Technical Report

Somalia: Surface Water and Riverine Assessment

Cover photograph: Jubba river in Jamame. *(Photo courtesy: Ahmed Mohamed Hassan, Director of Hydrometeorology Department, Ministry of Energy and Water Resources, Federal Government of Somalia)*

Administrative support: Joy Mildred Adhiambo Mboya and Meseret Tsegaw Chekole

Editorial support and design: Anjali Dar Sengupta

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Somalia: Surface Water and Riverine Assessment

By: Klas Sandström

An accompanying report (of a suite of six reports) with

Economics of Water: Digging for Data—Towards Understanding Water as a Limiting or Enabling Factor for Socioeconomic Growth in Somalia

Contents

Abbreviations and Acronyms

FAO	Food and Agriculture Organization
FAOSTAT	Food and Agriculture Organization Corporate Statistical Database
Ha	Hectare
l/cap/day	Liter per capita per day
m^3/ha/year	Cubic meter per hectare per year
MCM	Million Cubic Meters
MCM/yr	Million cubic meter per year
km^2	Square kilometer
WASH	Water, Sanitation and Hygiene
WB	World Bank

Executive Summary

Surface Water in Somalia

The Jubba and Shabelle rivers are the only perennial rivers in Somalia. They both originate in relatively high rainfall areas in upstream Ethiopia, where 90 percent of their flow is generated before entering into Somalia. The Jubba flows all the way to, and enters into, the Indian Ocean, while Shabelle river ends in an area close to Jubba river along the coastline. For most years, Shabelle river is a closed basin, that is, all water is consumed within the basin limits, except during occasional years when very wet conditions cause the river to overflow and enter into Jubba river and the ocean.

The flow in Luuq, close to where Jubba river enters Somalia, is about 5,900 MCM/yr (million cubic meters per year). In the past as well as today, that volume is little reduced along the river's flow towards the ocean. The flow entering the Indian Ocean is about 5,000 MCM/yr. The same figures for Shabelle river are 2,400 MCM/yr in Beledweyne, the entry point into Somalia, and about 1,500 MCM/yr at the end point, an area of alluvial deposits close to Jubba river. It implies that the Jubba flow is more than twice that of the Shabelle, and only reduced by less than 20 percent from evapotranspiration, groundwater recharge, and utilization. The Shabelle, on the other hand, is almost halved by the same processes before drying up at the end.

The Shabelle river during dry season. *(Photo courtesy: Ahmed Mohamed Hassan)*

Water use in the Jubba basin is low (suitable land to irrigate is lacking), whereas the Shabelle basin contains extensive areas suitable for irrigated agriculture. The Lower Shabelle is often referred to as the "bread basket of Somalia". However, with river infrastructure (dams, barrages, irrigation canals) in poor shape, due to many years of conflict and lack of maintenance, food production (2021) is today far below past levels.

Water Supply

Climate change and upstream development in Ethiopia are likely to have major future effects on downstream Somalia. The effects differ between the two rivers. Jubba river has a large and steady flow and will not change much. There will be much water available for development throughout that basin. However, Shabelle river faces major changes in coming decades. Given today's predictions about climate change, the total annual volume of water may not change much; if anything, it may increase slightly (Tierney et al. 2015), but increased runoff variability may cause difficulties in downstream areas. That can include the entire river to, both, dry up at irregular frequencies (as in 2016–2017) and a reduced probability that minimum flow volumes are available at specific periods during the year. Furthermore, if an existing Master Plan for development in upstream Ethiopia is implemented, the downstream flow will be massively reduced and agriculture will change fundamentally.

Table 1 shows the flow in MCM/yr in five locations along the two rivers in Somalia. The flow is given as a mean value and as minimum flows to be exceeded at three different time scales (as an example: in Beledweyne, in the Shabelle, mean annual total is 2,460 MCM/yr, but only 473 MCM/yr will be exceeded at 80 percent of the time. A level of 80 percent [or higher] is required for most crops to grow well.[1] Floods are likely to occur at 20 percent or less of the time when the flow exceeds 4,320 MCM/yr).[2]

Table 1. Annual Flow at Five Locations along Jubba and Shabelle in Somalia (in MCM/yr)

Jubba	Mean	20%	50%	80%	Shabelle	Mean	20%	50%	80%
Luuq	5,866	9,398	4,762	978	Beledweyne	2,460	4,320	1,892	473
Baardhere	6,086	9,618	4,888	1,135	BuloBurti	2,176	3,816	1,545	315
Marera	5,866	10,028	4,636	1,009	M. Weyne	2,050	3,942	1,671	410
Kaitoi	5,645	9,492	4,857	1,135	Afgoi	2,208	3,816	1,577	315
Jamame	5,298	9,240	4,478	851	Awdhegle	1,419	2,460	1,451	284

It should be noted that the above calculations represent long-term annual averages (monthly values added together) for the period 1964–1989, that is, at a time when climate change was not yet marked and water was used by a population that was much smaller than the one today. The above numbers represent interannual variability in the range of +/-75 percent; inter-monthly variability exceeds +/-100 percent.

How water supply will develop in coming decades is difficult to predict, but assuming upstream development in Ethiopia in combination with a drought year (reducing inflow by 30 percent), the following numbers (in Table 2) on mean annual runoff for Luuq and Beledweyne may develop. The year 1990 is included as a baseline.

Table 2. Estimates for Mean Annual Runoff for Luuq and Beledweyne

Luuq/ Beledweyne	1990		2020		2035		2050	
	Jubba	Shabelle	Jubba	Shabelle	Jubba	Shabelle	Jubba	Shabelle
Baseline inflow	5,866	2,460	5,866	2,460	5,866	2,460	5,866	2,460
Ethiopia reduction	0	0	0	0	-885 (15%)	-840 (35%)	-1,180 (20%)	-1,920 (80%)
Climate change reduction	0	0	-1,700	-700	-1500	-500	-1,400	-160
New net inflow	5,866	2,460	4,166	1,760	3,481	1,120	3,286	380

New net inflows' values should be compared with the baseline inflow in Luuq and Beledweyne. For example, the new net inflow in Beledweyne is 380 MCM/yr, as compared with the baseline inflow of 2,460 MCM/yr. The reduction is massive and, if happening, will have major implications on downstream conditions in Shabelle. On top of this are the minimum assured flow concerns, reducing useful amounts of water even further, as discussed above.

[1] FAO Somalia, personal communication.

[2] The total numbers for inflow in Luuq and Beledweyne are not stated exactly as 5,900 and 2,400 MCM/yr, respectively, in this table. As two different sources of data, differing slightly, are used for this presentation, the difference is kept where relevant.

In terms of water supply, are the risks and vulnerabilities to agriculture and livelihood systems significant? As noted before, Jubba river will be little affected, but in Shabelle river climate change and upstream development will potentially reduce required minimum amounts of water at given time intervals and for areas in need of water. This will increase the risk of crop failure and how agriculture is planned and practiced. There are many coping mechanisms for this, such as the construction of dams to regulate runoff, improve water use efficiency, and to change from livelihood crops to cash crops. Still, if the inflow of water is reduced to possibly 10–20 percent of today's baseline flow, no coping mechanism can manage the situation.

To what extent can the above supply figures be sustainable and support specific uses depends on how much water is needed and for how long a period. Total annual amounts do not provide enough information. The variability is so large that supply figures must be assessed in terms of specific needs.

The effect of climate change is also difficult to adequately assess and present. This report includes a 30 percent reduction in streamflow in some calculations (see above), but how often that happens—for example, every second, third or fifth year—and those implications are not included. That requires a full-scale hydrological model and considerable time and resources.

Water Demand and Need

The demand for water is huge in Somalia, but suppressed by the user's ability to pay for costly water or to collect it from faraway locations. The need for water—to grow more food, maintain better hygiene, initiate businesses—is equally large. Both terms are linked to conditions existing in the two river basins. These conditions are presented in Table 3 as a baseline (1990), the present time (2020), and two future conditions (2035 and 2050).

Table 3. Basin Conditions

Basin Parameters	1990		2020		2035		2050	
	Jubba	Shabelle	Jubba	Shabelle	Jubba	Shabelle	Jubba	Shabelle
Population (million)	0.9	1.6	2.1	3.5	3.1	5.2	3.9	6.5
Livestock (million)	4.1	6.7	4.0	6.7	6.1	10.2	7.7	12.8
Irrigated land (1,000 ha)	46	62	15	50	25	80	25	32
Industry & services	–	–	–	–	–	–	–	–

Converting these conditions into needs for water depends on what level of human well-being is desired as a basis for calculations. If the level chosen is subsistence lifestyles, relatively little water is required per person per day for basic food and water, sanitation and hygiene (WASH) needs. However, if higher levels of well-being are planned, more water is needed. In a dry and poor environment, the need for water is typically much higher than the supply can offer in realistic terms. Table 4 presents water needs that can be satisfied by available supply conditions in Jubba and Shabelle basins and based on such living conditions that are found in a poor, dry environment.

Table 4. Water Needs Supplied in Jubba and Shabelle Basins

Basin Parameters (MCM/yr)	1990		2020		2035		2050	
	Jubba	Shabelle	Jubba	Shabelle	Jubba	Shabelle	Jubba	Shabelle
Household WASH	8	13	19	31	29	49	43	71
Livestock drinking	11	19	16	27	25	42	36	60
Irrigated agriculture	515	679	165	550	275	880	275	348
Industry & services	–	–	–	–	?	?	?	?
Environmental flows	590	240	590	240	590	240	590	

It is important to note that the above supplied water needs are based on long-term annual flows of water. For specific dry season months or dry years, enough water is not necessarily available to satisfy stated needs. As an example, for scenario 2050, there is not enough water available to irrigate all land that is potentially available in the Shabelle basin for agriculture or to satisfy the needs of environmental flows.

Resilience in Riverine Areas

Resilience in the two-river area in Southern Somalia should be based on some key conditions (MoEWR 2021a): blue water agriculture delivers about 10 percent of all food consumed in Somalia. This is a small share and will not change much in coming decades. The remaining food is derived from green water agriculture (55 percent) and imports (35 percent). The share that imported food represents is likely to increase in coming years. Altogether, this implies that blue water resilience is used to support and supplement green water agriculture, livestock rearing, high-value uses, and possibly, over time, urban industry and services.

Many opportunities exist in the Jubba basin to expand water use in irrigated agriculture—including both subsistence farming and large-scale cash crop production for export—and for WASH needs and urban industry and services to develop. Over the foreseeable future, there will be enough water to support such activities. Baardhere Dam, once planned in upstream sections but never built, can emerge as a potential investment opportunity to promote, for example, banana agriculture for export.

The risks in terms of climate change and upstream development in the Jubba basin are limited. The main limitations to expanded water use are the lack of suitable land to irrigate and, potentially, increasing temperatures due to climate change. That may be a serious future limiting factor in low-altitude agriculture.

On the other hand, the Shabelle basin is a very different context compared to the Jubba basin. Resilience is a major issue in Shabelle development. It can be addressed in many ways, including formulating rules and knowledge management about water allocation, rehabilitating river infrastructure (and thus increasing food production by reducing flow variability by building dams and barrages), increasing agriculture water use efficiency by introducing new farming systems), and promoting regional development and win-win opportunities by linking Ethiopia’s and Somalia’s water plans together. Still, the major risks—climate change and upstream development—loom high in Shabelle development. If these come true, the future of the Shabelle will be very different compared to the past. But until that happens, development must continue, albeit by an inclusion of risk in planning.

Support to Urban Development

Blue water, as found in the riverine areas of Southern Somalia, is a scarce commodity. Whenever possible, it should be allocated to higher-value uses such as household consumption (WASH), cash crops, intensive small-scale urban agriculture, stall-feeding of high-value livestock, industry, and urban services. Urban development should have precedence over low-value rural use of water. Such water use can be enhanced by improved farming systems, supplemental green-blue water applications, and new crops. As long as that does not happen, however, urban needs should have priority.

Napier grass being collected in a commercial fodder farm in neighboring Kenya. (*Photo courtesy: Wikimedia Commons/Kamweti wa Mutu*)[3]

The viability of developing and scaling up water-use efficient agriculture—both in urban and rural areas—exists. It requires secure water supplies (in terms of both allocation rights and physical variability), new knowledge and farming systems, and access to the food market. Investments in roads and accessing agriculture information are key inputs into such systems. Given that a market demand exists—much food is imported to urban areas and paid for in cash—opportunities surely exist as well. To support livestock export by setting up a chain of feedlots—supported by nearby commercial fodder farms (as in the picture above), which shows Napier grass being collected in Kenya)—that connect countryside with coastline export ports is a high-value use of available blue water resources.

[3] This photo is taken from: https://en.wikipedia.org/wiki/Cenchrus_purpureus

Introduction

This technical report[4] analyses the impact of four parameters—upstream transboundary investments, climate change, runoff variability, and sectoral demands—on downstream surface water flow in the Jubba and Shabelle rivers in Somalia.

The Executive Summary presents an overview of the report. The different parameters are then presented in greater detail in subsequent chapters. The report analyzes four different scenarios from the past, present and future of Somalia: in the 1990s (before civil strife escalated); today (that is, 2020); in 2035; and in 2050.

Upstream transboundary investments are judged to be the most important of the above four parameters. The potential effect of basin investments in Ethiopia on downstream flow is huge—the Shabelle river could dry up for long periods, in particular, in the lower parts where most irrigated agriculture takes place (the Jubba river will be less affected). If such plans are implemented, and they exist today as a Master Plan for the Ethiopian sections of upstream Shabelle basin, the fundamentals for investments in the Shabelle basin will change. A similar game-changer is also valid for potential changes in runoff due to climate change. While total rainfall amounts may remain the same, or even increase slightly (WB and FAO 2018), the variability is predicted to increase and likely to cause harm to downstream users. This—very much demonstrated by the dry Shabelle river in 2016 and 2017 (as in the photo at right) and in everybody's mind today—may have huge impacts on today's investment plans. The scenarios presented here, including two with upstream development, may come true—or not at all. Only the future will tell.

The dry Shabelle river in 2016. *(Photo courtesy: Ahmed Mohamed Hassan)*

However, plans exist and efforts are ongoing to get teams from Ethiopia and Somalia together for trust-building activities and to agree to meet and discuss shared water concerns. Such transboundary issues are being promoted as regional development, win-win, and having shared benefits. A

[4] This technical report is one of a suite of six supporting documents along with the 'Economics of Water: Digging for Data—Towards Understanding Water as a Limiting or Enabling Factor for Socioeconomic Growth in Somalia' report. The other five supporting documents comprise: (a) three technical reports (Somalia: An Institutional Analysis Report; Somalia: Groundwater Assessment Technical Report; and Water+ in Somalia: A Sectoral Analysis); (b) Somalia: Groundwater Quality Technical Note; and (c) a Summary Report. All the reports can be accessed at: the Ministry of Energy and Water Resources' website (https://moewr.gov.so) [the reports will be available in 2022 as the site is currently under development]; the World Bank's Water Global Practice website (https://www.worldbank.org/en/topic/water); as well as the World Bank's Somalia website (https://www.worldbank.org/en/country/somalia).

downstream "right to water" perspective is discouraged, as it is unlikely to succeed given the very asymmetric power conditions that exist in the basins (MoEWR 2021b).

A simple hydrological model was developed for this report in order to study the two rivers. It was developed as a subcomponent to a larger national model assessing alternative water resources management options and their linkages to water and food security, trade, and diaspora remittances. The Jubba and Shabelle basins' submodel uses annual data on rainfall and runoff, water and land use, population dynamics, and livestock and environmental needs for water. Data are mainly derived from four sources: Basnyat (2007), World Bank and the Food and Agriculture Organization (2018), Michalscheck et al. (2016), and FAOSTAT[5] (2020). Generally, data are of very varying quality, often of questionable quality, and sometimes based on assumptions and guesstimates. In using the data, there is often a need to simplify and use numbers that seem reasonable.

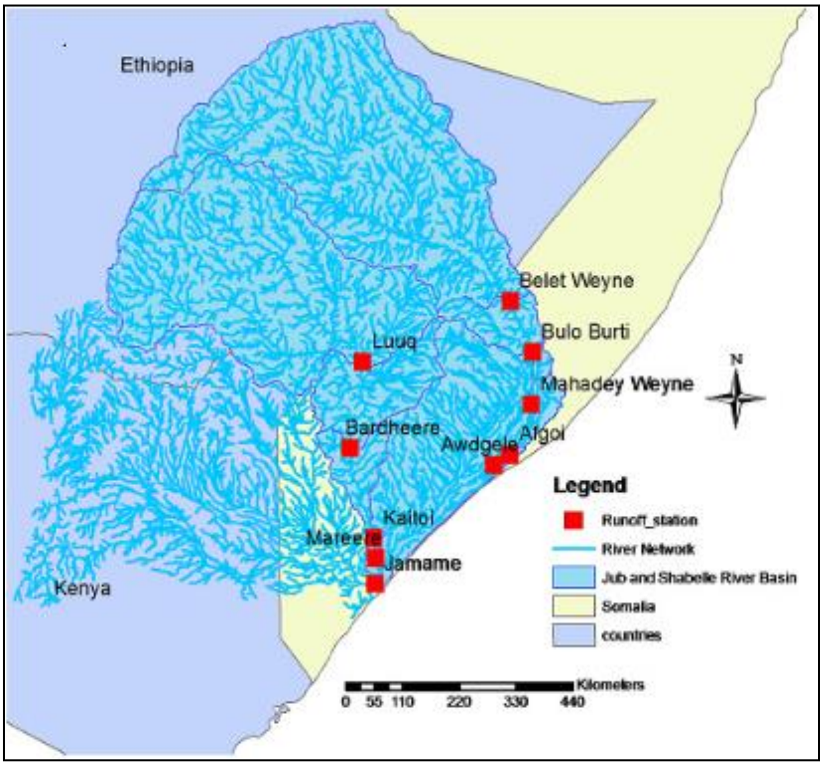
Given data quality, the generated results should be taken with some caution. Specific numbers are, by default, not true; it is impossible to generate 'true' results, but scale issues and how different results compare with each other are more likely correct. Similarly, the scenarios made for 2035 and 2050 are, as all scenarios, merely projections of today into a future that we know little about. The scenarios should be used for what they are worth, remembering that much will change between today and 2050.

[5] The Food and Agriculture Organization Corporate Statistical Database.

1 Jubba and Shabelle Basins

The Jubba and Shabelle rivers are the only perennial rivers in Somalia, with 90 percent of their flow originating from neighboring Ethiopia. The Jubba river has three main tributaries in its upper catchment in Ethiopia: the Dawa, Genale and Weyb, all of which flow southeastwards. The Weyb and Genale unite to form Jubba river just north of Doolow in Ethiopia; the Dawa tributary joins the Jubba in Doolow Town, just after the Somalia-Ethiopia border. The total length of Jubba river is 1,800 km, with a catchment area of about 210,010 km^2 (square kilometers). The Shabelle river emerges on the eastern Ethiopian highlands at an altitude of about 4,230 meters. It has two main tributaries in the Ethiopian catchment: the Fanfan and Shabelle. The flows of the Fanfan tributary are intermittent, and only join the Shabelle during high rainfall seasons. The river is 2,526 km long, with a catchment area of 283,000 km^2. Figure 1 shows the joint catchment area, with the location of river runoff gauging stations also shown. Runoff in these stations is given in Chapter 4.

Figure 1. The Jubba and Shabelle Basins



The alluvial plains of the Jubba and Shabelle in Somalia have been described as the “breadbasket of Somalia”. For many decades—or centuries—irrigated agriculture has been practiced along these plains, producing food not only for local consumption but also for export. The waters of the two rivers have also supported livestock rearing. Available records indicate that before the collapse of the former Somali government in 1990, over 220,000 hectares (ha) of land along the flood plains were under either controlled irrigation or recession farming. Maize, sesame, fruits, and vegetables were some of the crops grown for local markets, while sugarcane and rice were grown for both local and foreign markets. A major export product was bananas. A large dam, the Baardhere dam, was planned on the Jubba river but it was never built following upstream Ethiopian concerns.

Today, however, the situation has changed. Irrigated agriculture along the lower Shabelle is reduced. According to available information, not one of the large barrages (eight on Shabelle, one on Jubba) is functioning. Due to the civil war and a lack of opportunities to maintain installations—not only the barrages but also irrigation canals, locks, and irrigated lands—this system is not working well today. The opportunities to rehabilitate and restore parts of the past production capacity exist, but that requires major investments, cooperation between state and federal governments, and safe working conditions.

2 A Water Balance Model

The model uses a set of linked excel spreadsheets. It is easy to use and can be adapted to new conditions. All entry data and specific parameters are separated from calculations and thus easily adapted to new knowledge and conditions. The model includes the following parameters.

2.1 Potential Upstream Basin Development in Ethiopia

In addition to already existing upstream river infrastructure and abstractions, the Ministry of Water Resources in Ethiopia has developed a Master Plan (Ministry of Water Resources 2005) for upstream river investments. Implementation is delayed, but the use of water in agriculture and in domestic and livestock sectors is projected to increase in order to meet a growing population's demand for water and food (Michalscheck et al.2016). When this will happen, and how downstream flow will be affected, is unknown. Still, several dams for hydropower generation are planned and, if implemented, would change current flow patterns fundamentally.

Besides such nonconsumptive uses, the implementation of planned irrigated agriculture projects entails potentially massive expansion of water use. The model takes this into account by reducing downstream flow by 15 percent and 30 percent in 2035 for the Jubba and Shabelle, respectively, and by 20 percent and 80 percent, respectively, in 2050.

2.2 Climate Change and Runoff

Rainfall is predicted to come down in heavier events and hence floods are likely to become more frequent in the Jubba and Shabelle basins (Petersen and Gadain 2012). This is compatible with predications indicating higher average rainfall in the Horn of Africa in coming decades (Tierney et al. 2015). Droughts are also likely to become more frequent, as an outcome of greater rainfall variability, both seasonally and interannually (WB and FAO 2018).

In the model, runoff below Luuq (Jubba river) and Beledweyne (Shabelle river) can be reduced as an outcome of droughts in the region. This can be done by setting a chosen percentage reduction (for example, 10 percent) and a specific frequency of occurrence (for example, every fourth year). It directly affects the availability of water below these points.

However, due to the irregular frequency of floods and drought, and time and data constraints, the climate impact is not included in the main modeling work that delivers predictions of water availability. In the tables presenting modeled results, this impact is set as zero. However, a climate effect—reducing runoff by 30 percent from upstream—is included in summary results presented in the Executive Summary.

Similarly, the rainfall-runoff coefficient, linked to land use and rainfall intensity, is also assumed to not change over time. A full hydrological model would be required to assess that effect on downstream runoff.

2.3 River Flow Probabilities

A flow probability is the percentage of time the flow will exceed a certain discharge volume (this is useful in planning activities that require a minimum of water for a certain length of time). Decreasing flows and their probability at 20 percent, 50 percent, and 80 percent are given for five locations in each basin within Somalia. The probability is given for the annual total runoff (in a certain location) and, as such, reflects both interannual variability and intraannual variability (between dry and wet seasons).

The latter, if assessed separately, implies an additional variation of +/-75 percent and +/-150 percent, respectively, on given long-term average (1964–1989) flow numbers. Furthermore, given that the probability curves were developed based on runoff between 1964 and 1989, and that the occurrence of droughts and floods have increased over time (Federal Directorate of Environment and Climate Change 2020), the discharge likely to be exceeded at certain timeframes is probably lower today. The general deterioration of flood control and river regulation infrastructure, including deposition of sediments, has further increased water flow variability.

2.3.1 Population Growth

For all four periods studied (the 1990s, 2020, 2035, and 2050), population numbers are taken from Worldometer (based on United Nations Population Division). Numbers refer to Somalia at large. Southern Somalia is assessed to represent 43 percent of the population, with Jubba basin water servicing 30 percent and the Shabelle 50 percent of this, and the remaining 20 percent depending on groundwater in the in-between areas.

2.3.2 Water Allocation and Use

Four uses have been identified and modeled: household WASH, livestock (drinking only), irrigated agriculture, and environmental flows. They are allocated in that specific order of priority. If water becomes scarce, it is the last in priority that runs dry first.

The dry Shabelle river in 2016. *(Photo courtesy: Ahmed Mohamed Hassan)*

Household WASH is based on the number of people, level of urbanization, and use as follows: urban poor (50 percent) 20 l/cap/day, urban non-poor (50 percent) 40 l/cap/day, rural (all) 20 l/cap/day. Livestock, as a weighted average of current animal types, consume 4 MCM/1 million animals/year (from the rivers) and include about 10 million in Southern Somalia (in total). Numbers are set to grow in parallel with population growth.

Actual irrigated agriculture water use depends on whether water and land is available, and if any of the two limit the use. Irrigated agricultural water use is based on 11,000 m^3/ha/year (Basnyat 2007). This figure, an average of reported locations, is based on field crop water requirements and irrigation demand calculated using CROPWATER, an FAO agriculture water software. Environmental flows are calculated as 10 percent of the 2020 inflow, thus being 590 MCM/yr and 240 MCM/yr for the Jubba and Shabelle, respectively (Basnyat 2007).

Based on the above, the model provides a simple water balance. Inflow from upstream Ethiopia is reduced by any upstream development. The effects of climate change are not included in the tables and graphs below as already discussed.

The received net inflow is reduced by household WASH, livestock, irrigated agriculture, and environmental flow. This reduction is shared *equally* among all five sections of the two rivers (named as below). For the Shabelle this may imply a too large use in the upstream part, as compared with the downstream areas where large irrigated fields exist. This can be further studied.

The derived ocean runoff/excess is either entering the Indian Ocean (Jubba river) or feeding groundwater along the basin or in the very end (in the case of the Shabelle).

Stated rainfall amount is calculated for the Somalia sections of the two basins. What falls within irrigated land adds to food produced, otherwise it contributes to infiltrated green water and potential rainfed agriculture and livestock feeding. This water is transpirated or evaporated back to the atmosphere, except for 3 percent that recharges groundwater. Internal runoff that feed the two rivers is not included in the model, due to lack of data. The amount can be substantial in places, but not compared to full river flows. The scale differences between transpiration/evaporation and water productively used in agriculture should also be noted. A small reduction in transpiration/evaporation can enable a big increase in water productively used in agriculture. Improved land management can benefit productive transpiration (that is, growing food) and produce 50–200 percent more food per land area and given rainfall.

The tables in Chapter 4 present water flows as MCM/year (million m^3 per year). Converted into m^3/second, the numbers turn much smaller—100 MCM/yr is equal to about 3 m^3/second of river flow.

3 Four Scenarios and Four Water Balances

The four scenarios presented here include a baseline, present conditions, and two future conditions.

Data used in developing the four scenarios have been taken from Basnyat (2007) and Michalscheck et al. (2016). In brief, the scenarios represent the following conditions.

3.1 A Baseline: The 1990s

This represents conditions before internal strife worsened in Somalia, when most people lived in rural areas, the water flow in Jubba and Shebelle rivers followed well known and reliable patterns, and all the (eight + one) barrages were in place and contributed to large-scale irrigated agriculture. This amounted to about 45,000 ha and 60,000 ha, in the Jubba and Shabelle, respectively.

Basin populations for the Jubba and Shabelle were about 0.9 and 1.6 million, respectively. Upstream Ethiopian use of upstream water was negligible.

3.2 The Present: 2020

Following many difficult years, urbanization is pronounced; the two rivers, and in particular the Shabelle, show an increasingly variable and unreliable flow. The Shabelle basin irrigation system has degraded and all barrages are dysfunctional. The irrigated area in the Jubba and Shabelle is 15,000 ha and 50,000 ha, respectively (Shabelle possibly less).

Basin populations for the Jubba and Shabelle are 2.1 and 3.5 million, respectively. Ethiopian use of upstream water is still negligible.

3.3 Modest Change: 2035

By this time, the population is larger and even more people are urbanized. River flows are even further variable and unreliable, especially in Shabelle river, and farmers face difficulties in planning their irrigation schedules.

The preconflict river infrastructure has been restored and expanded, and irrigated agriculture production has increased to the largest area ever found in the Jubba and Shabelle: 25,000 ha and 80,000 ha, respectively. Inflow from upstream Ethiopia is reduced by 15 percent and 30 percent for the Jubba and Shabelle, respectively, but as an outcome of upstream dams may also provide some reduced variability, an effect benefitting downstream Somali farmers.

The populations in the Jubba and Shabelle basins are 3.1 and 5.2 million, respectively.

3.4 Major Change: 2050

The two basins are now significantly altered, very much as an outcome of population growth and upstream Ethiopian development. Urbanization, partly driven by an exodus from rural areas, is about 65 percent of the population, and river flows are very different compared with 50 years previously.

While irrigation infrastructure was restored and expanded in the 2030s, it cannot be fully utilized in 2050 due to a lack of water (in Shabelle river). Following large scale development in Ethiopia, inflow has been reduced by 20 percent in the Jubba and 80 percent in the Shabelle, and merely 32,000 ha of land can be irrigated in the Shabelle (57 percent less than in 2035).

Downstream flow is very low, in particular during dry and semi-dry months, probably implying a dry river for extensive periods. Environmental flows and/or groundwater recharge have dried up.

Farmers in upstream locations may benefit from reduced inflow variability, as an outcome of Ethiopian investments, and thus maintain functioning irrigation systems. However, downstream farmers will suffer from changes that are likely to take place. This includes increased flow variability, likely to cause many problems to downstream farmers.

The populations in the Jubba and Shabelle basins are 3.9 and 6.5 million, respectively.

4 Water Supply, Allocation, and Use

4.1 Summarized Flows of Water

Based on water supply, allocation, and use, the four scenarios outlined in Chapter 3 deliver annual amounts as presented in Table 5.

Table 5. Four Water Balances in Jubba and Shabelle Rivers

Parameter/Basin	1990+		2018		2035		2050	
	Jubba	Shabelle	Jubba	Shabelle	Jubba	Shabelle	Jubba	Shabelle
Total precipitation (MCM/yr)	19,890	29,403	19,890	29,403	19,890	29,403	19,890	29,403
Gross runoff 2018 (MCM/yr)	5,900	2,400	5,900	2,400	5,900	2,400	5,900	2,400
Upstream diversion reduction (MCM/yr)	0	0	0	0	885	840	1,180	1,920
New downstream flow (MCM/yr)	5,900	2,400	5,900	2,400	5,015	1,560	4,720	480
Climate change reduction (MCM/yr)	0	0	0	0	0	0	0	0
Inflow Somalia (MCM/yr)	5,900	2,400	5,900	2,400	5,015	1,560	4,720	480
Household WASH use (MCM/yr)	8	13	19	31	29	49	43	71
Livestock drinking (MCM/yr)	11	19	16	27	25	42	36	60
Irrigated agriculture (MCM/yr)	515	679	165	550	275	880	275	348
Environment (MCM/yr)	590	240	590	240	590	240	590	0
Ocean runoff/Excess (MCM/yr)	4,776	1,449	5,110	1,552	4,096	350	4,096	0
Rangeland transpiration (MCM/yr)	5,788	8,556	5,788	8,556	5,788	8,556	5,788	8,556
Rangeland evaporation (MCM/yr)	13,505	19,965	13,505	19,965	13,505	19,965	13,505	19,965
Population (Million)	0.9	1.6	2.1	3.5	3.1	5.2	3.9	6.5

The parameter "Inflow Somalia" represents the amount of water per year that enters Somalia from Ethiopia. It is derived from a baseline inflow of 2,400 MCM/yr ("Gross runoff" from Ethiopia) with potential reductions in terms of upstream development and climate change effects (although, as noted above, it is not applied here as data are not available about future potential effects of climate change). All figures are based on people and livestock utilizing water derived from the rivers. People and livestock in southern Somalia are assumed to be distributed as 30 percent in the Jubba basin, 50 percent in the Shabelle basin, and 20 percent (depending on groundwater) in the in-between areas.

4.2 Water Use and Flow Distribution

Table 6 provides a baseline inflow of water in Luuq (Jubba river) and Beledweyne (Shabelle river) and at four additional downstream stations in each basin. Calculations are based on data collected between 1964 and 1989. Given that data are old, it is assumed that the flow distribution in each river represents a "natural" state, with limited amounts of water diverted for agriculture or human consumption. The reduced flow that occurs is due to evapotranspiration and groundwater recharge. The four flow categories represent the (i) annual average flow; (ii) minimum flow exceeding 20 percent time-wise; (iii) minimum flow exceeding 50 percent time-wise; and (iv) minimum flow exceeding 80 percent time-wise. This table remains the same for all four scenarios.

A distributed profile of water flow in the basins has been calculated for each scenario. It is based on the above calculated "Inflow Somalia" and reduced by the four defined uses (WASH, livestock, irrigated agriculture, environmental flow), being shared as 20 percent for each of the five sections in each basin (names as below). As noted above, maybe this allocates too much water used in upstream Shabelle sections, but until more is known about this, the distribution works well.

Table 6. Water Probabilities to Exceed Alternative Flow Durations in Five Locations in Jubba and Shabelle River Basins

Jubba (m^3/s)					Shabelle (m^3/s)				
	Mean	**20%**	**50%**	**80%**		**Mean**	**20%**	**50%**	**80%**
Luuq	186	298	151	31	**Beledweyne**	78	137	60	15
Baardhere	193	305	155	36	**BuloBurti**	69	121	49	10
Marera	186	318	147	32	**M. Weyne**	65	125	53	13
Kaitoi	179	301	154	36	**Afgoi**	70	121	50	10
Jamame	168	293	142	27	**Awdhegle**	45	78	46	9

For each scenario, a table and two figures have been developed (below). The table shows the river flow in the five locations in each river after the four types of uses have been deducted from the four types of flows (Mean, 20 percent, 50 percent, and 80 percent). Deductions accumulate downstream. The figures plot the four flows for each river. Do note the different y-scales. The Jubba flow is, at all times, much larger than the Shabelle flow.

4.2.1 A Baseline: The 1990s

Table 7. Mean and Flow Durations for 1990 in Five Locations in Jubba and Shabelle River Basins after Use Has Been Deducted

Reduced with uses along river. All negative values turned 0 (MCM/yr)									
Jubba	**Mean**	**20%**	**50%**	**80%**	**Shabelle**	**Mean**	**20%**	**50%**	**80%**
Luuq	5,641	9,173	4,537	753	**Beledweyne**	2,270	4,130	1,702	283
Baardhere	5,637	9,169	4,438	686	**BuloBurti**	1,795	3,435	1,165	0
Marera	5,191	9,354	3,961	335	**M. Weyne**	1,479	3,371	1,101	0
Kaitoi	4,746	8,593	3,957	236	**Afgoi**	1,446	3,055	816	0
Jamame	4,174	8,116	3,354	0	**Awdhegle**	468	1,508	499	0

Figure 2. Jubba Flow Duration Curve, 1990s

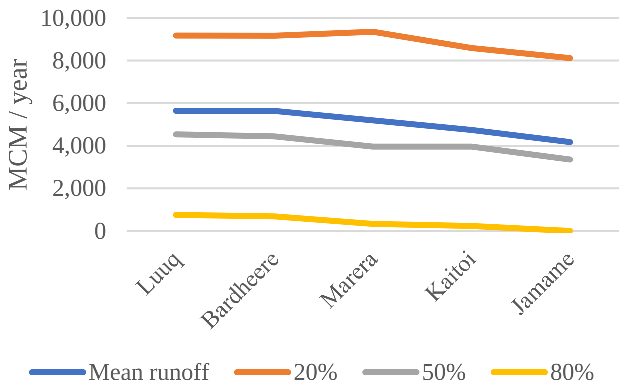
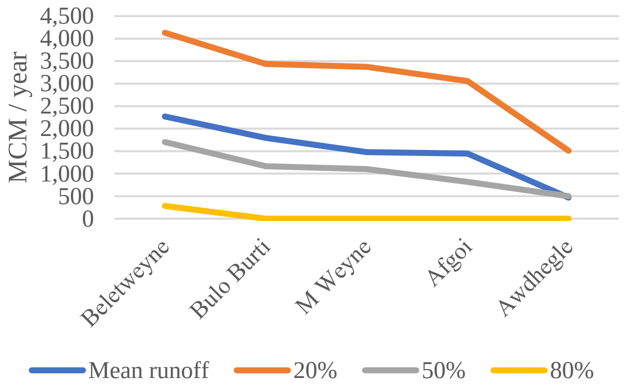


Figure 3. Shabelle Flow Duration Curve, 1990s



4.2.2 The Present: 2020

Table 8. Mean and Flow Durations for 2020 in Five Locations in Jubba and Shabelle River Basins after Use Has Been Deducted

Reduced with uses along river. All negative values turned 0 (MCM/yr)									
Jubba	**Mean**	**20%**	**50%**	**80%**	**Shabelle**	**Mean**	**20%**	**50%**	**80%**
Luuq	5,708	9,240	4,604	820	**Beledweyne**	2,290	4,151	1,723	304
Baardhere	5,771	9,303	4,572	819	**BuloBurti**	1,837	3,477	1,206	0
Marera	5,392	9,555	4,162	535	**M. Weyne**	1,541	3,433	1,163	0
Kaitoi	5,013	8,861	4,225	504	**Afgoi**	1,529	3,138	899	0
Jamame	4,509	8,451	3,689	62	**Awdhegle**	572	1,612	603	0

Figure 4. Jubba Flow Duration Curve, 2020

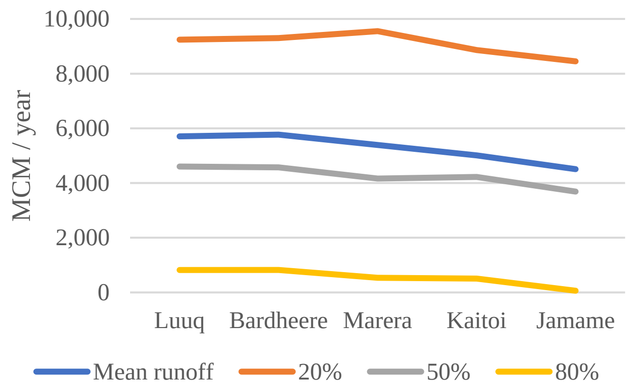
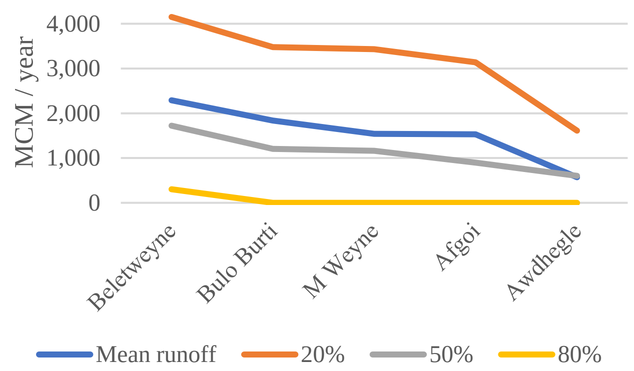


Figure 5. Shabelle Flow Duration Curve, 2020



4.2.3 Modest Change: 2035

Table 9. Mean and Flow Durations for 2035 in Five Locations in Jubba and Shabelle River Basins after Use Has Been Deducted

Reduced with uses along river. All negative values turned 0 (MCM/yr)									
Jubba	**Mean**	**20%**	**50%**	**80%**	**Shabelle**	**Mean**	**20%**	**50%**	**80%**
Luuq	4,802	7,804	3,864	647	**Beledweyne**	1,357	2,566	988	65
Baardhere	4,806	7,808	3,787	597	**BuloBurti**	930	1,996	520	0
Marera	4,434	7,973	3,389	306	**M. Weyne**	606	1,836	360	0
Kaitoi	4,063	7,333	3,393	230	**Afgoi**	467	1,512	57	0
Jamame	3,584	6,935	2,887	0	**Awdhegle**	0	389	0	0

Figure 6. Jubba Flow Duration Curve, 2035

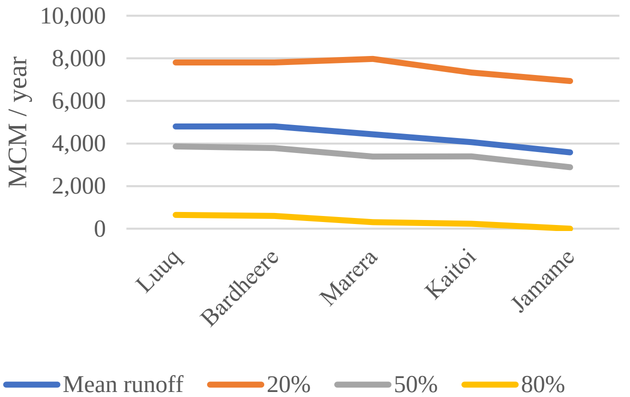
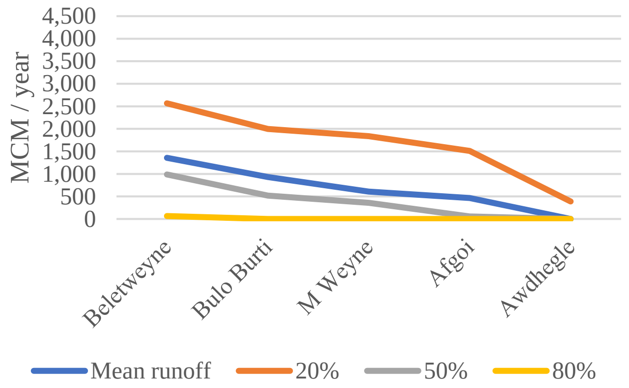


Figure 7. Shabelle Flow Duration Curve, 2035



4.2.4 Major Change: 2050

Table 10. Mean and Flow Durations for 2050 in Five Locations in Jubba and Shabelle River Basins after Use Has Been Deducted

Reduced with uses along river. All negative values turned 0 (MCM/yr)									
Jubba	**Mean**	**20%**	**50%**	**80%**	**Shabelle**	**Mean**	**20%**	**50%**	**80%**
Luuq	4,504	7,329	3,621	593	**Beledweyne**	396	768	282	0
Baardhere	4,492	7,317	3,533	531	**BuloBurti**	243	571	117	0
Marera	4,126	7,456	3,142	241	**M. Weyne**	122	500	46	0
Kaitoi	3,761	6,839	3,130	153	**Afgoi**	58	379	0	0
Jamame	3,294	6,448	2,639	0	**Awdhegle**	0	12	0	0

Figure 8. Jubba Flow Duration Curve, 2050

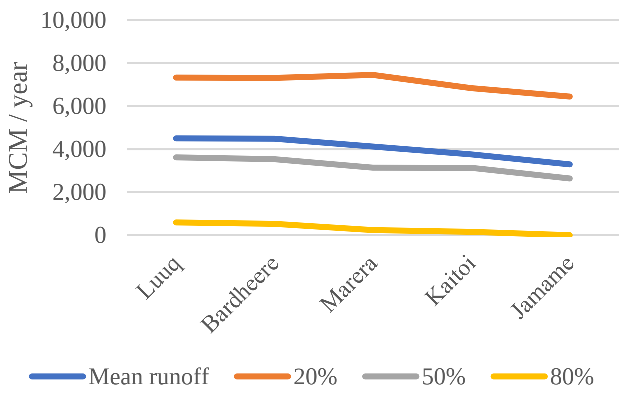
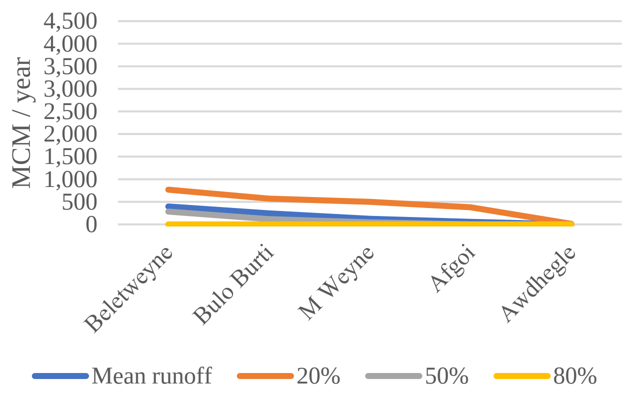


Figure 9. Shabelle Flow Duration Curve, 2050



5 Discussion

5.1 Runoff and Reliability

After assessing the tables and graphs in Chapter 4, it is clear that water flows decrease downstream and that the opportunities to make use of water in the two basins differ. Three initial points to note are: First, there is a natural reduction in flow in both basins due to evapotranspiration and groundwater recharge. Second, the Jubba carries large volumes of water and this is likely to continue in the future as well, irrespective of development in either Ethiopian or Somali sections of the basins. Third, the Shabelle is at risk of drying up, not only during certain dry years, such as what happened in 2016–2017, but also for extensive periods during each consecutive year. The effect increases with downstream location.

As noted above, the different probabilities show the minimum amount of water available for a certain percent of time. Based on literature reviewed (Basnyat 2007; Petersen and Gadain 2012), these probabilities are most likely linked to a combination of interannual and intraannual flow variability (there is both a huge flow variability from year to year and an equally huge flow variability between dry and wet seasons).

This should be followed up to gain more information on flow variability, as that has an important impact on planning future expanded irrigated agriculture.

Farmers in, for instance, BuloBurti in the Shabelle basin, would, in theory, be able to irrigate land with 571 BCM of water per year in 2050 (summarizing all months). That water is the annual total of monthly amounts being exceeded at 20 percent of the time, a very low amount of reliable supply. In reality, that is not good enough for farming; farming requires much higher probabilities. In the case of BuloBurti that would be 117 BCM/year at 50 percent duration, a higher reliability, but a smaller amount. And developing agriculture based on 80 percent reliable supply cannot happen—such water does not exist.

What a reasonable water probability for irrigated farming is can be discussed. It depends on crop types, farming systems, installations such as dams and possibly access to groundwater, and the general demand for food and work.

In order to supply water according to the traditional farming calendar, with water needs peaking in June-July and November-December, and in a scenario post rains and with high flows for both *gu* and *deyr*,[6] irrigation requirements are: 75 percent as reliable flows for cereals and 90 percent for perennials.[7] Such numbers would exclude BuloBurti from growing both cereals and perennials in 2050.

The figures given above are based on the period 1964–1989. The natural runoff today probably differs compared with that period with additional wet and dry periods (although droughts and floods also occurred a long time ago, reported from the ’50s and onwards). Today, as a consequence of changing weather patterns and climate change, the variability has probably increased—while total annual averages may remain the same—thus making it even more difficult to depend on runoff in the Shabelle (Tierney et al. 2015).

[6] The *gu* rains begin in April and last until June. *Deyr* rains are generally in October-November.

[7] FAO Somalia, personal communication.

A conventional solution to the problem outlined above is to build a dam, catch all flows, and regulate downstream runoff. As variability increases in the Shabelle, that would be a simple solution to a complex problem. But a dam also has to take into account future Ethiopian upstream development, both in terms of regulating the flow and diverting runoff into new farm areas. Such development is modeled in the two future scenarios presented in Chapter 4.

5.2 Climate Change

As noted earlier, detailed climate change effects on runoff are not included in the various scenarios and their flow variability. To do that would require more information and a hydrological model to assess the variability and its impacts downstream. In addition, the effect of climate change is irregular, maybe turning one year out of five very dry and another year very wet. Such effects are difficult to include in regional development. An "average" flow does not adequately describe conditions for sustainable agriculture.

5.3 Available Water

In Jubba river, water is available at all times for all uses. The only exception is possibly the combination of a very dry year, a use that requires access to much water at all times, and in a future where some development has taken place in upstream Ethiopia and people and livestock populations in downstream Somali sections have increased. Otherwise, investments requiring reasonable amounts of water are feasible.

Shabelle river, however, is a different story. Today (2020), water is available throughout the basin, except at the very end and at 80 percent flow duration (based on modeled results and summarized annual data). Still, farming takes place and can be expanded. More people and livestock can get water for WASH and drinking needs.

However, under conditions where climate change has reduced inflow in Beledweyne by 30 percent, and 80 percent duration is required, water supply cannot meet agricultural needs (Figure 10). A similar drastic reduction is found all along the basin until its end.

The environmental flow, also linked to groundwater recharge, is gone, and the basin will be dry for several months per year.

Figure 10. Shabelle River Flow in 2020 with Climate Effect Included

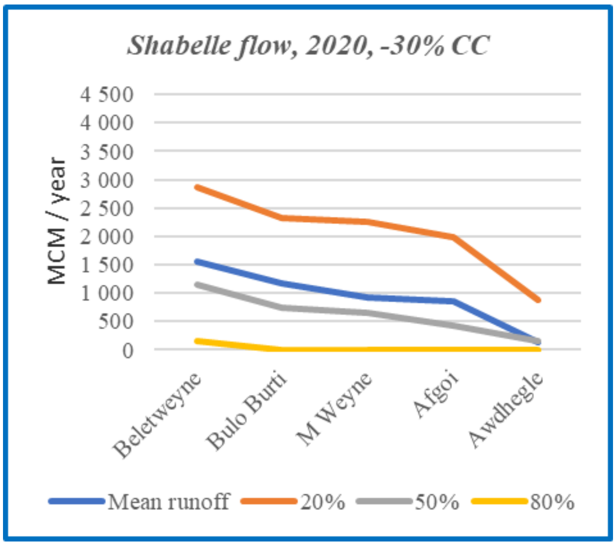
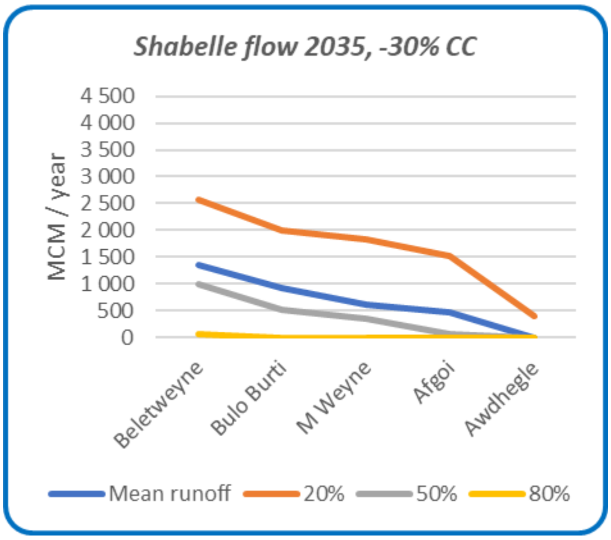


Figure 11. Shabelle River Flow in 2035 with Climate Effect included



The same conditions in 2035, and with new upstream Ethiopian river infrastructure in place, portray an even more increasingly difficult and water scarce situation (Figure 11).

Long term average runoff in 2035 delivers enough water in Shabelle to sustain people and livestock, but water is only available in the lower sections for a few months per year (that is, probably only in the midst of the wet season). Otherwise the basin is likely to stay dry.

The 2035 flow pattern is further exacerbated in 2050, when the river probably runs dry for most of the year. Irrigated farming is reduced, as compared with both 2020 and 2035, not because of land scarcity, but due to water scarcity. A potential climate change effect on inflow from Ethiopia makes the situation much more difficult to manage.

5.4 Investment Opportunities

Many investment opportunities exist linked to surface water in the two basins. They are outlined here. However, before these are developed, the following studies should be carried out for both rivers:

- **An updated study on river flow.** It should be based on a combination of past data and hydrological modeling utilizing remote sensing data (including upstream basin sections in Ethiopia)—including potential changes in runoff variability due to climate change—and deliver flow duration curves for the full rivers.
- **A review of current agricultural water practices and seasonality.** In coming decades, the flow is likely to both decline and turn more variable (both interannual and intraannual). Shabelle river is likely to turn dry for several months each year. How can irrigated agriculture cope with such changes? What amount of water is required during certain months per year to maintain a productive agricultural sector? Updated duration curves will support such an analysis.
- **Future climate smart, cash-crop agriculture**. Agriculture in both the Shabelle and Jubba basins has to adapt to reduced water availability, higher variability, a need to deliver decent livelihood conditions to more people, and to generate export incomes to pay for imported basic food requirements.

Investment opportunities include the following:

- Build the Baardhere Dam and expand irrigated agriculture in the Jubba basin. About 120,000 ha of new land can be put under additional irrigation and, if used for banana cultivation, can provide a much-needed export cash crop income.
- Build a dam upstream of Beledweyne (or if better located, within Ethiopia) to generate reduced variability and increased reliability of water in downstream irrigated agriculture.
- A gradual commercializing of Jubba and Shabelle agriculture, from low value crops towards higher-value export crops such as sesame, lime, and banana.
- Develop supplemental irrigation schemes—that is, based on rainfed agriculture—which, during certain key periods of plant growth, have an extra assured supply of blue river water and thus could increase production. The productivity per volume of such added blue water can be huge.
- Develop perennial livestock feed crops that utilize green water, but at times have blue river water added (supplemental irrigation). It would form the basis for high-quality livestock export (that is, well-fed, healthy livestock, selling at good prices).

- Improve water use efficiency in irrigated Shabelle agriculture. Most likely, it can be turned many times more productive, cutting water losses and improving production per volume of water applied.

- Given that much food is imported and commercial food markets exist in major cities, investments that improve the connections between domestic food production and markets by means of transport (roads), facilitators (traders), and market information (internet/smart phones) can assist in promoting cash crop production.

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