GW1 and GW2 domestic demand will be 67.0 and 230.2 mcm, respectively (Figure 9).

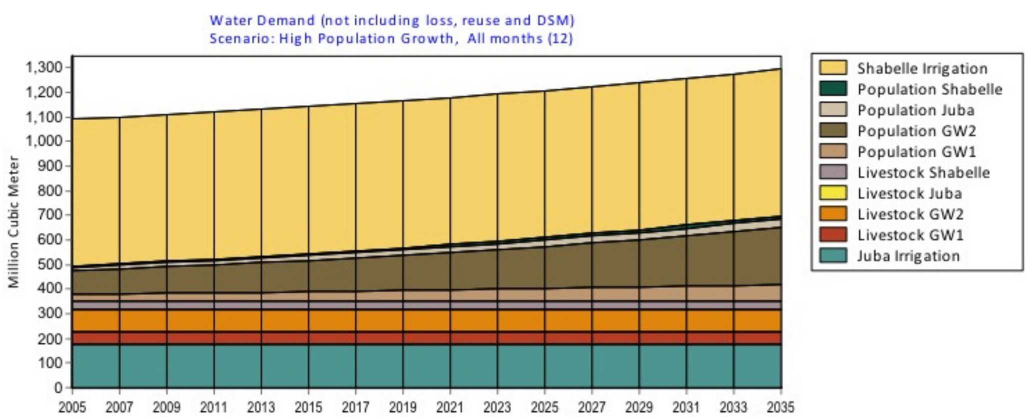


*Figure 9 - High population growth.*

*Table 1 - Available flow for environmental demand from two rivers at different months (mcm).*

| | JAN | FEB | MAR | APR | MAY | JUNE | JULY | AUG | SEPT | OCT | NOV | DEC |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Juba | 35 | 12 | 8 | 13 | 217 | 188 | 214 | 349 | 337 | 476 | 239 | 112 |
| Shabelle | 9 | 8 | 7 | 12 | 96 | 44 | 40 | 118 | 175 | 154 | 48 | 18 |

***Environmental Flow Demand***

The environmental flow is varying within a month and the result was computed using the 90% value of the flow duration curve. Only 20 % of the total annual Shabelle River flow volume has been available as environmental flow but at Juba River more than 40 % of the annual flow volume is available for ecosystem safety (Table 1).

***Water Supply Requirement***

If Irrigation structures are built along Juba River, the irrigation water will increase from 3.4% to 37.4%. However, the constructed irrigation canals at Shabelle River are not working properly, the water demand for irrigation after all structures rebuild will be increased from 18.2% to 64.1% of the annual river flow volume (Figure 10).

***Unmet demands***

The current irrigation practices at the Shabelle River develop a water deficit. The unmet demands highly occur at water use for irrigation especially during maximum water requirement. During scenario 2, the water demand on the Juba and Shabelle Rivers have highly unmet water requirements.

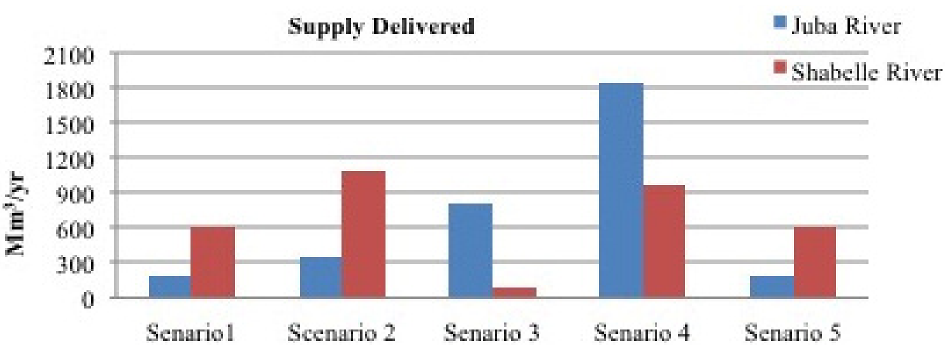


*Figure 10 - Supply delivered.*

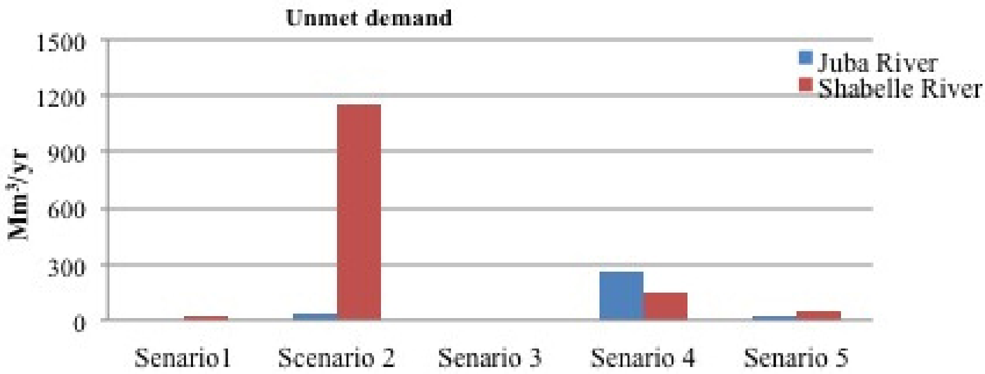


*Figure 11 - Unmet demand.*

## Conclusion

The irrigation coverage in the Shabelle River basin covers much of the irrigation practice in the country even if water deficit is common during peak growing season. In the future the water deficit will aggravate on this river due to expansion of irrigation structure, increase population and development of different sectors along its courses. The irrigation coverage and other practices along Juba River basin are much less as compare to its monthly and annual river flow volume. Juba River flow during in dry season in higher volume than from Shabelle River and join Indian Ocean without further uses for development. But still there is a high potential for irrigation and other development works at Juba River as compare to the annual volume of water that the river discharges. In general, the irrigation infrastructure is much less constructed along the Juba River basin as compare to Shabelle River and this causes the irrigated area much lower than its potential as compare to its annual water discharge. There is much amount of water abstraction from the Shabelle River along its basin for irrigation uses. Environmental flow requirement should be considered in advanced when developmental work plan either of the two rivers.

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