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Managing Somalia's Surface and Groundwater Resources for a Resilient Future

March 2024

Contents

List of Figures

About the Author

Dr. Abikani Abdullahi Moallim holds a Ph.D. in Soil and Water Resources Engineering, and he is a Water Resources policy fellow with HIPS. He also serves as Senior Advisor of Water and Irrigation at Somalia's Ministry of Agriculture and Irrigation (MoAI).

Executive Summary

In recent years Somalia has experienced some extreme environmental disasters, such as floods and droughts, compounded by the country's prolonged political and security challenges. Rising temperatures and shifting rainfall patterns are causing alterations in rainfall and water availability, resulting in both droughts and an increased susceptibility to flooding. A major issue is the prolonged droughts that Somalia has been enduring in recent years and that have led to critical water scarcity and food insecurity.

Somalia shares two major perennial transboundary rivers, the Juba and Shabelle, with Ethiopia and Kenya. These rivers play a crucial role in Somalia's economy, water supply, and food security. The management of these transboundary rivers is currently characterized by fragmentation and a lack of coordination among riparian countries. The potential for water-related conflict between Somalia and neighboring countries over the utilization of these two rivers has raised concerns. However, it is worth noting that Somalia has a federal system of government in place, and there are no disputes or conflicts, particularly concerning the Shabelle and Juba rivers, regarding the allocation and sharing of river water between its states.

The Water Evaluation and Planning (WEAP) tool is used to model water systems at the basin, regional, or local level and to assess the impacts of various water management scenarios on water supply, demand, and quality. The model includes various components such as hydrology, water demand, water allocation, water quality, and environmental flows. At the time of this study, current irrigation practice in the Shabelle and Juba river basins involved 50,000 ha and 15,000 ha, respectively. These findings indicate that the domestic water demand for the current period is 912 million cubic meters (Mm^3). Under a long-term plan, irrigation practice in these two river basins would be 135,000 ha and 32,000 ha respectively. The long-term plan results reveal that the domestic and irrigation water demand on the Shabelle river would be 1,542 Mm^3. The findings also show that, under this long-term plan, the water demand on the Juba river would be 1,627.5 Mm^3 for domestic use and 2,419 Mm^3 for irrigation. Higher rainfall would increase the flow of water in the Juba river. It is possible that the Shabelle river has undergone more human interventions than has the Juba river, resulting in an increased flow of water for the Juba.

Achieving the vision and strategic actions of Somalia's National Development Plan (NDP-9) is dependent on effective governance and necessitates the strengthening of Somalia's institutions and capacity in political and environmental governance. Enhancing the governance frameworks for water resource management and development will involve not only improving the legal and regulatory environments but also the ongoing development of policies and strategies to guide sustainable water development interventions.

The absence of clear roles among the institutions involved in the water sector leads to conflicting responsibilities and competition for resources, particularly in relation to the allocation of funds for water projects. However, it is now crucial to adopt tailored approaches that can align the governance frameworks of the federal government and member states in the water sector. This alignment will facilitate effective water resource management and the provision of essential water services.

The conjunctive use of surface and groundwater has been found to be a beneficial approach to managing water resources. In areas where surface water sources are limited or unreliable, groundwater supplements can help meet the demand for water and can ensure a more reliable water supply. Overall, the conjunctive use of surface and groundwater is a valuable strategy for optimizing water resource management. A key advantage of conjunctive use strategies is the flexibility they provide in managing and allocating water resources. The combination of these two sources allows for a more reliable and continuous water supply. Another advantage of conjunctive use strategies is the potential for improved water quality. Finally, the development of conjunctive use strategies in Somalia is vital to mitigate water scarcity challenges and to build resilience against future drought events. By optimizing the domestic and agricultural use of water, promoting water security, and supporting socioeconomic development, conjunctive use strategies can contribute to a sustainable future for Somalia.

1. Introduction

Global population growth, the need for increased food production, environmental damage from various human-induced events, and the effects of climate change are all contributing to the vulnerability of water resources. In Somalia, water resources are primarily surface water and groundwater. The country has two perennial rivers, the Shabelle and the Juba, which are the main sources of water for irrigation, livestock and domestic/rural supply. It also has four major river basins that cover one-third of Ethiopia, one-third of Kenya, and one-third of Somalia, with 90 percent of the flow originating from neighboring countries (Kammer, 1989). Both rivers are hugely important for agricultural production and domestic water supply. Evapotranspiration, which is variable and ranges from 1,500 mm/year to 1,750 mm/year is a major component of water loss for the basins of both rivers (Hutchinson and Polishchouk, 1989).

The worsening water resources sector has been mismanaged as a result of decades of conflict in Somalia and is influenced by climate change in the sector. Due to climate change, numerous farmers lack access to enough water for agriculture; this impacts the production of the main staple food crops in the absence of facilities to develop water resources. Somalia is dealing with more frequent floods, more droughts, and sea level rise in addition to water scarcity. This could potentially make it harder to find clean water to drink, could cause rivers and other water sources to dry up, and could affect the quality of the water.

The surface and groundwater resources in Somalia are under threat due to climate change and to population growth. It is essential to prioritize the protection and sustainable management of these resources to ensure survival. The conjunctive use of surface and groundwater is a key strategy in water supply management that must be implemented to enhance water resources development, management, and conservation within a basin. Numerous countries are combining utilization of surface and groundwater to improve both the availability of domestic water and the efficiency of irrigation practices in agriculture. Li et al. (2018) proposed the use of surface and groundwater in conjunction to maintain high agricultural productivity at a reasonable cost, to raise the depth of the groundwater table, and to decrease the accumulation of salts in the root zone. In addition to reducing water scarcity, the combined use of surface and groundwater resources might improve the environment in irrigated regions and increase water use efficiency (Singh, 2014). Safavi and Enteshari (2016) developed models for the conjunctive use of surface and groundwater to reduce the water shortage in three irrigation areas and showed that the model can be used as a decision support system tool.

In regions like Somalia that are impacted by water scarcity, the sustainable management of surface and groundwater is crucial. Furthermore, groundwater is essential to providing water security for humans as well as livestock. However, the supply of water throughout the country has suffered severe effects due to human activity. Due to the unavailability of permanent streams and the country's arid climate, the only source of water in most of Somalia is groundwater, with the exception of the basins of the two perennial rivers, Juba and Shabelle. Groundwater is used as drinking water by almost 95 percent of the population. For the majority of the country, there is a lack of groundwater and access to it is highly restricted due to scarce resources. This scarcity is the result of relatively low effective rainfall, a very deep groundwater table in many regions, and increased water salinity. Due to a weak governance system that lacks adequate control and monitoring measures, groundwater resources are generally affected by the issues of overexploitation and contamination. Poor management of water resources is responsible for the depletion of surface and groundwater resources. Investigation of the root causes and of solutions to water scarcity is also insufficient. Furthermore, the country lacks adequate water infrastructure, adequate management, and strategies and policies for managing water resources. Therefore, this study aims to assess and investigate the effectiveness of the conjunctive use of surface water and groundwater for better utilization and management of water resources.

1.1 Objectives of the study

The main aim of the current study is to assess and propose conjunctive use of surface water and groundwater for better utilization of water resources in Somalia. Therefore, the study will achieve the following objectives:

- Investigate the use of surface and groundwater resources in Somalia.
- Examine the institutions and policies governing water management in the country.
- Identify the country's main challenges that relate to water availability, use, and management.
- Propose practical solutions to the challenges that people face on the use and management of water.

1.2 Rationale and outline of the study

The rationale behind the conjunctive use of surface water and groundwater is to optimize water resource management and overcome the limitations of relying on a single water source. The goal is to create a more reliable and sustainable water supply using both surface water and groundwater.

The conjunctive use of surface water and groundwater involves the simultaneous management and utilization of both sources of water to meet the demands of various sectors, such as agriculture, industry, and domestic water supply. This approach allows for greater flexibility in water allocation, particularly during drought or when one source is limited. An outline for the conjunctive use of surface and groundwater typically includes the following components:

I. Assessment and monitoring:

- Evaluate the available surface water and groundwater resources.
- Monitor water levels, quality, and availability on an ongoing basis.

II. Water allocation planning:

- Determine the water demand from various sectors and prioritize allocation accordingly.
- Develop an integrated water management plan that includes both surface water and groundwater utilization.

III. Infrastructure development:

- Construct and maintain infrastructure such as dams, reservoirs, and wells to capture and store surface water and groundwater.
- Develop a network of canals, pipelines, and pumping stations to transport and distribute water to various locations.

IV. Water recharge and storage:

- Implement techniques to enhance groundwater recharge, such as artificial recharge through infiltration basins or injection wells.
- Optimize storage capacity by utilizing underground aquifers or building storage reservoirs for surface water.

V. Management strategies:

- Implement appropriate water management strategies to balance surface water and groundwater use, considering factors such as availability, quality, and sustainability.
- Emphasize water conservation and efficiency measures to reduce overall water demand and minimize over-reliance on either source.

VI. Groundwater management:

- Implement measures to prevent over-extraction of groundwater, such as regulating pumping rates and implementing water rights or permits.
- Monitor groundwater levels and quality to ensure sustainable use and to prevent contamination.

VII. Stakeholder engagement and collaboration:

- Engage with relevant stakeholders, including local communities, water users, and government agencies, to ensure their involvement in decision-making processes and to promote water stewardship.

The conjunctive use of surface water and groundwater is a comprehensive approach to water resources management and aims to optimize water supply, enhance resilience to droughts, and improve overall water sustainability. Careful planning, coordination, and ongoing monitoring are required to ensure the effective and sustainable use of both surface water and groundwater resources.

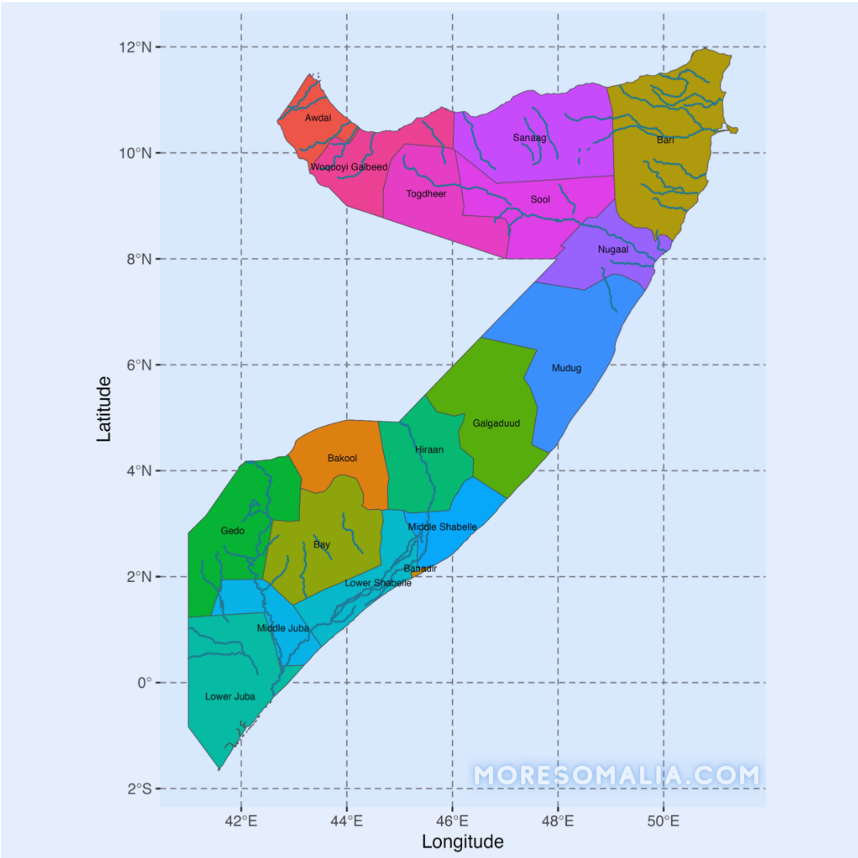
1.3 Methodology

This study uses a mix of qualitative and quantitative methods. Firstly, a desk review was conducted based on thorough analysis of full text, and identification of research articles that fully met the search criteria, based on the Web of Science (WOS) and Scopus databases. A systematic literature review was conducted to study the gap and justify the current study. Secondly, hydrological data (such as rainfall, temperature, river flow, and discharge) was collected from relevant institutions such as Somalia Water and Land Information Management (SWALIM), the Ministry of Energy and Water Resources (MoEWR), and the Ministry of Agriculture and Irrigation (MoAI) as well as any other relevant institutions. Thirdly, groundwater data (such as aquifer, rate of consumption, well water levels, and number of wells) was collected from relevant institutions. During the data collection, a proper consultation was conducted with water authorities, ministries of water, irrigation and agriculture. Finally, a strategy for the conjunctive use of surface water and groundwater was developed.

1.4 Study area

Somalia, a country located in the Horn of Africa, has a total area of approximately 637,657 km2. It is bordered by Ethiopia, Djibouti, and Kenya and has a long coastline along the Indian Ocean. As shown in Map 1, the country is divided into seven states: Somaliland, Puntland, Galmudug, Hirshabelle, Jubaland, Southwest, and Banadir, each subdivided into districts, and the largest city is Mogadishu.

The study of geographical features, such as the Somali Peninsula, Gulf of Aden, and Indian Ocean, can provide insights into the country's physical geography and its interactions with neighboring regions. Somalia has experienced political instability and conflict for many years; this has greatly impacted its social, economic, and environmental conditions. Environmental degradation, including deforestation and desertification, is a pressing concern in Somalia. The overexploitation of natural resources, coupled with a lack of effective environmental management, has led to soil erosion, loss of biodiversity, and water scarcity. Somalia's National Adaptation Programme of Action (NAPA) has highlighted water resources as a sector that is extremely vulnerable to the impacts of climate change.



Map 1: Study area of Somalia (https://moresomalia.com/somalia-maps/)

1.5 Climate of Somalia

The seasonal variation in Somalia's climate is a consequence of changes in wind patterns (Basnyat and Gadain 2009). The country experiences a major wet season from March to June and a minor wet season from October to December, as shown in Figure 1. Relative humidity ranges from 82 percent to 85 percent throughout the year, with coastal zones maintaining around 70 percent humidity during the dry season. The spatio-temporal variability of climate, driven by temperature increases in various parts of northern and central Somalia, can lead to significant fluctuations in rainfall.

The elevation of the air's water-holding capacity is expected to result in seasonal variations in the country's rainfall patterns, accelerating the hydrological cycle and influencing rainfall variability. Somalia faces recurrent droughts, which can have devastating impact on agriculture, livestock production, and the overall economy of the country. Factors such as El Niño, unpredictable rainfall patterns, and climate variability often combine to trigger these droughts. The coastal regions of Somalia, which are prone to occasional tropical cyclones and experience higher humidity from May to October due to the Indian Ocean's monsoon system, are particularly vulnerable. These cyclones, characterized by strong winds and abundant rainfall, can be lethal and cause destruction to infrastructure. Overall, the hot and dry climate in Somalia presents numerous challenges for its population and results in food insecurity, water shortages, and heightened vulnerability to natural disasters.

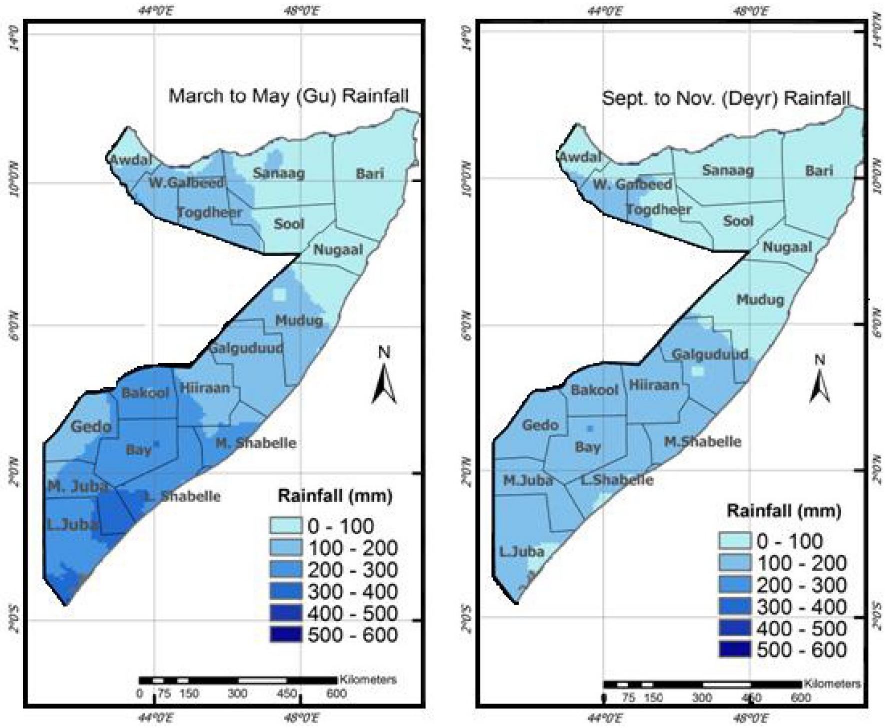


Figure 1: Rainfall during Gu and Deyr rainy seasons in Somalia (Source: Federal Republic of Somalia, 2013).

1.6 Rainfall trends

In Somalia, the amount of rainfall varies significantly depending on the region and season (Fig. 2). The country typically has a dry climate with little rainfall. The annual rainfall in Somalia is typically low and unpredictable, with the central semi-arid regions of the country receiving only 50–150 mm of rainfall due to an extremely hot and arid climate (Houghton et al., 2011). On average, the country receives about 250 mm of rainfall annually, with the southern region experiencing approximately 400 mm and the southwest region receiving more than 550 mm of rainfall (FAO, 1995).

The variability in rainfall across the country can be attributed to continental and global climate changes, as well as to orographic and coastal influences. The four major river basins in Somalia exhibit varying levels of rainfall variability; the upper stream location within the Kenyan-Ethiopian highlands receives as much as 1,270 mm of rainfall annually (Conway et al., 2009). In contrast, annual rainfall in the central part of the basin is as little as 300 mm while the southwest part of the basin receives 500–700 mm annually.

The period from December to March, known as Jilaal, is characterized by hot and dry weather in the northeastern part of the country, while the northern and southern regions face dry air and extreme heat conditions (Sebhat and Wenninger 2014). Gu, which lasts from March to June, is considered the primary rainy season, with the southern parts of the country receiving more rainfall compared to other areas. The Gu season contributes to almost half of the country's annual rainfall. The Hagga season, from July to September, is the second dry season, during which the Shabelle and Juba basins receive 12 percent and 7 percent of the annual rainfall, respectively. The Deyr season, from October to December, is a shorter rainy season, with the southern coastal region experiencing less rainfall.

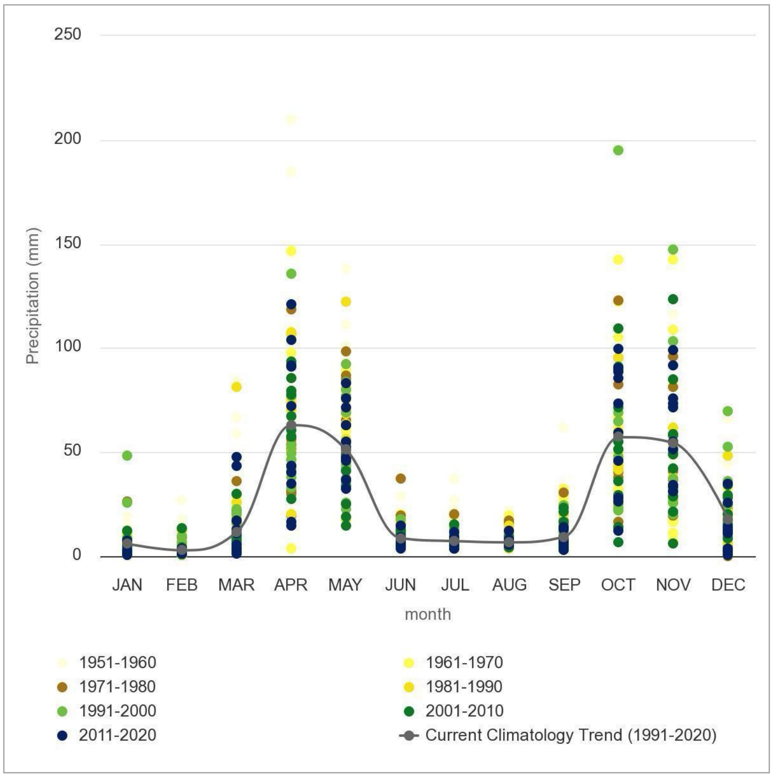


Figure 2: Variability and rainfall trends in Somalia (World Bank)

1.7 Temperature

Somalia's temperature fluctuates depending on the specific region and season (Fig. 3). Overall, the country has a hot and dry climate, with daytime temperatures often exceeding 30°C. Coastal areas benefit from cooler temperatures due to the influence of the ocean, while inland regions can experience scorching heat, with temperatures soaring above 36°C. The country experiences a rainy season from March to June, which brings slightly lower temperatures. However, even during this period, Somalia is prone to droughts and temperatures remain high, worsening the already arid conditions in the country. The latest climate variability forecasts suggest a steady rise in precipitation anomalies and a median temperature increase ranging from 3.2°C to 4.3°C. These changes are expected to result in unpredictable occurrences of droughts and floods in Somalia. According to the Intergovernmental Panel on Climate Change (2022), by 2030, Somalia is projected to experience a rise in temperature ranging from approximately 1.4°C to 1.9°C compared to pre-industrial levels. Furthermore, the frequency of extremely hot days, with temperatures reaching a maximum of 35°C, is expected to escalate in specific regions of the country, particularly in south and central Somalia. The country has undergone a gradual and uninterrupted increase in average annual temperatures since 1901, particularly since the 1960s when compared to the average temperature between 1901 and 2020. This temperature increase is particularly evident in the arid and semi-arid regions, which are inherently prone to high temperatures and extreme weather conditions (Beier and Stephansson 2012). During the El Niño period, East Africa experiences an increase in rainfall and flooding due to the warm ocean temperatures along the central and east-central equatorial Pacific.

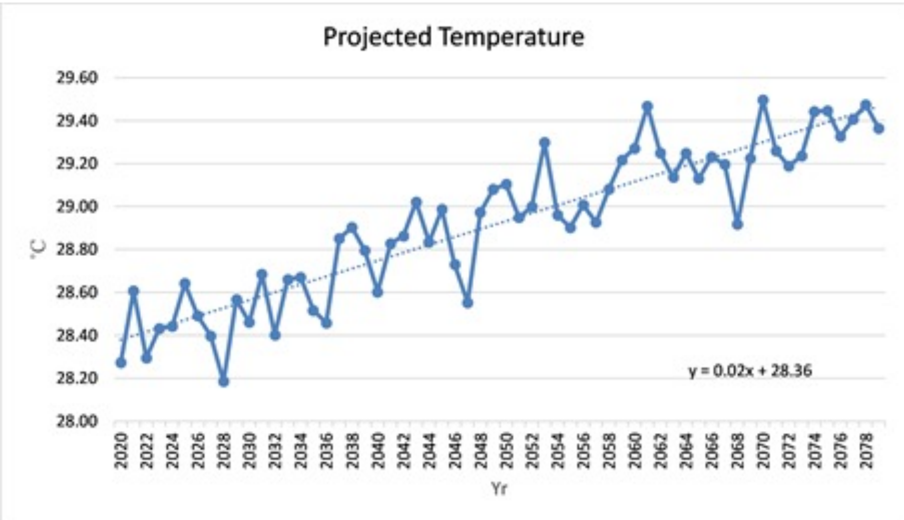


Figure 3: Projected annual average temperature in Somalia 2020–2079 (Source: Ogallo et al. 2018)

1.8 Application of the Water Evaluation and Planning (WEAP) model

WEAP (Water Evaluation and Planning) is a computer-based decision support tool designed for integrated water resource planning and management. It is used to model water systems at the basin, regional, or local level and to assess the impacts of various water management scenarios on water supply, demand, and quality. The model includes various components such as hydrology, water demand, water allocation, water quality, and environmental flows. It simulates the movement of water through river networks, reservoirs, groundwater aquifers, and various demand sectors such as agriculture, industry, and domestic use.

Model calibration is the process of adjusting the parameters and input data of the model to better represent the real-world system being analyzed. The calibration process involves comparing the model's predictions to observed or measured data and adjusting the parameters until an acceptable level of agreement is achieved. This process can include various parameters such as climatic data (precipitation, temperature), hydrological data (streamflow, groundwater levels), and water demand data. This calibration study compares predicted and actual flows using the WEAP model. Calibration was performed using observed streamflow data from the Somali Water and Land Information Management (SWALIM) gauging station. The selected station's natural stream flows were compared to model simulations. WEAP's calibration includes a connection to a parameter estimation tool (PEST), which automates the process of comparing WEAP outputs to historical data and adjusts model parameters to increase accuracy (WEAP 2014). PEST can assist by calibrating variables in the WEAP model, especially when employing the Soil Moisture technique for catchment hydrology.

2. Background literature review

2.1 The concept of conjunctive use of surface and groundwater

The integrated use of surface and groundwater is a comprehensive strategy for water management that enhances water availability and sustainability. By effectively combining surface water and groundwater sources, this approach aims to meet the water demands of different sectors. This technique has been widely employed, with instances of both success and failure. According to Evans and Evans (2012), the method that provides water for agriculture by using irrigation canals and wells together is known as conjunctive use of surface and groundwater. Conjunctive use is a commonly utilized method in areas such as Somalia, where agriculture and access to domestic water are limited. A main benefit of this approach is the increased reliability of the overall water supply.

The combination of surface and groundwater sources allows water managers to capitalize on each source's particular strengths while efficiently managing their limitations. For instance, during wet seasons the abundance of surface water can be utilized for irrigation, municipal supply, and other activities with high water demand. At the same time, groundwater can be recharged and stored for use during dry periods when surface water is scarce. Mahjoub et al. (2011) conducted a field study to investigate the conjunctive use of surface and groundwater and revealed that domestic water supply and irrigation requirements improved by preventing heavy water table drawdown in groundwater aquifer as well.

The implementation of conjunctive use offers numerous benefits in terms of water resource management. Conjunctive use optimizes operations through integrating the use of existing infrastructure, such as reservoirs, pumps, and canals, based on the availability of both surface and groundwater. The implementation of a synchronized strategy amplifies the effectiveness of these systems, consequently diminishing the necessity for building additional infrastructure. Therefore, conjunctive use provides a sustainable and cost-effective solution for managing water resources more efficiently. Abdolvandi et al. (2014) examined the conjunctive use of surface and groundwater using system dynamics and found that through improved irrigation efficiency or proper financial planning for the adoption of agricultural techniques, integrated management options can contribute to the sustainability of water resources in the region. The research conducted by Ruud et al. (2001) and Sarwar (1999) involved the use of MODFLOW, a GIS-linked model for the conjunctive use of surface and groundwater flow. Wrachien et al. (2002) provided an in-depth overview of the conjunctive use of surface water and groundwater, highlighting the importance of a holistic management approach. The interaction between surface and groundwater was further explored by Sophocleous (2002). Furthermore, the implementation of conjunctive use serves as an effective measure in mitigating the impacts of groundwater depletion. Due to its easy accessibility and reliability, groundwater is frequently overexploited. However, excessive pumping can result in a decline in groundwater levels, land subsidence, and even the intrusion of saltwater in coastal regions. By incorporating surface water into the water supply mix, the dependency on groundwater can be minimized, facilitating aquifer recharge and preventing further depletion.

2.2 Success and failure of conjunctive use

In South Africa, the Orange River Basin serves as a successful case study of conjunctive use in practice. In response to the high water demand for irrigation in the basin, the Department of Water and Sanitation implemented a conjunctive use strategy. This involved the construction of surface reservoirs to capture and store floodwaters, alongside the simultaneous utilization of groundwater sources for irrigation during dry periods (Colvin et al. 2003).

Farmer incomes grew and agricultural productivity improved due to the integrated approach, which contributed to ensuring a sufficient supply of water throughout the year. In Gambia, implementation of the Infiltration Gallery System also demonstrates the successful utilization of conjunctive use. To combat the limited availability of surface water, an infiltration gallery was constructed with precision to recharge an underlying aquifer using the excess runoff and river water during the rainy season. The stored groundwater was then extracted during the dry season to meet domestic and agricultural needs. According to Bodian et al. (2018), this innovative approach has improved water availability, especially for smallholder farmers, leading to increased agricultural productivity and food security.

In East Africa, the Nile Basin serves as a prime example of the obstacles and shortcomings faced in the successful implementation of conjunctive use. Political conflicts and a lack of transboundary cooperation have greatly contributed to these challenges. The basin's presence in multiple countries has led to ongoing disputes over water allocation, impeding the efficient management of surface water and groundwater resources. The lack of a comprehensive agreement among the countries sharing the same river has resulted in the unsustainable extraction and overuse of both surface and groundwater resources (Figueroa and Smilovic 2021). Consequently, the region is currently experiencing restricted socioeconomic growth, environmental imbalances, and a shortage of water (Zeitoun et al. 2013). In Central Africa, the failure of conjunctive water use in the Lake Chad Basin can be attributed to various factors, including climate change and unsustainable water management practices. The lake, once recognized as the sixth-largest freshwater lake on a global scale, has undergone considerable shrinkage due to increased water withdrawals, population growth, and fluctuations in climate conditions. According to Mohammed (2017), the uncontrolled extraction of surface and groundwater for domestic and irrigation use, without proper coordination and regulation, has caused water scarcity and ecological degradation, which has led to widespread socioeconomic challenges, including the displacement of communities and intensified conflicts over the limited water resources.

2.3 Climate change impact on surface water

In recent times, Somalia has been confronted with numerous challenges that include extreme weather events such as floods and droughts, problems related to infrastructure and the current political and security crises. Somalia's agricultural production depends mainly on irrigation supply from the Shabelle and Juba river basins. In this situation, the development and adaptation of water resources planning and management are crucial. Surface water in Somalia is significantly impacted by the changing climate. The rising temperatures and shifting rainfall patterns are causing alterations in rainfall and water availability, resulting in both droughts and an increased susceptibility to flooding. A major issue is the prolonged drought that Somalia has endured in recent years, which has led to critical water scarcity and food insecurity.

Reduced rainfall and higher rates of evaporation have led to a decrease in water levels in rivers, lakes, and groundwater sources, making it difficult for livestock and communities to access water supplies. In addition, extreme weather events such as heavy rainfall and flooding have become more frequent and more intense due to the effects of climate change. The country's weak infrastructure is battered by these events, which contaminate water supplies and lead populations to flee.

The consequences of climate change on surface water in Somalia extend beyond issues of water scarcity and flooding. Alterations in precipitation patterns also have an impact on the overall quality of water resources. Numerous studies have demonstrated a higher presence of pollutants in the watershed resulting mainly from the influence of several factors including land use, fertilization intensity, type of vegetation cover, and rainfall (Chen et al. 2016; Xing et al. 2017). Due to the increased risk of waterborne illnesses, the contamination poses a major danger to community health and well-being. Furthermore, with irrigation as a major component of the country's agricultural industry, the country's available surface water is decreasing. The scarcity of water resources poses a significant obstacle to crop production and livestock grazing, thereby exacerbating the already existing challenges of food insecurity and economic instability. The adverse effects of climate change further worsen the situation by intensifying water scarcity, leading to increased incidents of flooding, pollution, and food insecurity in Somalia. To effectively tackle these issues, it is imperative to implement sustainable water management strategies, establish resilient infrastructure, and foster international cooperation to effectively mitigate and adapt to the impacts of climate change.

The agricultural sector in Somalia relies heavily on rainfall for the cultivation of crops. Therefore, the irregular rains and the frequent occurrence of droughts during the growing seasons have significantly affected agricultural production and have led to severe food shortages, famine, and the loss of livestock. Prior to the civil war, the irrigated agriculture sector covered an estimated area of 240,000 hectares. However, following the collapse of Somalia's central government in the 1990s and the prolonged conflict, this area has diminished considerably. Studies have revealed that the impact of climate change on agriculture and water resources in Somalia is already discernible. The escalating temperatures, which contribute to the rise in sea levels, lead to the intrusion of saltwater into coastal regions. In addition, the availability of freshwater resources has diminished significantly, thereby reducing local populations' access to clean drinking water.

2.4 Water availability

The availability of surface and groundwater in Somalia has been affected by climate change (Mourad 2020). The IPCC (2022) models predict that East Africa will have more precipitation and generally wetter conditions due to the intensified hydrological cycle caused by rising temperatures, particularly during the rainy season.

Basnyat and Gadain (2009) state that increasing agricultural water demand from the Shabelle basin during the dry period has led to higher surface water abstractions and is causing an imbalance between availability and demand for water. The increase in water demand has resulted in a decline in water availability during dry seasons, and has also escalated conflicts over water in the watersheds (Aeschbacher et al. 2005). Without appropriate management, the escalating demand for scarce water resources by diverse sectors will have profound implications for all stakeholders and the surrounding ecosystem. The scarcity of water in Somalia is exacerbated by conflict and instability. Management and accessibility of the water supply are challenging because of the damaged water resources infrastructure and the displaced population. This is more prevalent in rural and remote regions where water shortages are more common.

The Juba and Shabelle rivers play a crucial role in irrigation development in the country, in addition to serving as a source of water for domestic and agricultural purposes. As the country's freshwater source, these basins face challenges such as hydrological water deficit and seasonal variations in river flow (Gadain and Mugo 2009). Basnyat (2009) showed that limited access to water in the region is due primarily to political instability, poor infrastructure, and inadequate measures to manage flood fluctuations. These rivers can dry up during prolonged droughts and are frequently affected by variations in rainfall. Furthermore, the Juba and Shabelle are highly relied upon for irrigation and agriculture, which puts further demand on the existing water supplies.

The domestic water supply in Somalia depends heavily on groundwater, which accounts for 80 percent of the total withdrawals. However, the country's aquifers are often deep and exhibit high salinity levels. With the Shabelle and Juba rivers being the only perennial surface water sources, implementing infrastructural solutions is imperative in overcoming the service-related obstacles. Groundwater quality and dependability, however, can vary, and excessive extraction has resulted in lower water levels and saltwater intrusion in coastal regions. Access to clean and safe drinking water is a significant challenge. According to UNICEF (2018), only 32 percent of Somalia's population has access to clean drinking water, and only 39 percent has access to sanitary facilities. The country has high mortality rates, particularly for children under five, for whom the mortality rate can reach 133 per 1,000 live births as the lack of clean, safe water has increased the prevalence of waterborne diseases like cholera (AfDB 2016).

2.5 Water quality

Clean water is not only a basic need of human beings, but it is also a major influence on the aspects of human life (Ahmed 2005). However, the quality of surface and groundwater is influenced by many variables, including the environment, climatic conditions, seasonal changes, land use, and natural and man-made water pollutants.

Considering the increase in water use for different types of consumption and the discharge of waste waters into rivers and groundwater, many water quality parameters are typically monitored to determine the water's suitability for various purposes.

Several countries throughout the world are now dealing with the issue of water quality, which has been aggravated by rising human demands on the environment and by climate change (Van Engelen et al. 2022). Providing a safe and renewable supply of drinking water is one of the critical drivers of a country's sustainable development. Contamination of surface and groundwater resources has become a global concern, highlighting the importance of widespread collaboration among academic researchers and government agencies at all levels to address these issues. The quality of water resources is widely acknowledged to significantly influence numerous human activities. Eighteen of the world's twenty poorest countries, according to the World Bank (2018), are located in arid and semi-arid regions and are especially vulnerable to floods and drought.

Araya et al. (2023) have indicated that the Horn of Africa, including Somalia, has natural features that favor high groundwater salinity; this affects agriculture production, biodiversity, and water security. Saltwater intrusion from the sea has a detrimental effect on the water supply in Somalia due to the excessive extraction of groundwater (FAO 2005). Said et al. (2021) evaluated several water quality parameters at Bosaso city and found the majority of the wells to be unsuitable for domestic consumption due to high salinity. In Mogadishu, an investigation by Abdishakur et al. (2022) using the Water Quality Index (WQI) revealed that the majority of wells in the city were not safe for drinking purposes. Recent studies show that pollution of drinking water poses a substantial health risk (Ahmed et al. 2020; Shayo et al. 2023). According to a World Health Organization (2011) statistical survey, about 80 percent of all diseases in developing countries are water borne.

3. Findings and analysis

3.1 Surface and groundwater resources

Somalia's water resources are dominated by surface water from the country's two perennial rivers (Fig. 4). The Shabelle is 2,526 km long and the Juba is 1,808 km long. As shown in Figure 5, the rivers' average flow rates are estimated to be 75 m3/s and 180 m3/s, respectively (FAO, 1995). The catchment area of the Shabelle is 283,504 km2 and that of the Juba is 210,010 km2 (Basnyat and Gadain, 2009). The country has four major river basins that also cover one-third of Ethiopia, one-third of Kenya and one-third of Somalia, with 90 percent of the flow originating from neighboring countries (Kammer, 1989). The Shabelle river originates from the eastern Ethiopian highlands at an altitude of 4,230 m above sea level, and flows in the southern direction. In fact, the Shabelle river is a tributary of the Juba, which makes a single basin. However, as the Shabelle's flow joins the Juba only during heavy rainfall, the rivers are effectively separate.

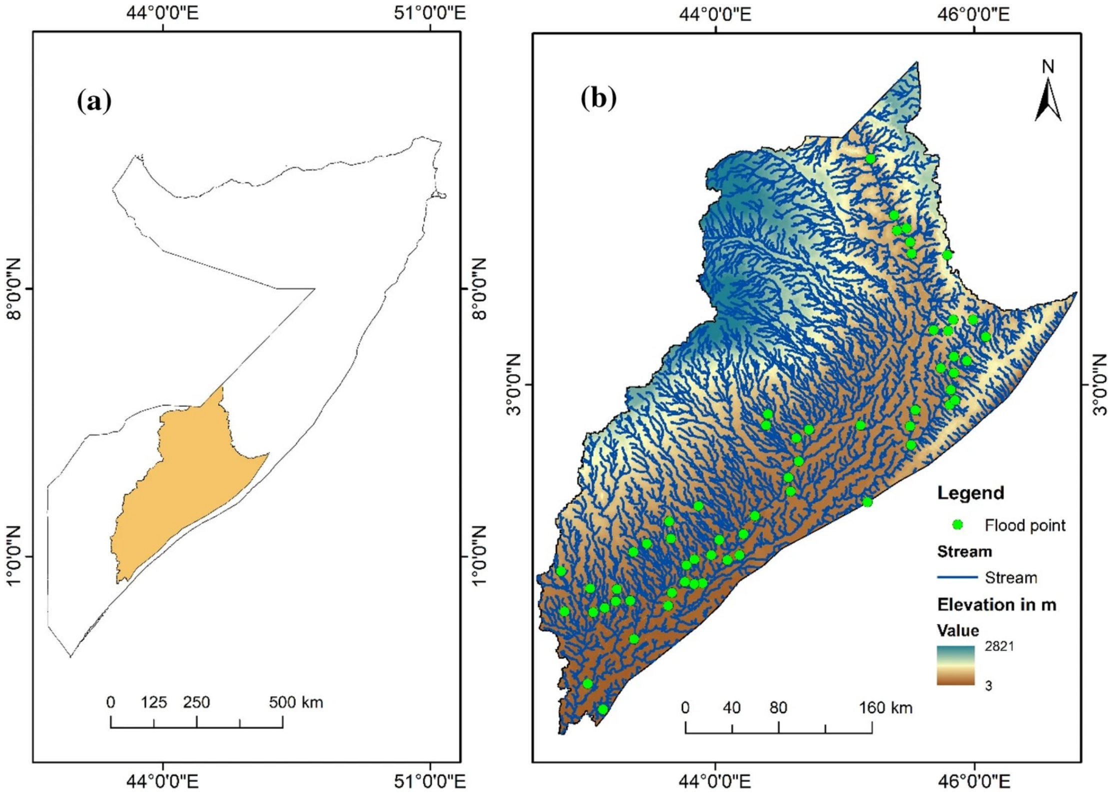


Figure 4: Geographical locations of Shabelle and Juba rivers of Somalia

Analysis of river flow data shows that the mean monthly river flows increase in October and November. During these periods the Shabelle's upstream and downstream reached above 5.5 m and 8.0 m for the Jowhar and Beledweyne districts as shown in Figures 6 and 7, respectively. The result also indicates a high chance of recurrent flash floods until the end (October to December) of 2023. Furthermore, seasonal flow variability might be predicted in both future periods relative to the reference period of 2010; however flows continue to peak in the rainy seasons in April and May (Gu) and in November (Deyr) for all and baseline data.

Recent floods along the Shabelle and Juba rivers during periods of heavy rainfall in the region indicate that flooding is fully reliant on local rainfall and the frequency of rainfall in the basin area located upstream. At the same time, water levels along the Shabelle river have been gradually rising. The present findings indicate that river levels at Beledweyne have reached bank-full levels, resulting in severe flooding and immense population displacement. Water levels in Jowhar are also rising, reaching the bank-full level. Rising water levels expose the area to serious risk of frequent flooding. The river-water level in Jowhar is currently 5.6 m; however, due to the predicted rainfall, it is anticipated that the level of the Shabelle river will rise further, posing a moderate to high danger of flooding.

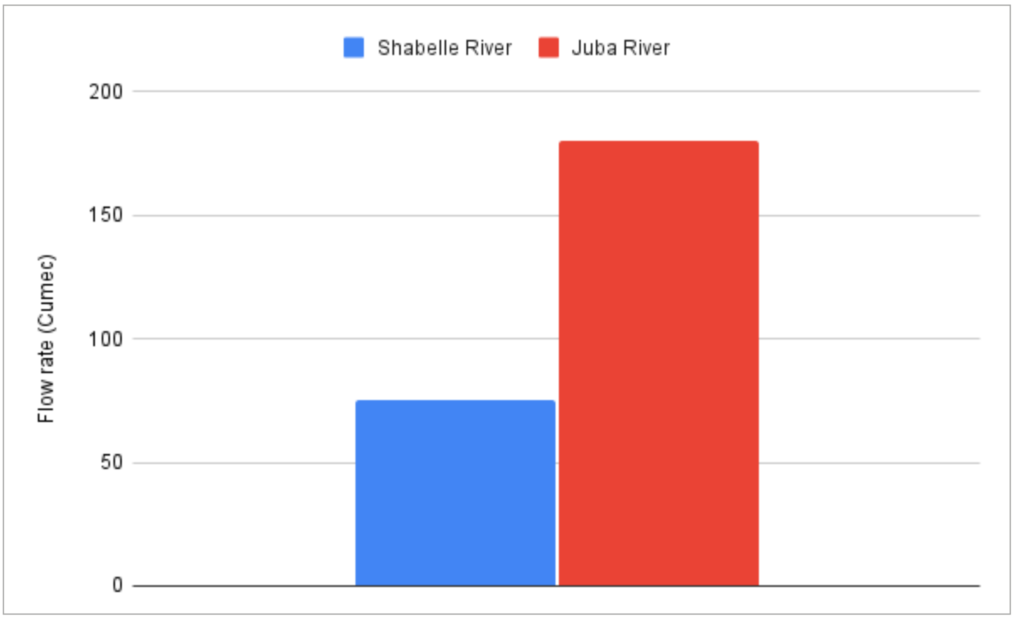


Figure 5: The average flow rates of Shabelle and Juba rivers of Somalia

The major component of water losses for both basins is potential evapotranspiration, which varies and ranges from 1,500 mm/year to 1,750 mm/year (Hutchinson and Polishchouk 1989). In addition, the surface water resources of Shabelle and Juba headwaters are abundant due to high annual rainfall and fewer losses (Conway et al. 2009). In the middle sections of the rivers, the surface water losses increase drastically due to the low rainfall, and the volume of surface runoff becomes very high. The long-term average annual flow volumes of the Shabelle and Juba rivers are estimated (based on 1963–1990 data) as 5.9 billion cubic meters and 5.4 billion cubic meters, respectively (Basnyat and Gadain, 2009).

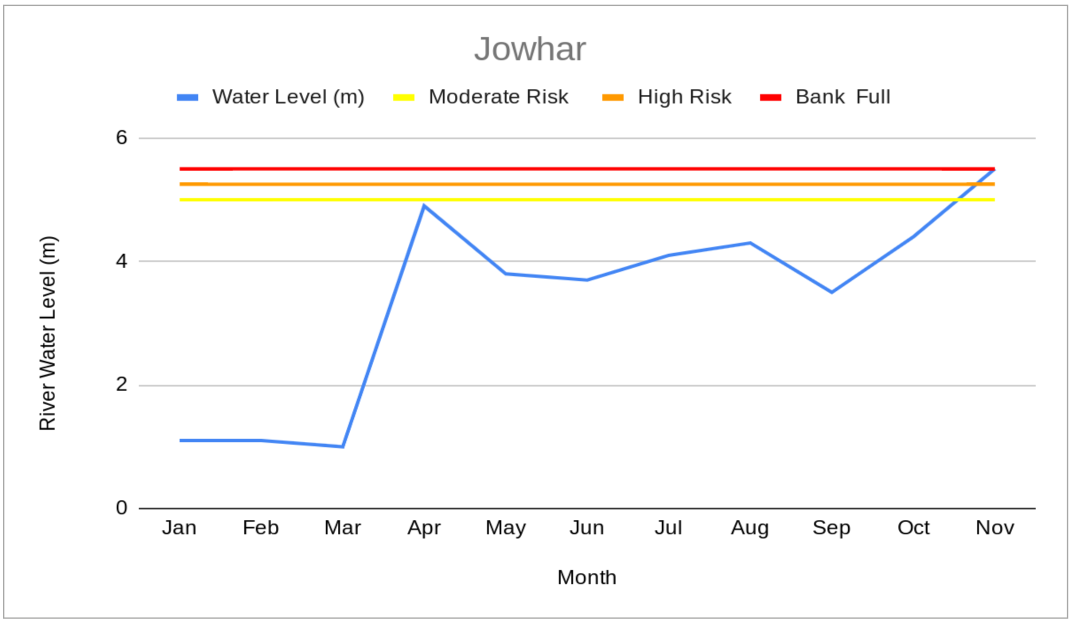


Figure 6: Daily river-water flow of Shabelle river at Jowhar district, Somalia

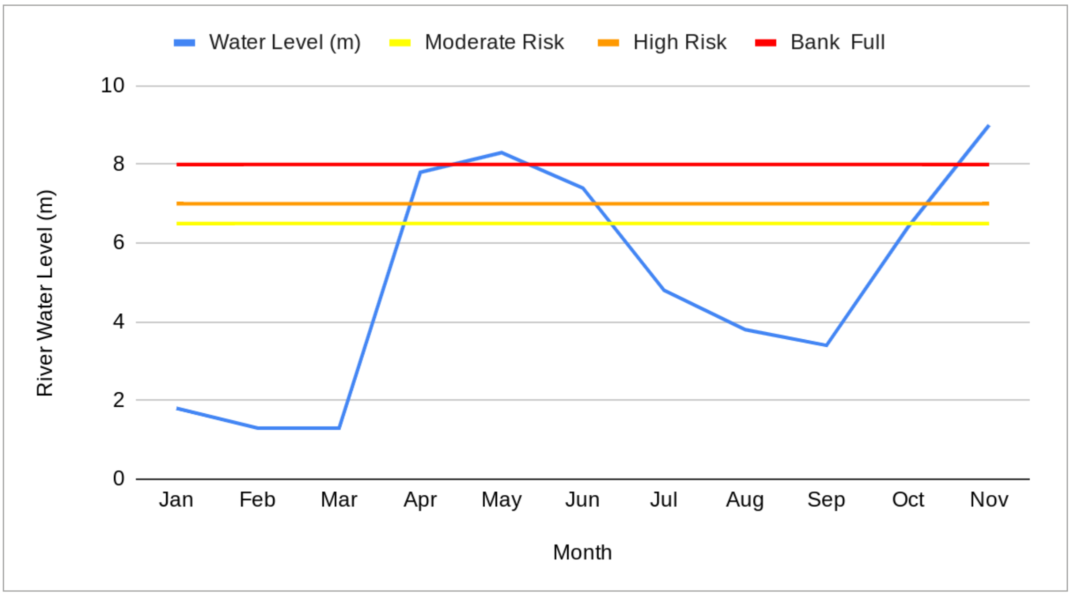


Figure 7: Daily river flow of Shabelle river at Beledweyne district, Somalia

Groundwater is essential to the Somali population's domestic water supply, livestock raising, and small-scale agriculture. Springwater, shallow wells, and boreholes are Somalia's primary sources of groundwater. An estimated 95 percent of the population relies heavily on groundwater as their main source of drinking water. The predominant use of groundwater is for drinking purposes, especially in urban centers. In rural areas, a substantial amount of groundwater is utilized for livestock watering. The practice of irrigation is not extensively implemented, except in areas along the two primary perennial rivers. Additionally, there is a scarcity of large-scale industrial groundwater usage within the undeveloped industrial sector. According to Basnyat (2009), boreholes are the most essential water sources in Somalia, as a greater part have water over time and give water when other sources dry out. The profundity of most boreholes in the nation is in the scope of 90 m to 250 m; however, the depths can reach more than 400 meters in some places (Basnyat, 2007). In rural areas, wells and boreholes are often managed by community management committees chaired by elders or village heads. Traditional norms and masculine leaders determine the legitimacy of water demands within a community. According to Basnyat (2009), they are responsible for determining water distribution and operation and maintenance methods.

A study conducted by FAO/SWALIM in 2012 examined the situation in the northern provinces of Somaliland and Puntland, where there is a lack of perennial surface water. The study estimated that the total annually rechargeable groundwater in the major aquifer systems is approximately 4.3 x 109 m^3. While most drilled boreholes have yields ranging from 1 to 5 l/s, there are variations with some boreholes having lower or higher yields.

. It was noted that certain boreholes may not be able to sustain high pumping rates, but increasing borehole capacity by installing higher capacity pumps or larger pipe diameters could potentially lead to higher groundwater yields. Studies conducted recently reveal that deep aquifers in the Horn of Africa, both onshore and offshore, which were not thoroughly investigated in the past, could harbor large volumes of fresh water with low to medium salinity levels. A recent study conducted by Quiroga et al. (2023) revealed the presence of more than 600 km^3 of freshwater reserves stored in deep aquifers. These aquifers are located at depths ranging from 400 to 1,200 meters, with certain areas reaching depths of up to 2,500 meters. Additionally, the study highlighted that approximately 50 km^3 of rain infiltrates the ground annually in the highlands of East Africa. This water then gradually moves through the subsurface of Somalia, with around 10 to 15 km^3 ultimately replenishing low-salinity aquifers. The Food and Agriculture Organization global information system on water resources and agricultural water management (FAO AQUASTAT) indicates estimated total available renewable water resources, encompassing surface and groundwater, as 14.7 km^3. In addition, the total withdrawal of water for domestic, agricultural, industrial, and environmental purposes was calculated to be 3.3 km^3 annually.

Many variables—including environment, climate, land use, and pollution of water bodies from natural and man-made sources–affect groundwater quality. Due to the increasing use of water for various purposes and the discharge of wastewater into groundwater, many aspects of water quality are typically monitored over a period of time. To construct composite indices that are clear to both the general public and to non-technical water managers and policy makers, it is crucial to integrate the outcomes of these measurements. There are concerns about the quality of groundwater in Africa. An estimated 300 million people in Africa lack access to clean drinking water (Makoba and Muzuka 2019) because of pollution from human and natural causes, which affect the amount and quality of drinkable water. Comte et al. (2016) examined obstacles in managing groundwater resources along the coast of East Africa, concentrating on groundwater accessibility in relation to sociological and physical factors. Furthermore, the uncontrolled extraction of groundwater can result in the intrusion of saline water into coastal aquifers. This occurrence, known as saltwater intrusion, renders the water unsuitable for drinking, irrigation, and other purposes. Given Somalia's significant coastline, this issue becomes even more critical, posing a threat to the availability of freshwater resources in the country. Additionally, the distribution of groundwater in Somalia remains unequal and inefficient, exacerbating water scarcity in certain regions. Despite the fact that assessing water quality is considered an essential component of all groundwater development initiatives in the area, it is widely recognized that data regarding groundwater quality in Somalia is limited.

In Somalia, the primary method of groundwater extraction involves the utilization of wells, boreholes, and underground springs. These sources play a vital role in providing a consistent and relatively uncontaminated water supply, especially in rural areas where access to surface water is limited.

The extraction of groundwater has become indispensable for the Somali population, particularly for rural communities, nomadic herders, and small-scale farmers who rely heavily on it for their survival. The uncontrolled withdrawal of groundwater in Somalia is causing a multitude of issues. Over-extraction may deplete aquifers, diminishing the quantity and quality of water resources. Consequently, rural and urban populations may encounter limited access to clean drinking water and water for domestic purposes and agricultural irrigation, negatively impacting their overall welfare.

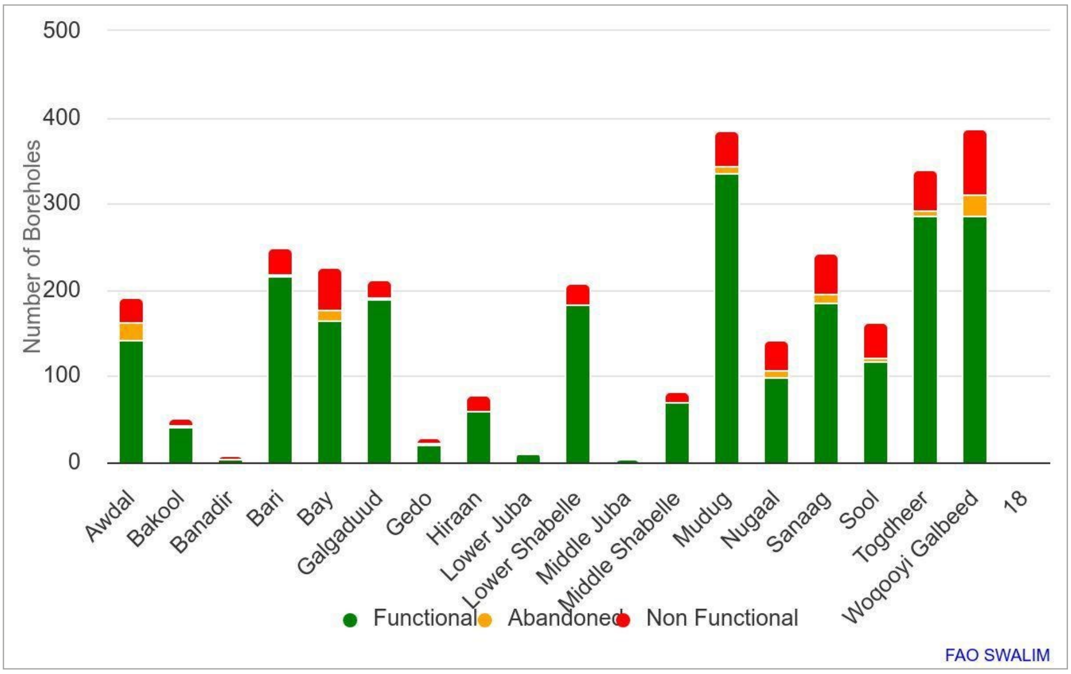


Figure 8: Distribution of boreholes per region (Source: FAO, SWALIM)

3.2 Water demand analysis

Current period (2023)

Demand for domestic and irrigation water in Somalia is a critical issue due to limited access to safe and clean water sources. The country faces numerous challenges in meeting the water needs of its population. In this study, current irrigation practice in the Shabelle and Juba river basins involves 50,000 ha and 15,000 ha, respectively. The finding indicates that the domestic water demand for the current period (2023) is 912.8 Mm^3. Irrigation water demand under the current period was estimated as 1,341.3 Mm^3 as shown in Figure 9.

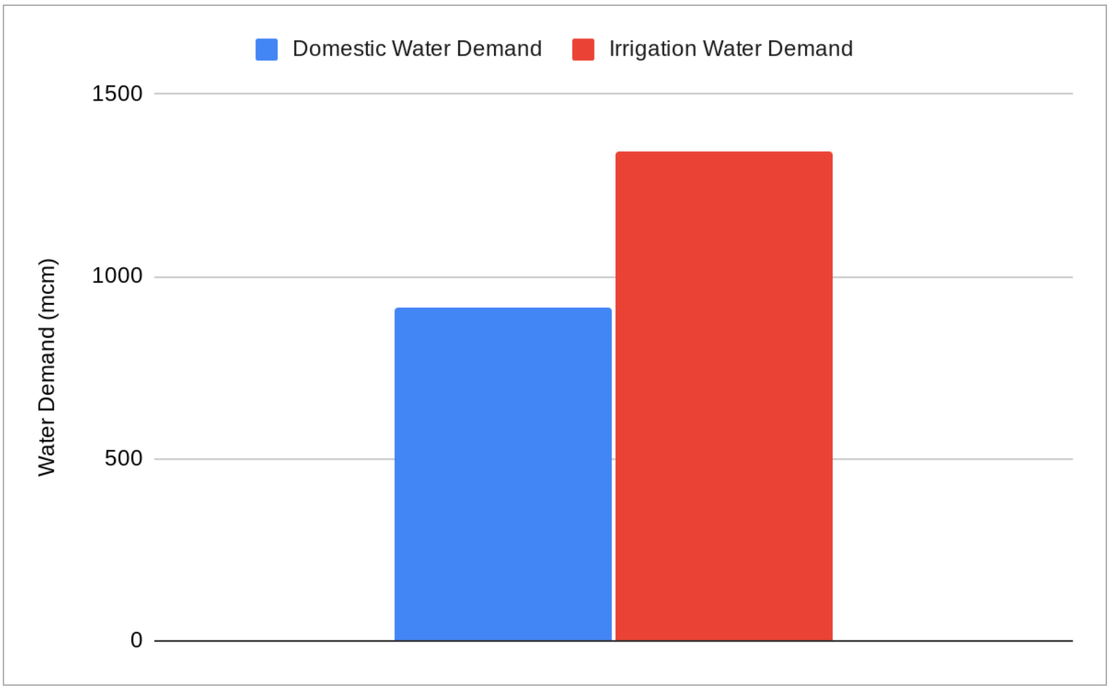


Figure 9: Estimated domestic and irrigation water demand under current period at Shabelle river

For the Juba river, the projected domestic and irrigation water demands were 1,007.6 Mm^3 and 1,836.1 Mm^3, respectively. The Shabelle river basin has historically received more attention and funding for irrigation infrastructure due to its higher agricultural potential, greater water resources, and more favorable topography. The intensity might be influenced by economic factors, as the Shabelle region is noted for its agricultural output ability.

Long-term projection (2050)

Under the long-term plan, irrigation practice in the Shabelle and Juba river basins is 135,000 ha and 32,000 ha respectively. The long-term plan results reveal that domestic and irrigation water demands from the Shabelle river are 1,542.1 Mm^3 and 1,812.4 Mm^3, respectively. The findings also show that, under the long-term plan, the demands for domestic and irrigation water from the Juba river are 1,627.5 Mm^3 and 2,419.2 Mm^3, respectively, as shown in Figure 10. The Juba river receives more rainfall than the Shabelle river. This could be due to such factors as geographic location, wind patterns, and topography. Higher rainfall would lead to increased flow of water in the Juba river. It is possible that the Shabelle river has undergone more human interventions than has the Juba river, resulting in an increased flow of water for the Juba.

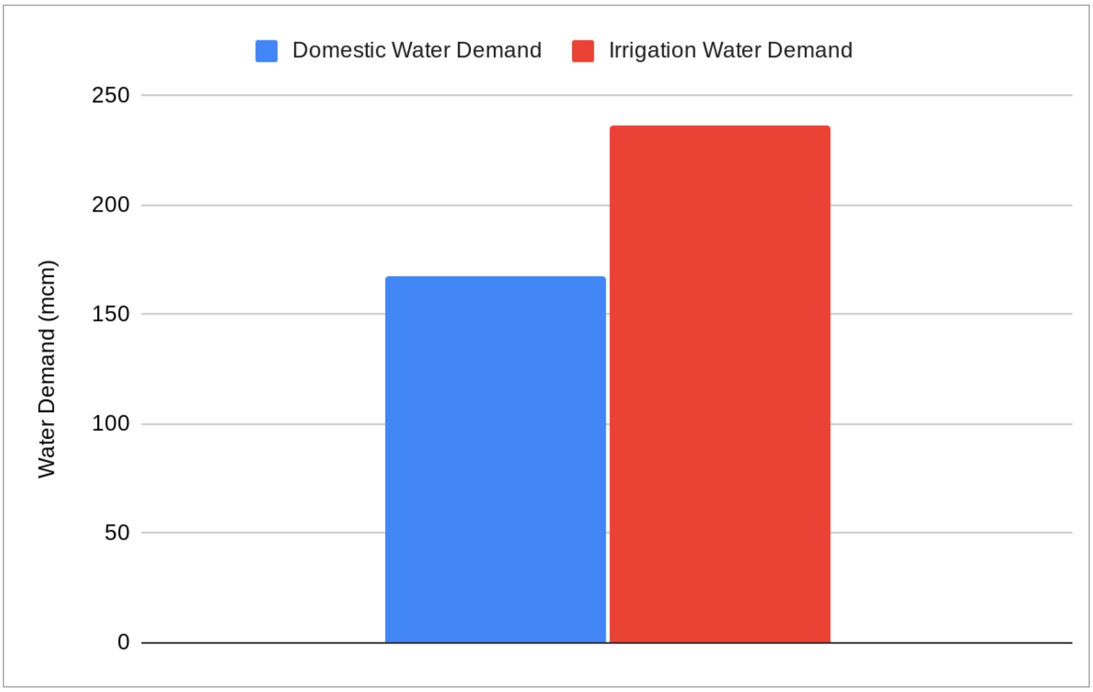


Figure 10: Estimated domestic and irrigation water demand under current period at Juba river

3.3 Institutions and policies governing water resources management

In Somalia, water management is primarily decentralized and led by local authorities and communities. There is no centralized water management institution at the national level due to the country's system. The Ministry of Energy and Water Resources (MoEWR) is responsible for water resources management and policy formulation. However, due to the federal system, Federal Member States (FMS) and local administrations have assumed primary responsibility for managing water resources in their respective regions. In the water sector, the allocation of policy-level responsibilities is currently distributed among multiple institutions. For instance, the Ministry of Energy and Water Resources is currently accountable for formulating policy, providing guidance, and ensuring the coordination of national water resources. However, there is a lack of harmonized management of water resources between the Federal Line Ministries and Federal Member States, leading to a fragmented approach. Post-civil war, federal states endeavored to enhance conditions with international support. However, the administrations of these states were unable to improve the livelihood of the Somali population due to the lack of a documented system outlining roles and responsibilities, leading to increased gaps among various institutions.

The achievement of NDP-9's vision and strategic actions is dependent on effective governance and necessitates the strengthening of Somalia's institutions and capacity in political and environmental governance. Enhancing the governance frameworks for water resource management and development will involve not only improving the legal and regulatory environments but also the ongoing development of policies and strategies to guide sustainable water development interventions. The key policies governing water management in Somalia include the National Water Policy and the Water Law. The National Water Policy aims to achieve sustainable management and utilization of water resources, promote equitable access to water, and encourage the participation of communities in water management. The Water Law provides the legal framework for water rights and responsibilities, water allocation, and dispute resolution mechanisms.

The limited institutional capability to prioritize, manage, and execute ongoing and proposed investment opportunities is evident. The absence of clear roles among the institutions involved in the water sector leads to conflicting responsibilities and competition for resources, particularly in relation to the allocation of funds for water projects. The challenges related to capacity at the local level have significant implications for the livelihoods of the community. While there are ongoing efforts to enhance governance at the federal and member state levels, it is equally important to focus on improving water sector governance at the local levels. Somalia has been making consistent advancements in strengthening the collaborative ties between federal state and member state ministries. However, it is now crucial to adopt tailored approaches that can align the governance frameworks of the federal government and member states in the water sector. This alignment will facilitate effective water resource management and the provision of essential water services. It will also help minimize conflicts in terms of mandates and ensure the optimal utilization of the limited resources available.

The international community, in collaboration with development-financing institutions and cooperating partners, has played a pivotal role in supporting Somalia in addressing and responding to diverse crises, as well as in advancing the country's development agenda. International organizations and NGOs are also actively involved in water management efforts in Somalia, providing essential technical knowledge, financial resources, and capacity-building assistance to local authorities and communities. This support has been extended through development initiatives and targeted humanitarian aid, and will continue to be crucial in assisting Somalia in addressing a wide range of water sector challenges and associated developmental issues.

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Table 1: Institutions governing the water resources sector in Somalia

Ministry name	Role
Ministry of Energy and Water Resources (MoEWR)	Responsible for overall water resources management in the country
Ministry of Agriculture and Irrigation	Responsible for irrigation management in the country

3.4 Somalia's national strategy and policy on water resources

The National Strategy and Policy on Water Resources in Somalia has been formulated with the aim of addressing the significant challenges faced by the country in terms of water management. These policies provide a comprehensive outline of the goals, strategies, and policies that will guide the sustainable development and management of water resources in Somalia. Key principles that underlie these strategies and frameworks include the necessity for integrated water resource management, equitable and inclusive water allocation, and the involvement of all stakeholders in decision-making processes. The strategies also emphasize the importance of protecting water sources and ensuring their sustainability for future generations. The National Development Plan 2020–2025 emphasizes the adverse effects of water scarcity on households, communities, health outcomes, and economies. This critical issue poses multifaceted challenges, impacting various aspects of society. At the household and community levels, limited access to water resources hampers daily activities and compromises basic needs. Moreover, the scarcity of water has detrimental effects on public health, exacerbating the risk of waterborne diseases and inadequate sanitation. Additionally, economies suffer as industries reliant on water face disruptions, agricultural productivity declines, and water-related conflicts arise.

The Ministry of Energy and Water Resources (MoEWR) has laid out a comprehensive strategy for the water sector covering the period 2021–2025. The strategy encompasses three key objectives:

1) Establishing an effective governance framework for the water sector

2) Implementing integrated water resources management

3) Enhancing the delivery of essential water services

The strategy is particularly focused on addressing the impacts of climate variability on water resource management and development. To facilitate the successful implementation of this strategy, a roadmap has been devised. The roadmap provides a comprehensive plan for establishing effective cooperative platforms that will serve as a support system and guide for the implementation of various actions. Additionally, these platforms will be responsible for monitoring and evaluating the progress made.

Over the next five to ten years, the NDP-9 will serve as the principal catalyst for the National Water Resources Strategy Plan, with the objective of ensuring sustainable, equitable, and secure water resources for national unity, economic growth, and the well-being of all citizens, while maintaining harmony with the natural environment.

Currently, the absence of a national Water Act poses a significant obstacle, as this legislation should establish the necessary legal structure, time frames, and application guidelines for various water management instruments. Moreover, it should address crucial aspects such as sectoral coordination, integration with other planning instruments, and the reporting frameworks essential for effective implementation. In addition, the National Water Policy is now under review and requires major amendments. The National Water Act and Policy Frameworks on Water Resources should focus on the following key areas:

- **Water governance and use:** This includes strengthening institutional capacities and regulatory frameworks for effective water management.
- **Water infrastructure development:** The frameworks outline plans for the construction and rehabilitation of water infrastructure, including dams, reservoirs, and irrigation systems.
- **Water resource conservation and protection:** Strategies are outlined to protect water sources from pollution, manage water demand, and promote efficient water use in various sectors such as agriculture, industry, and domestic use. There is also a focus on managing and mitigating the impacts of climate change on water resources.
- **Water sector financing:** The frameworks identify the need for sustainable financing mechanisms to support the development and maintenance of water infrastructure, as well as the management of water resources.
- **Capacity building and knowledge sharing:** The strategies emphasize the importance of strengthening the capacity of water resource professionals through training programs and knowledge-sharing platforms.

These frameworks provide a comprehensive roadmap for Somalia to address its water management challenges and promote sustainable development of water resources in the country.

3.5 Challenges of water resources development in Somalia

3.5.1 Natural challenges

Somalia's surface water resources are confronted with significant natural challenges that have a profound impact on the country's ability to sustainably manage and utilize this essential resource. The predominantly arid and semi-arid climate in Somalia results in limited rainfall and high evaporation rates, making it difficult to maintain surface water supplies. One major natural challenge facing Somalia's surface water resources is the scarcity of rainfall, with erratic and irregular rainfall patterns observed across the country, particularly in regions receiving less than 100 mm of rainfall annually. The inadequate precipitation levels lead to decreased river flow and limited replenishment of lakes and reservoirs, creating obstacles in establishing a consistent and sustainable water supply for residential and agricultural use. Furthermore, the region faces challenges from the high evaporation rates caused by the hot and dry weather conditions. Elevated temperatures and strong winds intensify evaporation, resulting in further reduction of surface water reserves. The situation is especially challenging in areas where water bodies are shallow or exposed, exacerbating water scarcity challenges and impeding communities from meeting their water needs. Furthermore, Somalia encounters obstacles in managing surface water resources due to its varied topography. The country's landscape includes flat plains in certain areas and rugged, mountainous terrain in others. The uneven topography results in uneven water distribution, with certain regions facing limited access to surface water resources based on their geographical location. This complicates the development of water storage and distribution infrastructure, further worsening water scarcity issues.

The degradation and siltation of rivers and water bodies present significant obstacles to the management of surface water resources in Somalia. Unsustainable land use practices, including deforestation, overgrazing, and inappropriate agricultural methods, contribute to soil erosion and the accumulation of sediment in water bodies. Therefore, the storage capacity and flow rates of these water bodies are reduced, making it challenging to capture and store water during the rainy season. Moreover, these issues directly impact the quality and availability of water for communities downstream. In addition to these challenges, Somalia also faces the adverse effects of climate change on its surface water resources. The country is highly vulnerable to climate variability and extreme weather events, such as droughts and floods. Droughts have become more frequent and severe, leading to a decrease in surface water availability and intensifying competition among water users. Conversely, heavy rainfall often triggers flash floods, which not only damage to infrastructure but also contaminate water sources. Consequently, these events further exacerbate the already existing water scarcity issues in the region.

3.5.2 Technical challenges

Somalia faces significant obstacles in managing and utilizing surface water resources due to limited access to clean and reliable water sources. The country's ability to sustainably utilize surface water is impeded by a range of technical and expertise-related challenges. One challenge is the inadequate infrastructure for effective surface water management. Somalia's inadequate infrastructure, characterized by the absence of a comprehensive system of dams, reservoirs, and canals, hinders the effective harnessing and distribution of surface water. This deficiency limits the country's ability to store and utilize surface water for irrigation, domestic use, and industrial purposes. Furthermore, the lack of expertise and technical knowledge in sustainable surface water management further complicates the situation in Somalia.

In addition to the lack of infrastructure and expertise, climate change and variability pose a significant technical challenge to the management of surface water resources in the country. The country experiences frequent droughts and erratic rainfall patterns, which leads to fluctuations in surface water availability. These changing climatic conditions further complicate the management and utilization of surface water resources. Without adequate technical knowledge and expertise to adapt to these changing conditions, Somalia struggles to develop resilient and sustainable solutions to address its surface water challenges. The technical and expertise challenges in managing surface water in Somalia are significant obstacles to the sustainable use of this vital resource. The lack of infrastructure, expertise, and resilience in the face of climate change hinders the availability and accessibility of clean water in the country. However, with proper investment in infrastructure development and capacity building, Somalia can overcome these challenges and ensure the sustainable utilization of its surface water resources for the benefit of its population.

The scarcity of water services and the widespread poverty prevailing in Somalia have made water one of the most elusive commodities in the country (Mourad, 2020). The involvement of public-private partnerships has played a pivotal role in ensuring access to safe drinking water for the populace. However, there is a need for further improvements to enhance water affordability and to meet international standards. The lack of adequate water resource development facilities has resulted in a scarcity of water for agricultural purposes, affecting the production of key staple food crops in the country. The degradation of irrigation systems over the past thirty years can be attributed to a lack of funding as well as to the migration of people from rural areas, resulting in a loss of expertise in maintaining these systems and passing down traditional knowledge to the next generation.

3.5.3 Economic challenges

Somalia is one of the world's under-developed countries and still has not recovered from the economic damage caused by thirty years of civil wars. The country faces numerous economic and financial challenges in the management and preservation of its surface water resources. These challenges are fueling the escalating water crisis in the country and are exacerbating the already dire living conditions for its people.

The country's limited infrastructure of dams, reservoirs, and water storage facilities poses difficulties in capturing, storing, and purifying the available surface water. The absence of adequate infrastructure greatly hinders the ability to satisfy the growing water needs of the population and to meet agricultural and industrial requirements. The substantial expenses associated with establishing and maintaining such infrastructure pose a significant financial burden, particularly for the government of Somalia, which has limited funds. Consequently, allocating sufficient resources to tackle this challenge is a daunting task. Moreover, the ongoing conflict and political instability in Somalia exacerbate the economic and funding challenges in effectively managing surface water resources. The lack of a stable government and regulatory framework further complicates the implementation of efficient water management policies and the enforcement of regulations. The ongoing uncertainty and security create a discouraging environment for foreign investment in infrastructure development and hinder the allocation of sufficient funding for water projects. The lack of a stable political landscape makes it difficult to secure financial aid and investments for maintaining a sustainable and reliable water supply. Somalia grapples with significant economic and financial challenges in managing its surface water resources because of limited infrastructure, water wastage, and political instability. However, by prioritizing water infrastructure development, investing in effective water management, and tackling the ongoing conflict, Somalia may overcome these obstacles and move toward a sustainable and reliable surface water supply. These efforts will not only enhance people's living standards, but will also contribute to the country's economic growth and development.

3.5.4 Transboundary challenges

River-water transboundary challenges in Somalia refer to the various problems and difficulties faced in managing and utilizing the river-water resources shared between Somalia and its neighboring countries. These challenges arise due to the nature of rivers that flow across national boundaries, requiring cooperation and coordination among the riparian nations. One of the major challenges facing Somalia in managing the Juba river water is the lack of a comprehensive and formalized agreement with Ethiopia regarding water sharing. The absence of a bilateral or multilateral agreement creates uncertainties and conflicts over the utilization of the river-water resources. As a result, Somalia is often at a disadvantage when it comes to negotiating its fair share of water, as Ethiopia has greater control over the river due to its upstream location. Another critical challenge is the competition for water resources between different sectors, such as agriculture, industry, and domestic use.

The Juba river is essential for irrigation purposes and is a significant source of water for agriculture in Somalia. However, the demand for water for industrial and domestic purposes is also increasing, leading to conflicts over water allocation and distribution. This competition for resources often exacerbates tensions and disputes between riparian nations, as each country seeks to secure adequate water supply for its own needs.

Additionally, the lack of institutional frameworks and mechanisms for transboundary water management exacerbates the challenges faced by Somalia. Effective management of shared river waters requires strong institutions, cooperation, and negotiation platforms to address concerns and resolve conflicts. However, in the case of Somalia, the absence of such mechanisms hampers the ability to develop and implement sustainable water management strategies, perpetuating the challenges faced by the country.

Somalia, in conjunction with its neighboring countries, Ethiopia and Kenya, shares two major perennial transboundary rivers, namely the Juba and Shabelle. These rivers play a crucial role in supporting the country's economy, water supply, and food security. However, the management of these transboundary rivers is currently characterized by fragmentation and a lack of coordination among Somalia's line ministries and stakeholders. This lack of unity not only hinders the development of Somalia's water sector but also poses the risk of escalating conflicts over water resources. The potential for a water-related conflict between Somalia and its neighboring countries over the utilization of the Shabelle and Juba rivers has raised concerns. According to Flintan and Tamrat (2002), water, being the most valuable resource, may become the primary source of conflict in Africa in the coming twenty-five years. However, it is worth noting that Somalia has a federal system in place, and there are no disputes or conflicts regarding the allocation and sharing of river water between its states, particularly concerning the Shabelle and Juba rivers. A significant number of local water resources committees and farmers lack the necessary technical knowledge concerning the primary factors contributing to water shortages. Therefore, unless the community's capacity is enhanced, disputes and conflicts over the allocation of the limited available water resources are expected to continue. According to the 2006 United Nations Development Programme (UNDP) report, local authorities advocate for engagement and negotiation as the primary means of resolving conflicts. They perceive injustice, poverty, and power imbalances as the exclusive underlying causes of water problems, rather than attributing water scarcity to climate change or to the absence of cooperation and agreements between riparian countries regarding the management of transboundary water sharing.

3.6 Development of conjunctive use of surface and groundwater strategies

Development of conjunctive use of surface and groundwater strategies is an important approach to address water scarcity and ensure sustainable water management. This strategy involves the coordinated use and management of both surface water and groundwater resources to maximize their potential and meet the increasing water demands of various sectors. Conjunctive use of surface and groundwater strategies is particularly relevant in regions like Somalia that are facing challenges such as population growth, climate change, and water availability limitations. These challenges have resulted in an imbalance between water demand and supply, and traditional water management approaches are no longer sufficient.

Conjunctive use strategies offer a solution by integrating different water sources to ensure a constant and reliable water supply. The conjunctive use of surface and groundwater strategies also promotes the sustainability of water resources. Groundwater is often seen as a hidden resource, as it exists in aquifers below the ground. Over-extraction of groundwater can lead to the depletion of aquifers and trigger negative consequences, such as land subsidence and saltwater intrusion. By incorporating surface water into the water supply mix, the reliance on groundwater alone can be reduced, allowing aquifers to recharge and replenish or refill naturally. To implement conjunctive use strategies effectively, it is crucial to have a robust water infrastructure and management framework.

A key benefit of conjunctive use strategies is flexibility in managing and allocating water resources. The availability of surface water resources is directly impacted by the changing climate. During dry seasons, there may be inadequate surface water to fulfill the demands from various sectors such as agriculture, industry, and domestic consumption. Groundwater, on the other hand, is relatively more constant and can be used during dry periods when surface water resources may not be sufficient. The combination of these two sources allows for a more reliable and continuous water supply. Another advantage of conjunctive use strategies is the potential for improved water quality. Surface water sources are more susceptible to pollution and contamination from various sources, such as agricultural runoff and industrial discharges. Groundwater, in comparison, is generally better protected from pollution due to natural filtration processes.

The development of conjunctive use strategies in Somalia offers several potential benefits:

- By integrating surface and groundwater sources, conjunctive use reduces dependence on a single water source, thus improving overall water security. Diversifying water sources helps to mitigate the impact of droughts and reduces the vulnerability of communities relying solely on surface or groundwater.

- Conjunctive use strategies facilitate reliable water supply for agricultural activities that enable farmers to enhance production, adopt crop diversification, and promote food security in the country. By optimizing irrigation techniques and water allocation, conjunctive use improves the overall efficiency and sustainability of agriculture.

- Effective conjunctive use management can help sustain ecosystems dependent on water resources. Balancing water abstraction between surface and groundwater sources ensures adequate river flow and maintains ecological processes, thereby supporting biodiversity and preserving the health of ecosystems.

- Conjunctive use strategies contribute to socioeconomic development by providing a reliable water supply for domestic, industrial, and commercial sectors. Improved access to water promotes human well-being, supports industries, and stimulates economic growth.

The development of conjunctive use strategies in Somalia is vital to mitigate water scarcity challenges and build resilience against future drought events. Through comprehensive resource assessments, improved infrastructure, and sustainable water management plans, Somalia can harness the benefits of integrating surface and groundwater sources. By optimizing domestic and agricultural water use, promoting water security, and supporting socioeconomic development, conjunctive use strategies can contribute to a sustainable future for Somalia.

The conjunctive use of surface and groundwater offers several environmental and socioeconomic benefits, including the following:

- Sustainable water management;
- Reduced reliance on surface water;
- Aquifer recharge;
- Ecosystem preservation;
- Water quality improvement;
- Conservation of energy.

4. Conclusion

The conjunctive use of surface and groundwater has been found to be a beneficial approach to managing water resources. In areas where surface water sources are limited or unreliable, supplementing with groundwater can help meet the water demand and ensure a more reliable water supply. Additionally, it can help in times of drought or during seasons of low surface water availability. By combining the two sources, the risk of water scarcity or inadequate supply is reduced. However, careful management and monitoring are necessary to ensure sustainable use and prevent overexploitation of groundwater resources. Overall, the conjunctive use of surface and groundwater is a valuable strategy for optimizing water resource management. However, the effective implementation of this strategy requires addressing various challenges related to hydrological complexity, legal frameworks, water quality, environmental impacts, and infrastructure. Overcoming these challenges demands interdisciplinary collaboration, robust governance frameworks, and the adoption of sustainable water management practices. Only through such concerted efforts can the conjunctive use of surface and groundwater become a viable and sustainable solution for meeting water demands in the face of increasing water scarcity.

5. Policy Recommendations

Implementing the following policy recommendations can help in optimizing water availability, promoting efficient water use, and ensuring the sustainability of surface and groundwater resources through their conjunctive use.

First, implementing an integrated water resources management (IWRM) approach can help in the conjunctive use of surface and groundwater resources. Understanding the interdependence of water resources and the necessity of managing them sustainably are key components of this strategy. Developing a comprehensive water resources management plan can ensure the coordinated and efficient use of both surface and groundwater sources.

Second, reviewing and revising water rights and allocation policies can facilitate the conjunctive use of surface and groundwater. Promoting equitable distribution, limiting unsustainable extraction, and establishing explicit legal frameworks for water rights are some examples. A comprehensive analysis of current water rights and their adequacy for conjunctive use should be conducted.

Third, investing in infrastructure development can support the conjunctive use of surface and groundwater. A possible solution to this would be the development of linked storage facilities like recharge ponds and reservoirs. Developing distribution systems that can efficiently utilize both surface and groundwater sources can optimize water availability for various needs.

Fourth, implementing managed aquifer recharge (MAR) strategies can enhance the conjunctive use of surface and groundwater. This involves artificially recharging aquifers by directing and storing excess surface water during periods of abundance. MAR can help stabilize groundwater levels and improve the overall sustainability of water resources.

Fifth, conducting educational campaigns and raising awareness among water users, farmers, industry, and the general public is essential for promoting the conjunctive use of surface and groundwater. This can involve disseminating information on sustainable water practices, the benefits of conjunctive use, and the need for responsible water consumption.

Sixth, collaboration between various stakeholders, including government agencies, communities, and water user associations is crucial for effective conjunctive use of surface and groundwater. Developing regional cooperation mechanisms, sharing best practices, and fostering dialogue can help in addressing conflicts and ensuring a coordinated approach to water resources management.

Finally, considering the potential impacts of climate change, it is vital to introduce the conjunctive use of surface and groundwater. Incorporating climate change projections into water management plans can help in developing adaptive strategies and ensuring the long-term sustainability of water resources.

6. References

Abdishakur, A. E., Ali, A. M. S., & Hassan, A. M. (2022). Assessment of Drinking Water Quality in Mogadishu, Somalia. Journal of Civil Engineering Research & Technology, 4(2), 1-7.

Abdolvandi, A. F., Parsamehr, A., Babazadeh, H., Eslamian, S., & Hosseinipour, E. Z. (2014). Conjunctive Use of Surface and Groundwater Resources Using System Dynamics Approach: Case Study of Namroud Dam. In World Environmental and Water Resources Congress 2014 (pp. 323–334).

Aeschbacher, J., Liniger, H., & Weingartner, R. (2005). River Water Shortage in a Highland–Lowland System. Mountain Research and Development, 25(2), 155–162.

African Development Bank (AfDB). Improving Access to Water and Sanitation Services in Somalia, OWAS/EARC/ORTS/GECL Departments 2016. Available online: https://www.afdb.org/fileadmin/uploads/afdb/Documents/Project-and-Operations/Somalia-_AR-_Approved-Improving_Access_to_Water_and_Sanitation_Services_in_Somalia.pdf (accessed on 8 February 2019).

Ahmed, R. (2005). Studies on the Chemistry Control of Some Selected Drinking and Industrial Waters. Pakistan J. Sci. Ind. Res., 48(3): 174–179.

Ahmed, J., Wong, L. P., Chua, Y. P., Channa, N., Mahar, R. B., Yasmin, A., ... & Garn, J. V. (2020). Quantitative microbial risk assessment of drinking water quality to predict the risk of waterborne diseases in primary-school children. International Journal of Environmental Research and Public Health, 17(8), 2774.

Araya, D., Podgorski, J., & Berg, M. (2023). Groundwater salinity in the Horn of Africa: Spatial prediction modeling and estimated people at risk. Environment International, 176, 107925.

Basnyat, D.B. and Gadain, H.M. 2009. Hydraulic Behaviour of the Juba and Shabelle Rivers: Basic Analysis for Irrigation and Flood Management Purposes, Nairobi, Kenya: FAO-SWALIM (GCP/SOM/EC045) project. Technical Report no. W–13.

Beier, A. C., & Stephansson, E. (2012). Environmental and Climate Change Policy Brief Somalia. Sidas Helpdesk for Environment and Climate Change.

Bodian, A., Dezetter, A., Diop, L., Deme, A., Djaman, K., & Diop, A. (2018). Future climate change impacts on streamflows of two main West Africa river basins: Senegal and Gambia. Hydrology, 5(1), 21.

Chen, Q., Mei, K., Dahlgren, R. A., Wang, T., Gong, J., & Zhang, M. (2016). Impacts of land use and population density on seasonal surface water quality using a modified geographically weighted regression. Science of the Total Environment, 572, 450–466.

Colvin, C., Le Maitre, D. C., & Hughes, S. (2003). Assessing terrestrial groundwater dependent ecosystems in South Africa (Vol. 1090). Pretoria: Water Research Commission.

Comte, J. C., Cassidy, R., Obando, J., Robins, N., Ibrahim, K., Melchioly, S., & Davies, J. (2016). Challenges in groundwater resource management in coastal aquifers of East Africa: Investigations and lessons learnt in the Comoros Islands, Kenya and Tanzania. Journal of Hydrology: Regional Studies, 5, 179–199.

Conway, D., Persechino, A., Ardoin-Bardin, S., Hamandawana, H., Dieulin, C., & Mahé, G. (2009). Rainfall and water resources variability in sub-Saharan Africa during the twentieth century. Journal of Hydrometeorology, 10(1), 41–59.

Evans, W. R., & Evans, R. (2012). Conjunctive use and management of groundwater and surface water. Thematic Paper, 2.

FAO-SWALIM (Balint Z, Stevanovic Z, Gadain H et al.). (2012). Hydrogeological Survey and Assessment of Selected Areas in Somaliland and Puntland. Technical Report No. W-20, FAO-SWALIM (GCP/SOM/049/EC) Project, Nairobi, Kenya.

Food and Agriculture Organization (FAO). (1995). Irrigation in Africa in figures, Water Report 7. https://www.ircwash.org/sites/default/files/272.2-95IR-13033.pdf.

Food and Agriculture Organization (FAO). (2005). Somalia Water Report 29. http://www.fao.org/nr/water/aquastat/countries_regions/SOM/

Figueroa, A. J., & Smilovic, M. (2021). Groundwater irrigation and implication in the Nile river basin. In Global Groundwater (pp. 81–95). Elsevier.

Flintan, F., & Tamrat, I. (2002). Spilling blood over water? The case of Ethiopia. Scarcity and Surfeit: The Ecology of Africa's Conflicts. ISS, Pretoria, South Africa. p. 243–319.

Gadain, H. M. and Mugo, M. W. 2009. Report on UNICEF Water Interventions Mapping (2005– 2009), Technical Report No W-19, FAO-SWALIM, Nairobi, Kenya.

Houghton-Carr, H. A., Print, C. R., Fry, M. J., Gadain, H., & Muchiri, P. (2011). An assessment of the surface water resources of the Juba-Shabelle basin in southern Somalia. Hydrological Sciences Journal, 56(5), 759–774.

Hutchinson, P., & Polishchouk, O. (1989). The agroclimatology of Somalia. Somali Democratic Republic, Ministry of Agriculture, Food Early Warning Department.

Intergovernmental Panel on Climate Change (IPCC). (2022). Climate Change Impacts, Adaptation, and Vulnerability. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change, edited by: Pörtner, H.-O., Roberts, D. C., Tignor, M., Poloczanska, E. S., Mintenbeck, K., Alegría, A., Craig, M., Langsdorf, S., Löschke, S., Möller, V., Okem, A., and Rama, B., Cambridge University Press, https://doi.org/10.1017/9781009325844, 2022b.

Kammer, D. 1989. A brief description of major drainage basins affecting Somalia with special reference to surface water resources. Mogadishu, Somalia: FAO.

Li, P., Qian, H., & Wu, J. (2018). Conjunctive use of groundwater and surface water to reduce soil salinization in the Yinchuan Plain, North-West China. International Journal of Water Resources Development, 34(3), 337–353.

Mahjoub, H., Mohammadi, M. M., & Parsinejad, M. (2011). Conjunctive use modeling of groundwater and surface water. Journal of Water Resource and Protection, 3(10), 726.

Makoba, E., & Muzuka, A. N. (2019). Water quality and hydrogeochemical characteristics of groundwater around Mt. Meru, Northern Tanzania. Applied Water Science, 9, 1–29.

Mohammed, A. (2017). Developing Methodologies for Sustainable Groundwater Management in sub-Saharan Africa: A case study of the Chad Basin around Maiduguri, Nigeria (Doctoral dissertation, Abertay University).

Mourad, K. A. (2020). A water compact for sustainable water management. Sustainability, 12(18), 7339.

Ogallo, L. A., Omondi, P., Ouma, G., & Wayumba, G. (2018). Climate change projections and the associated potential impacts for Somalia. American Journal of Climate Change, 7(2), June 2018

Quiroga, E., Bertoni, C., & Ruden, F. (2023). Deep low-salinity groundwater in sedimentary basins: Petrophysical methods from a case study in Somalia. Hydrogeology Journal, 31(3), 685–705.

Ruud, N. C., T. Harter and A. W. Naugle. (2001). A conjunctive use model for the Tule river groundwater basin in the San Joaquin Valley, California; Integrated Water Resources Management, Marino, M. A. and S. P. Simonovic (eds.), IAHS Publication No. 272. 167–173.

Safavi, H. R., & Enteshari, S. (2016). Conjunctive use of surface and ground water resources using the ant system optimization. Agricultural Water Management, 173, 23–34.

Said, A. A., Yurtal, R., Çetin, M., & GÖLPINAR, M. S. (2021). Evaluation of some groundwater quality parameters using geostatistics in the urban coastal aquifer of Bosaso plain, Somalia. Journal of Agricultural Sciences, 27(1), 88-97.

Sarwar A. (1999). Development of conjunctive use model, an integrated approach of surface and groundwater modeling using GIS, PhD Thesis, University of Bonn, Germany. pp 1–140.

Sebhat, M. Y., & Wenninger, J. (2014). Water balance of the Juba and Shabelle River basins the Horn of Africa. International Journal of Agricultural Policy and Research, 2(6), 238–255.

Shayo, G. M., Elimbinzi, E., Shao, G. N., & Fabian, C. (2023). Severity of waterborne diseases in developing countries and the effectiveness of ceramic filters for improving water quality. Bulletin of the National Research Centre, 47(1), 113.

Singh, A. (2014). Simulation–optimization modeling for conjunctive water use management. Agricultural Water Management, 141, 23–29.

Sophocleous, M. (2002). Interactions between groundwater and surface water: The state of the science. Hydrogeology Journal, 10, 52–67.

UNICEF. (2018). Drinking water, sanitation and hygiene in schools: Global baseline report.

Van Engelen, J., Essink, G. O., & Bierkens, M. F. P. (2022). Sustainability of fresh groundwater resources in fifteen major deltas around the world. Environmental Research Letters, 17(12), 125001.

WEAP. (2014). Water Evaluation and Planning. History and Credits. Stockholm Environment Institute. Retrieved July 1, 2014, from http://www.weap21.org/index.asp?action=219.

World Bank. (2018). Disaster Risk Management Development Policy Financing with a Catastrophe Deferred Drawdown Option.

World Health Organization (WHO). (2011). Guidelines for drinking-water quality. World Health Organization, 216, 303–304.

Wrachien, D. de and Fasso, C. A. (2002). Conjunctive use of surface and groundwater: Overview and perspective. J. Irrigation and Drainage, ASCE, 51(2), 1–15.

Xing, J., Song, J., Yuan, H., Li, X., Li, N., Duan, L., ... & Wang, Q. (2017). Fluxes, seasonal patterns and sources of various nutrient species (nitrogen, phosphorus and silicon) in atmospheric wet deposition and their ecological effects on Jiaozhou Bay, North China. Science of the Total Environment, 576, 617–627.

Zeitoun, M., Goulden, M., & Tickner, D. (2013). Current and future challenges facing transboundary river basin management. Wiley Interdisciplinary Reviews: Climate Change, 4(5), 331–349.

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