Future Technology
Open Access Journal
ISSN 2832-0379

November 2023| Volume 02 | Issue 04 | Pages 45-58

Journal homepage: https://fupubco.com/futech

https://doi.org/10.55670/fpll.futech.2.4.5

Future Publishing LLC

Review

Examining the impact of climate change on water resources in Somalia: The role of adaptation

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ARTICLE INFO

Article history:
Received 01 March 2023
Received in revised form
30 March 2023
Accepted 10 April 2023

Keywords:
Climate Change, Water resources, Somalia, Adaptation, Global responsibility,
Disaster management and preparedness

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DOI: 10.55670/fpll.futech.2.4.5

ABSTRACT

This review article explores the impact of climate change on water resources in Somalia, with a particular focus on the role of adaptation. The article discusses the effects of climate change on Somalia's water resources, including floods, drought, sea-level rise, drying up rivers, and poor water quality. It further examines the effects of climate change on surface water, groundwater, and precipitation and how it affects the ecosystem, communities, and economic and social impacts. The article also considers the health, food insecurity, and vulnerability to climate change in different regions of Somalia. It further discusses the capacity to mitigate climate change and the strategies of adaptation, such as building resilient cities and a holistic approach to risk management. The article also provides possible solutions, such as policy relevant to water audit and water management and the engagement of private, civil, and international sectors. Finally, the article argues that a major crisis can be averted if these strategies are implemented.

1. Introduction

Heat The impact of climate change on water resources in Somalia is one of the country's most pressing and pressing issues today. The country is already facing severe water scarcity, with a large portion of its population unable to access safe drinking water [1]. Climate change is exacerbating the already precarious water security situation in Somalia and is likely to significantly impact the country's water resources in the future [2]. In addition to water scarcity, Somalia also faces increased floods, drought, and sea-level rise due to climate change [3]. This could further undermine the availability of safe drinking water and lead to a drying up of rivers and other water sources, as well as poor water quality [2]. Moreover, climate change could also affect the availability and quality of surface water and groundwater, vital water sources for many communities in Somalia. The economic, social, and health impacts of climate change on water resources in Somalia are immense and could have a lasting impact on the country's future. This review article will discuss the various impacts of climate change on water resources in Somalia, the role of adaptation and mitigation strategies in addressing the impacts of climate change on water resources in Somalia, and potential solutions to address these impacts. This review article will draw upon existing literature to highlight the impacts of climate change on water resources in Somalia, the vulnerability of different regions of Somalia to climate change, and the capacity of the country to mitigate and adapt to the changes. The review article will also discuss the need for a holistic approach to addressing the impacts of climate change on water resources in Somalia, and the need for risk management strategies, policies relevant to water audit and water management, and the engagement of private, civil, and international sectors if a major crisis is to be averted.

2. Case study of Somalia

Somalia (Figure 1) is among the countries most vulnerable to the impacts of climate change. As a semi-arid country, Somalia is heavily dependent on water resources for agricultural and pastoral livelihoods and is particularly vulnerable to water scarcity and resource variability. Climate change is already having significant impacts on Somalia's

water resources, leading to increased water insecurity, water-related disasters, and water-related health risks [4].

Figure 1. Map of Somalia

Research has shown that Somalia's water resources are being impacted by climate change in several ways. Increased temperatures have caused the sea-level rise, which has led to saltwater intrusion into estuaries and groundwater sources [5]. Higher temperatures have also caused increased evaporation of water from rivers and reservoirs, leading to lower water levels and reduced river flows [6]. Further, changes in precipitation patterns due to climate change are leading to more frequent and severe droughts and floods, which are placing increased pressure on Somalia's water resources [7]. To address the challenges posed by climate change, the Somali government and international partners must take a comprehensive and system-wide approach to adaptation. This should include strengthening water inventors and standards, improving disaster management and preparedness, and investing in sustainable solutions to water insecurity [8]. The international community must also play a role in helping Somalia to adapt to climate change by providing financial and technical support to Somali efforts. Ultimately, the impacts of climate change on Somalia's water resources will require the combined efforts of all stakeholders, both local and international. By taking a system-wide approach to adaptation and implementing meaningful solutions, Somalia can improve its resilience to climate change and ensure the sustainability of its water resources [9].

3. Effects of climate change on water resources in Somalia

Somalia is one of the most vulnerable countries in the world to the impacts of climate change due to its geographical location in the Horn of Africa and its reliance on climate-sensitive sectors such as agriculture and pastoralism as primary sources of food and income. Climate change is profoundly impacting the availability and quality of water resources in Somalia, leading to a wide range of challenges for the country's water supply. Climate change has been a major issue of concern for Somalis (Figure 2), and the effects of climate change on water resources in Somalia are becoming more and more apparent. With a growing population and limited access to clean, safe drinking water, properly managing water resources is critical [10]. Studies have shown that climate change is already affecting water resources in Somalia. Rising sea levels from rising temperatures have caused saltwater intrusion in coastal areas. This has led to a decrease in the availability of freshwater resources, making it increasingly difficult for people to access clean drinking water [11]. Additionally, extreme weather events and prolonged droughts decrease surface water and groundwater levels. This has resulted in an increase in water shortages and scarcity, which directly impact the livelihoods of Somalis and the sustainable development of the country [12].

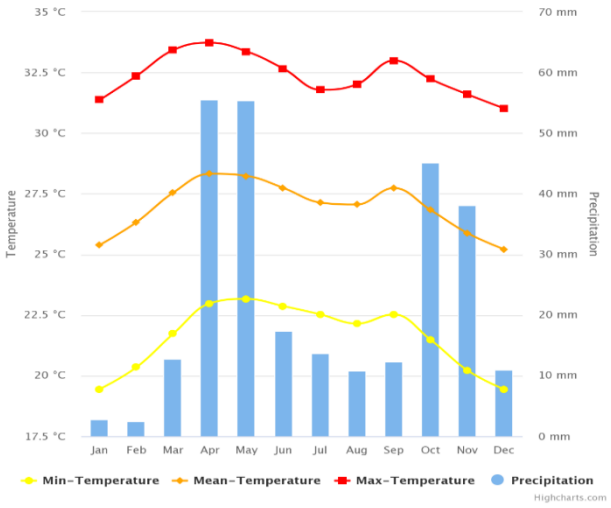

Figure 2. Monthly climatology of Somalia

3.1 Flooding

Flooding is a major environmental hazard that is increasingly exacerbated by climate change in Somalia. Increasing temperatures have resulted in increased evapotranspiration, meaning that less water is available for plants and animals, and less water is available for humans to use [13]. Higher temperatures have also increased the frequency and intensity of extreme weather events, such as floods and droughts. Furthermore, rising sea levels and groundwater extraction have caused water tables to drop, exacerbating the risk of flooding in coastal areas [14]. According to the United Nations Environment Programme (UNEP), Somalia has experienced an increase in the frequency and intensity of floods in recent years, which have led to the displacement of thousands of people, the destruction of agricultural land, and the loss of lives and livelihoods [15]. In 2018 alone, floods affected over 100,000 people in the country [16]. The UNEP report also found that climate change is likely to significantly impact Somalia, with a projected increase in drought and floods. This will majorly impact water availability and water resources management in the country [15]. According to the World Bank, climate change is likely to further decrease water availability in Somalia, as well as increase the risk of floods and drought. The World Bank estimates that by 2050, the number of people affected by floods in the country could rise to more than 400,000, and the number of people affected by drought could reach up to 3 million [16]. A recent report by the Intergovernmental Panel on Climate Change (IPCC) found that the most severe impacts

of climate change in Somalia are likely to be felt in water resources, with an increased risk of floods and droughts. The report recommends that the country should focus on adaptive strategies to reduce the risks posed by climate change [17]. Adaptation to flooding is key to reducing the impact of climate change on water resources in Somalia. This can include measures such as improved drainage systems, flood forecasting, and early warning systems [18]. Additionally, local communities can protect their water resources by creating and maintaining storage reservoirs, canals, and other water channels to hold excess water and reduce flooding [19]. Further, improved agricultural practices, such as terracing and water harvesting, can reduce soil erosion, limit the impact of runoff, and retain soil moisture. Climate change is increasingly exacerbating the risk of flooding in Somalia and impacting water resource availability. In order to mitigate this risk, adaptation measures must be taken at the local level to reduce soil erosion, improve drainage systems, and create water storage reservoirs [20]. Additionally, improved agricultural practices can also help limit the impact of flooding and retain soil moisture [21].

3.2 Drought

Drought is one of the most significant climate change impacts on Somalia's water resources. It is estimated that the country experienced a 15% decrease in rainfall between 1975 and 2000, and approximately two-thirds of the country is already classified as arid or semi-arid. This decrease in precipitation has resulted in severe water shortages, with some areas of the country experiencing water scarcity for as much as eight months of the year [22]. The drought has profoundly affected agricultural production in Somalia, resulting in decreased crop yields, land degradation, and poverty. Livestock production and access to safe drinking water have also been affected, resulting in a decrease in the overall health and well-being of the population. The drought has also resulted in increased competition for limited water resources, leading to conflict between pastoralists and other users of the resource [23]. In order to address the effects of the drought, the government of Somalia has implemented a variety of adaptation measures, including improved water management and conservation practices, the expansion of water storage capacity, and the development of desalination plants [24]. In addition, the government has implemented measures to improve the availability and quality of water, including the construction of water tanks, the installation of hand pumps, and the provision of safe drinking water [25]. However, these adaptation measures have had limited success in improving the availability and quality of water due to limited funding and capacity for implementation. In addition, the drought has exacerbated existing water insecurity issues due to poor infrastructure and inadequate governance systems, making it difficult for adaptation measures to be effectively implemented [26]. Somalia has been experiencing severe drought since 2016, resulting in over 6.2 million people in need of humanitarian assistance [27]. The number of people facing Crisis or Emergency levels of food insecurity has risen from 2.1 million in 2016 to 6.7 million in 2018 [28]. Over 1.3 million Somalis are internally displaced due to drought-related conditions [29]. In 2018, there was an estimated $1.5 billion in losses due to the drought in Somalia [30]. About 2.6 million Somalis are in need of access to safe water and sanitation services [31]. Over 40% of the population is living in extreme poverty [32]. Somalia is one of the most vulnerable countries to climate change, with temperatures projected to rise by up to 1.2°C [33]. Given the severity of the drought and its impacts on water resources in Somalia, it is clear that there is an urgent need for a system-wide approach to interventions that involve both global and local actors. This approach should include increased funding for adaptation measures, improved water infrastructure, and improved governance systems, as well as improved access to safe drinking water and improved disaster management and preparedness [34]. In addition, global responsibility is needed to ensure that the most vulnerable communities in Somalia have access to the resources they need to survive and thrive [35].

3.3 Water quality

Water quality is a major concern in Somalia due to climate change. According to the World Bank, Somalia is "at risk of becoming increasingly water-scarce due to climate change and unsustainable water use". Changes in precipitation and temperature have caused shifts in the water cycle, leading to decreased water availability and increased water insecurity [36]. In addition, rising sea levels, increased evaporation, and salinization of soil and water sources have all led to a decrease in the quality of water resources. The impacts of climate change on water quality are felt most acutely in rural areas, where access to safe drinking water is already limited [37]. Water sources that are already polluted by human activities, such as agricultural runoff, industrial effluent, and untreated sewage, are further impacted by climate change, making it difficult to meet the needs of rural communities. In addition, poor sanitation and hygiene practices, combined with limited access to resources, contribute to water-borne diseases such as cholera and typhoid. This has devastatingly impacted vulnerable populations, including women and children in rural areas [38]. In order to address the water quality crisis in Somalia, it is necessary to implement an integrated approach to adaptation that focuses on both immediate and long-term solutions. This includes investments in infrastructure, such as rainwater harvesting, desalination plants, and improved water management systems [39]. It also requires the establishment of water quality standards and effective monitoring systems, as well as improved access to safe water sources. Additionally, adaptation strategies should be implemented to reduce climate change's environmental, social, and economic impacts, such as improved agricultural practices, increased education access, and access to safe drinking water [40]. Ultimately, it is important to recognize the global responsibility to address the impacts of climate change on water quality in Somalia. This requires a system-wide approach to interventions and a commitment to sustainable development. It also requires a commitment to disaster management and preparedness to mitigate the risk of water-borne diseases and enhance the resilience of vulnerable populations [41].

3.4 Surface and groundwater systems

Surface water and groundwater systems are a vital part of the water resources in Somalia and are being heavily impacted by climate change. In Somalia, surface water resources include rivers, streams, and lakes, while groundwater resources are mainly in the form of aquifers that are largely shallow and of limited capacity. Climate change is having a direct and indirect impact on the surface and groundwater systems in Somalia. The direct impact is through the changes in temperature, precipitation, and sea level (Figure 3), which are leading to the decline in the availability of surface and groundwater resources. In addition, the indirect impacts of climate change on the surface and

groundwater systems include changes in land use, soil erosion, and sedimentation. These impacts are further exacerbated by the growing population, deforestation, and land degradation [42]. The impacts of climate change on the surface and groundwater systems in Somalia have led to numerous consequences for the local population, including reduced access to drinking water, increased water scarcity, and decreased agricultural productivity [43]. In addition, the increasing temperatures have put additional stress on the existing water resources, leading to increased salinity and decreased water availability for irrigation and other uses. In order to effectively address the impacts of climate change on the surface and groundwater systems in Somalia, a wide range of interventions is required. These interventions should include improved water management systems and policies, increased water harvesting and storage, improved irrigation techniques, and improved water quality standards [44]. In addition, there is a need for a system-wide approach to interventions, including disaster management and preparedness and the implementation of adaptation strategies. It is also important to recognize the global responsibility to ensure the effective management of water resources in Somalia. This includes the provision of support for water inventors and standards, and increased cooperation among local, regional, and international stakeholders [45]. In addition, it is essential to ensure that all interventions are conducted in a way that respects local customs, values, and traditions [46].

3.5 Precipitation and water vapor

Precipitation and water vapor are two of the most important aspects of the climate system, playing an integral role in the functioning of the global hydrological cycle which is essential for ensuring the availability of water resources for human and ecosystem use. In Somalia, these two components of the climate system have a significant impact on the water resources available for human and ecosystem use. In Somalia, climate change has led to extreme changes in precipitation patterns, resulting in an overall decrease in rainfall over the past decades. This decrease in rainfall has led to a decrease in surface water availability and an increase in water scarcity. The decrease in rainfall has also led to a decrease in groundwater availability as well as an increase in drought events [47]. This decrease in water availability has directly impacted the livelihoods of the people of Somalia, as the lack of water has made it more difficult for them to access the resources they need to survive [48]. In addition to the decrease in precipitation, climate change has also led to an increase in water vapor in the atmosphere, resulting in more extreme weather events such as flash floods and heavy storms [49]. These extreme weather events have caused significant damage to infrastructure, property, and human lives, as well as putting a strain on the already limited water resources in Somalia. In order to address the challenges posed by climate change and the resulting impacts on water resources in Somalia, adaptation measures need to be taken. This includes the development of water inventors, the establishment of water standards, and the implementation of a system-wide approach to interventions. In addition, disaster management and preparedness measures need to be taken to mitigate extreme weather events' impacts [50]. Ultimately, it is important to recognize that climate change is a global problem and that addressing it requires a global response. Therefore, it is essential that governments, international organizations, and civil society organizations work together to create effective adaptation strategies that can be implemented in Somalia to ensure the availability of water resources for the people of Somalia and the ecosystems upon which they rely [51].

3.6 Sea-level rise and ocean dynamics

Sea-level rise is an important aspect of climate change, which is having a significant impact on water resources in Somalia. Sea-level rise has caused coastal erosion and flooding in Somalia, resulting in significant changes in ocean dynamics [52]. This has had a detrimental effect on the livelihoods of coastal communities, as more and more land is lost to the sea, leading to crop failures and displacement of people. Sea-level rise can also lead to saltwater intrusion into coastal aquifers, contaminating the freshwater resources in Somalia. This can significantly affect the availability of freshwater for both rural and urban areas, leading to a decrease in local agriculture production and water supply for human consumption. Therefore, it is important to not only focus on adaptation measures to mitigate the impacts of sea-level rise but also to consider the global responsibility of reducing carbon emissions, which are the primary cause of climate change [53]. In order to cope with the impacts of sea-level rise, it is important to have a system-wide approach to interventions in Somalia. This should include investing in water inventors and standards, disaster management and preparedness, and resilient infrastructure [54]. Additionally, measures such as water harvesting, constructing levees, and planting mangroves can also help in mitigating the impacts of the sea-level rise [55]. Sea-level rise is a major impact of climate change on water resources in Somalia, which has the potential to significantly affect the livelihoods of coastal communities. Therefore, essential to implement a system-wide approach to interventions, which should include measures such as investing in water inventors and standards, disaster management and preparedness, and resilient infrastructure [54].

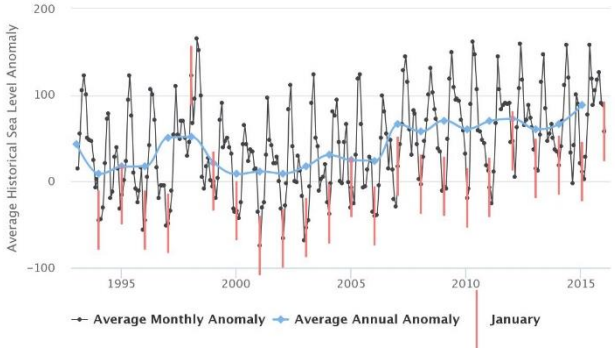

Figure 3. Historical sea level for the coast of Somalia

4. Impact of climate change on livelihoods in Somalia

Somalia is a country in East Africa and is particularly vulnerable to the impacts of climate change. The country has experienced a shift in its climate patterns over the past decades, leading to increased temperatures, increased frequency of droughts and floods, and decreased availability of water resources. This has significantly impacted the livelihoods of the people living in Somalia, particularly those who rely on farming and livestock for sustenance [56]. The impacts of climate change on livelihoods in Somalia can be seen in the form of decreased crop yields and reduced water availability. Due to warmer temperatures, farmers face reduced rainfalls, which leads to reduced crop yields and higher prices for food. Rainfall patterns have also changed,

leading to increased flooding in some areas and prolonged periods of drought in others. This has adversely affected the livelihoods of farmers, particularly those who rely heavily on rain-fed agriculture for their sustenance [57]. In addition, climate change has also led to increased water scarcity in Somalia. Decreased rainfall has led to reduced water availability in rivers and lakes, and increasing temperatures have increased evaporation rates. This has led to a decrease in water availability for agricultural and domestic use, further exacerbating the impacts of climate change on livelihoods. Furthermore, the increased frequency of floods and drought has also led to water-borne diseases, such as cholera, as well as an increase in water-related conflicts [58]. To address these issues, adaptation strategies must be put in place to ensure the sustainable use of water resources and reduce the impacts of climate change on livelihoods in Somalia. Such strategies include the implementation of water inventors and standards, the adoption of a system-wide approach to interventions, and disaster management and preparedness [59]. In addition, global responsibility must be taken to ensure that the necessary resources are available to help mitigate the effects of climate change. Overall, climate change is having a substantial impact on livelihoods in Somalia, and it is essential that adaptation strategies are implemented to reduce these impacts. It is also important to recognize the global responsibility that must be taken to ensure that the necessary resources are available to help mitigate the effects of climate change [60].

4.1 Economic impacts

The economic impacts of climate change on water resources in Somalia are both far-reaching and complex. In a country already facing severe economic challenges, climate change is making an already difficult situation even worse. Somalia is already one of the most water-stressed countries in the world, and the effects of climate change are expected to only worsen this situation. This is likely to have a significant impact on both the country's economy and the livelihoods of its people [61]. Climate change has already caused a decrease in the availability of water resources in Somalia, particularly during the dry season. This has resulted in water shortages and the need for water rationing, leading to increased water costs and a decrease in water availability for agriculture. This, in turn, has led to a decrease in crop yields, with a corresponding impact on the country's food security [62]. Furthermore, the increasing frequency and severity of droughts has caused a decrease in the availability of grazing land, resulting in an increase in the cost of livestock feed and a decrease in the availability of livestock products. This has had a direct impact on the livelihoods of pastoralist communities, as well as on the local economy [63]. In addition to the direct impacts of climate change on water resources, there are also indirect impacts. For example, climate change is expected to lead to increased frequency and intensity of floods, with a corresponding increase in the need for disaster management and preparedness. This is likely to place an additional strain on the country's already limited resources and could have serious economic and social implications [64]. There is an urgent need for the international community to take action in order to ensure that Somalia is able to cope with the economic impacts of climate change on water resources. This must include a system-wide approach to interventions that focus on both adaptation and mitigation, as well as the implementation of water inventors and standards to ensure the equitable distribution of water resources [65]. Moreover, the international community must also recognize that the country's economic and social challenges are inextricably linked to its water resources and ensure that its interventions are designed to address both issues [66].

4.2 Food security and agricultural production

Climate change has severely affected food security and agricultural production in Somalia, with increased droughts, floods, and other extreme weather events leading to decreased crop yields and livestock mortality. The impact of climate change on water resources in Somalia has been particularly acute, with water shortages and water insecurity becoming major issues. This has had a direct impact on food security and agricultural production, with decreased access to water resources leading to decreased crop yields, reduced livestock productivity, and decreased incomes for farmers, herders, and fishers [67]. Adaptation measures are essential to addressing the negative impacts of climate change on water resources and agricultural production in Somalia. These include improved water management, such as introducing new water inventors and standards, implementing a system-wide approach to interventions, and disaster management and preparedness [68]. In addition, global responsibility must also be taken to reduce emissions and mitigate the effects of climate change, which will reduce the frequency and intensity of extreme weather events and help to secure water resources for agricultural production [69].

4.3 Social impacts conflicts and migration

Climate change has had a significant impact on water resources in Somalia, resulting in a variety of negative consequences for the country's people and environment. The effects of climate change have been felt in the form of increased water scarcity and a decrease in water availability, leading to a decrease in agricultural production and subsequent food insecurity. This has had a direct impact on people's livelihoods and has also exacerbated existing conflicts over water resources [70]. Furthermore, climate change has caused the displacement of communities due to increasingly frequent and intense floods, droughts, and other extreme weather events [71]. The impacts of climate change on water resources in Somalia have been further intensified by the country's fragile political and economic situation, which has weakened its ability to adapt to and mitigate the impacts of climate change. The lack of financial resources, effective governance, and capacity to implement adaptation measures have hindered the country's ability to respond effectively to climate change [72]. Furthermore, the lack of access to safe drinking water, sanitation, and hygiene services has further exacerbated the situation [73]. In order to address the impacts of climate change on water resources in Somalia, there is a need for a system-wide approach to interventions. This should include adaptation and mitigation strategies and involve implementing appropriate technologies and management practices. In particular, there is a need to improve water inventors and standards in order to ensure access to safe and reliable sources of water [74]. Furthermore, there is a need to strengthen disaster management and preparedness in order to reduce the risk of floods, droughts, and other extreme weather events [75]. The global community is also responsible for addressing climate change's impacts on water resources in Somalia. This includes providing financial and technical assistance to help the country adapt to climate change and ensure access to safe and reliable water sources. In addition, international actors should also support the development of policies and initiatives that promote water conservation and the more efficient use of water resources [76].

4.4 Health impacts

The impacts of climate change on water resources in Somalia have been grave and have had a significant impact on the health of its population. Climate change has caused decreased rainfall, prolonged droughts, and increased temperatures in Somalia, leading to water scarcity and reduced access to clean and safe water. This has led to a decrease in agricultural production, resulting in food insecurity and malnutrition [77]. As a result, people in Somalia are more vulnerable to water-related diseases, such as cholera, diarrheal diseases, and malaria [78]. The most affected are pregnant women, young children, and the elderly, who are more vulnerable to the health risks associated with climate-related water insecurity. Water scarcity is also linked to the spread of vector-borne diseases, as the decrease in clean water availability encourages the growth of vector-borne diseases, such as malaria and dengue fever [79]. In order to better address the health impacts of climate change, the government of Somalia needs to implement adaptation strategies that consider the health of its citizens. For example, the government should focus on improving water access and sanitation, promoting hygiene practices, and addressing the lack of access to healthcare services, particularly in rural areas [80]. In addition, the government should focus on developing long-term strategies to increase access to clean and safe water, such as investing in water infrastructure and promoting water conservation [81]. In addition, the international community is responsible for supporting Somalia to mitigate the health impacts of climate change. This support should include providing financial and technical assistance to help the government of Somalia to build and maintain water infrastructure, develop water inventors and standards, and support a system-wide approach to water interventions [82]. Furthermore, the international community should focus on supporting disaster management and preparedness to reduce the health risks associated with climate-related water insecurity [83].

5. Impacts of transboundary water resources

The impacts of climate change on water resources in Somalia have been steadily increasing in recent years. This is due to the country's arid climate, which is characterized by limited rainfall and scarce water resources in most parts of the country [84]. As a result, water resource availability has been greatly reduced, and competition for resources has become increasingly intense. This has led to significant degradation of water resources and an increased risk of water-related conflicts. The trans-boundary water resources of Somalia, such as the Jubba River, Shabelle River, and Dawa River, are also affected by climate change. These rivers have been subject to increased flooding and decreased water availability, leading to a decrease in water quality. This has significantly impacted the livelihoods of people in the region, as they have to face increased risks of water-borne diseases [85].

5.1 Jubba River

The Jubba River is the longest in Somalia and serves as the lifeline for many communities, who depend on it for their livelihoods and survival. The river runs from the Ethiopian highlands, through Somalia and empties into the Indian Ocean in the south. The Jubba River is a vital source of water for many local communities and its impact on their lives is immense [86]. Climate change is a major threat to the sustainability of the Jubba River and its surrounding ecosystems. In recent years, there has been an increase in extreme weather events and a decrease in average rainfall, which has led to a decrease in the river's flow [87]. In addition, rising temperatures and changing weather patterns are expected to increase the frequency and intensity of floods and droughts, further impacting the water resources of the Jubba River [88]. These changes are likely to significantly impact the livelihoods of communities dependent on the Jubba River. For example, reduced access to water resources could lead to a decrease in agricultural productivity, decreased access to clean drinking water, and a decrease in fish stocks, which would all have an impact on the economic and social security of local communities [89]. Adaptation strategies are essential if communities are to cope with the impacts of climate change on the Jubba River. These strategies include improved water management and access, increased irrigation efficiency, water harvesting, and water storage capacity [90]. In addition, efforts should be made to promote sustainable fisheries and reduce water pollution [91]. In order to ensure the sustainability of the Jubba River and its surrounding ecosystems, global responsibility is also needed. Governments should put in place policies and regulations that encourage sustainable water use and promote the conservation of water resources [92]. In addition, international organizations should support local communities in developing adaptation strategies and access to resources [93]. Finally, a system-wide approach to interventions is needed. This approach should include the integration of water inventors and standards into the management of the Jubba River, the development of disaster management and preparedness plans, and the developing of a comprehensive monitoring system [94].

5.2 Shabelle River

The Shabelle River is one of the most important and heavily utilized sources of water in Somalia. It is the longest river in the country and serves as a vital source of freshwater for domestic, agricultural, and industrial uses. However, due to the effects of climate change, the river is facing increasing pressure and is becoming increasingly unreliable as a source of water [95]. The effects of climate change have had a profound impact on the Shabelle River. Warmer temperatures, increased variability in precipitation, and extreme weather events have all resulted in reduced water availability [96]. This has caused significant water shortages, decreases in water quality, and increased river salinization [94]. These impacts have led to decreased crop yields and significantly impacted the livelihoods of those dependent on the river for their livelihoods [95]. The impacts of climate change on the Shabelle River have necessitated the implementation of adaptation measures. These include water inventors and standards in order to ensure the efficient and effective use of the river's water [96]. Furthermore, a system-wide approach to interventions is needed to ensure the sustainability of the river. This includes disaster management and preparedness, as well as the implementation of mitigation measures to reduce the impacts of climate change [97]. In addition to local adaptation measures, global responsibility must be taken to address climate change's impacts. This includes the implementation of sustainable development strategies, as well as the implementation of global climate change policies. In order to ensure the sustainability of the Shabelle River, it is essential that global and local stakeholders work together to ensure the effective management of the river's resources [98].

5.3 Dawa River

The Dawa River is a major river in Somalia that runs through the country's Jubaland region. It is one of the main sources of water for the people of Somalia and is the main source of water for the region's agricultural production. As climate change continues to affect the region, the Dawa River has become increasingly vulnerable to drought, floods, and other environmental changes [99]. This has had a significant impact on the lives of the people who depend on the river for their livelihoods. The impact of climate change on the Dawa River has been far-reaching. A decrease in rainfall and increasing temperatures have caused the river to dry up during the summer months, resulting in decreased water flow and reduced water levels in the river. This has had a significant impact on local farmers, as the reduced water supply has decreased crop production. Additionally, the lack of water has led to an increase in water-borne diseases, such as cholera and malaria, as well as an increase in water-related conflicts among different communities [100]. To address the impact of climate change on the Dawa River, the Somali government and other stakeholders have implemented several adaptation strategies. These include the development of water inventors and standards, the establishment of system-wide approaches to interventions, and the implementation of disaster management and preparedness plans [101]. Additionally, the Somali government has been working with international organizations, such as the World Bank, to promote global responsibility for the impacts of climate change on the Dawa River [102]. Overall, the Dawa River is a major source of water for the people of Somalia and is an integral part of their livelihoods. Climate change, however, has had a significant impact on the river and its surrounding communities [103]. To address this, the Somali government and other stakeholders have implemented several adaptation strategies and are working with international organizations to ensure that the impacts of climate change on the Dawa River are managed properly [104].

6. The way forward and the role of adaptation

In order to effectively manage the impacts of climate change on water resources in Somalia, a system-wide approach to interventions should be implemented. This approach should include strategies to increase resilience to climate change, reduce vulnerability, and promote sustainable water management. These strategies should include improved water inventors and standards, better water-related infrastructure, improved water-use efficiency, and improved water governance [105]. Additionally, disaster management and preparedness strategies should be implemented to reduce the risks posed by extreme weather events and floods. The global community has an important role to play in supporting these adaptation efforts, including providing financial, technical, and capacity-building support, and enhancing the global dialogue on climate change adaptation [106].

6.1 Global responsibility and action

The global community has a responsibility to act on climate change and its impacts on water resources in Somalia. Climate change is expected to further reduce and degrade water resources in the country, leading to adverse impacts on people's livelihoods, food security, health, and wellbeing. Global action is needed to support Somalia in its efforts to adapt to climate change and protect its water resources for the benefit of present and future generations. The global community can support Somalia in adapting to climate change by providing technical and financial assistance to help improve water management and access to safe water sources. This includes developing and implementing policies and strategies that take into account the effects of climate change and ensure equitable access to water resources. This should include efforts to strengthen the capacity of local communities to manage their water resources, as well as investments in infrastructure and technologies to better capture, store, transport, and use water [107]. The global community should also support Somalia in developing and implementing systems of water inventors and standards. This will enable the country to better monitor and manage its water resources and ensure that the water that is available is of the highest quality [108]. The global community should also promote a system-wide approach to interventions in Somalia. This should include measures to reduce water losses, improve water security and ensure effective disaster management and preparedness. This should also include measures to reduce water pollution, improve water efficiency and incentivize sustainable water use [109]. The global community should also support Somalia in raising awareness about the impacts of climate change on water resources and the importance of protecting these resources for the benefit of present and future generations. This should include efforts to educate communities about the importance of conserving water, as well as promoting sustainable water management practices [110].

6.2 Science technology and innovation adoption

Science, technology and innovation (STI) adoption is a key factor in addressing the impacts of climate change on water resources in Somalia. Climate change is having a major impact on water resources in Somalia, causing a decrease in precipitation, a rise in temperatures, and an increase in the severity and frequency of droughts, floods, and other extreme weather events [111]. Adoption of STI can help to improve water resource management and adaptation to climate change by providing access to new and improved technologies and practices and by improving understanding of the impacts of climate change on water resources [112]. STI adoption can help improve the management of water resources in Somalia by providing access to advanced technologies and practices. This can include technologies such as remote sensing and satellite imagery, which can provide information on water availability and help with the identification of water resources. STI can also help improve water resource management through the use of advanced water resources management systems and tools, such as Geographic Information Systems (GIS) and decision support systems. STI can also improve understanding of the impacts of climate change on water resources in Somalia. This includes understanding the impacts of climate change on water availability and water quality, as well as the impacts of climate change on water-related ecosystems [113]. An improved understanding of the impacts of climate change can help inform adaptation strategies and policies and improve decision-making related to water resource management [114]. In addition, STI adoption can help improve access to water for Somali communities through the use of advanced water harvesting and water storage technologies. These technologies can help to improve water quality by reducing contamination and can also help to increase water availability by improving water storage capacity. STI adoption can also help improve the resilience of Somali communities to climate change by improving the capacity to manage climate-related

disasters, such as floods and droughts [115]. This can include improved early warning systems and better disaster preparedness and response plans. STI adoption can play an important role in addressing the impacts of climate change on water resources in Somalia, by providing access to new and improved technologies and practices and by improving understanding of the impacts of climate change on water resources. STI adoption can help to improve water resource management and adaptation to climate change and can help to improve access to water for Somali communities and improve the resilience of communities to climate change [116].

6.3 Institutions and policy instruments

The impact of climate change on water resources in Somalia is profound and widespread, posing significant challenges to the country's fragile environment and livelihoods. In order to effectively address the challenges posed by climate change, the Government of Somalia is committed to the development of effective institutions and policy instruments that can facilitate adaptation and resilience [117]. The following key initiatives have been identified as essential for helping to ensure the effective management of water resources in Somalia.

6.3.1 Establishing effective water governance structures

A key factor in achieving effective water management in Somalia is the establishment of effective governance structures. This includes the development of an integrated water policy framework, implementing water resources management plans, and establishing water rights and water resource users' organizations [118].

6.3.2 Developing an adaptation strategy

An important component of the water management strategy for Somalia should be the development of an adaptation strategy. This strategy should focus on the development of a comprehensive plan for managing the impacts of climate change on water resources in Somalia, as well as on the implementation of measures to reduce the vulnerability of water resources to future climate change [119].

6.3.3 Strengthening water infrastructure

In order to ensure effective water management in Somalia, it is essential to strengthening the water infrastructure. This includes the development of new storage and distribution systems, the rehabilitation of existing infrastructure, the implementation of water-saving technologies, and the strengthening of institutional capacity for water management [120].

6.3.4 Improving water quality

Improving the quality of water resources in Somalia is essential for ensuring the availability and sustainability of water resources. This includes the implementation of water quality monitoring programs, the development of water quality standards, and the adoption of appropriate management practices [121].

6.3.5 Encouraging water conservation

The development of water conservation strategies is essential for ensuring the long-term sustainability of water resources in Somalia. This includes the promotion of water conservation practices, such as the use of water-efficient technologies and the development of water conservation campaigns [122].

6.3.6 Establishing disaster preparedness and management plans

Given the increasing frequency and intensity of flooding and drought in Somalia, it is essential to develop appropriate disaster preparedness and management plans. This includes the development of early warning systems, the implementation of response and recovery plans, and the establishment of risk reduction measures [123].

6.4 Water inventors and standards

Water inventors and standards are important elements of climate change adaptation in Somalia. The reference [124] indicates that climate change has significantly reduced water availability in the region and is a major driver of water scarcity in the Horn of Africa. With an increase in temperatures, there is a decrease in available water resources, which impacts water availability for communities, agriculture, and livestock. As such, it is essential that water inventors and standards are established to ensure that water is managed in a sustainable manner and that there are adequate safeguards in place to prevent over-utilization of the resource [124]. Water inventors and standards are key to climate change adaptation in Somalia as they help regulate water management and ensure water is used sustainably. According to the United Nations Environment Programme (UNEP), water inventors can be used to measure the quality of water, monitor water flow and detect pollution levels. They can also be used to monitor water use to ensure that resources are managed responsibly and efficiently. Additionally, water standards are important in climate change adaptation in Somalia as they help to ensure that water is used equitably and that all members of a community have access to it. In addition to water inventors and standards, other measures must also be taken to ensure that water is managed in a sustainable manner. These include using water-saving technologies, introducing water harvesting systems, and creating water management plans. Furthermore, it is essential to ensure that policies are in place to protect the water resources of Somalia and promote the use of renewable water sources [125].

6.5 System-wide approach to interventions

The system-wide approach to interventions is an important strategy for addressing the impact of climate change on water resources in Somalia. This approach involves a comprehensive and coordinated plan of action to address the various issues associated with water resources in Somalia, including climate change. It involves a combination of measures, such as strengthening water management systems, developing water-related technologies, and improving water access and availability. The system-wide approach requires a holistic view of the problem and an understanding of the interconnections between water, climate change, and the various sectors of society involved. The focus should be on developing strategies and actions that address the underlying causes of water insecurity and climate change in Somalia, such as poverty, lack of access to resources and services, and inadequate infrastructure [126]. In order to ensure the success of the system-wide approach, it is important to involve all stakeholders, including the government, civil society, and the private sector. This will ensure that all sectors of society are aware of their responsibilities and have a shared understanding of the challenges faced. The system-wide approach also requires coordination between different levels of government and between different sectors of society. This includes the need to develop an integrated water management system, which involves sharing data and

information between different stakeholders. In addition, the system-wide approach should include measures to improve water access and availability, such as the development of water inventors and standards, as well as measures to reduce the impacts of climate change on water resources, such as disaster management and preparedness. The system-wide approach should also involve global responsibility, with a focus on addressing the global aspects of water insecurity and climate change. This includes the need to strengthen international cooperation and collaboration to ensure that all countries have access to the resources and services needed to manage water resources in a sustainable manner [127].

6.6 Disaster management and preparedness

Climate change is a global phenomenon that has profound impacts on all aspects of human life. In particular, the effects of climate change on water resources have been particularly devastating in Somalia, a country already facing water scarcity and facing increasing water insecurity. Climate change has caused a number of extreme weather events in Somalia, including floods, droughts, and heat waves. The increasing frequency and intensity of these weather events have significantly impacted the availability and quality of water. Droughts have caused a number of water sources to dry up, leading to a decrease in the availability of water for drinking, irrigation, and other uses. Floods have also caused water to become contaminated, leading to a decrease in the quality of available water. In addition, the rising temperatures have caused an increase in evaporation, leading to a decrease in the amount of available water [128]. The consequences of climate change on water resources in Somalia have been devastating. The scarcity of water has had a significant impact on the livelihoods of the people in Somalia, leading to increased poverty, health problems, and a decrease in agricultural production. In addition, the lack of available water has exacerbated existing conflicts over water resources, leading to further insecurity and instability in Somalia. Adaptation to climate change is essential for mitigating the impacts of climate change on water resources in Somalia. A number of approaches can be taken to ensure the sustainable management of water resources, such as the implementation of water inventors and standards, the introduction of water-saving technologies, and the establishment of water-harvesting systems. In addition, disaster preparedness and management must be improved in order to reduce the impacts of extreme weather events on water resources. The impacts of climate change on water resources in Somalia are a global responsibility. In order to mitigate the impacts of climate change, a system-wide approach to interventions must be taken. This includes the provision of adequate funding, the improvement of governance structures, and the enforcement of international standards. In addition, the international community must work together to develop strategies to protect and restore water resources in Somalia, and to ensure the sustainable use of water resources in the future. Climate change has had a significant impact on water resources in Somalia. The impacts have been devastating, leading to a decrease in the availability and quality of water, and to a decrease in the livelihoods of the people in Somalia. In order to mitigate the impacts of climate change, adaptation is essential, and a system-wide approach to interventions is needed [129].

7. Conclusion,

Climate change has had a profound impact on the availability of water resources in Somalia, and its impacts are likely to become more severe in the near future. The Somali people have been adapting to the impacts of climate change on water resources, but the scale of the challenge requires a system-wide approach to interventions with support from the global community. Adaptive strategies should focus on water inventors and standards, disaster management and preparedness, and livelihood impacts. In addition, global responsibility must be taken to ensure that Somalia is supported in its efforts to address the effects of climate change on water resources. Through these measures, Somalia can ensure that its water resources remain abundant and resilient in the face of a changing climate.

Ethical issue

The authors are aware of and comply with best practices in publication ethics, specifically with regard to authorship (avoidance of guest authorship), dual submission, manipulation of figures, competing interests, and compliance with policies on research ethics. The authors adhere to publication requirements that the submitted work is original and has not been published elsewhere.

Data availability statement

Data sharing is not applicable to this article as no datasets were generated or analyzed during the current study.

Conflict of interest

The authors declare no potential conflict of interest.

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