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Addressing the Challenges of Economic Water Scarcity in Kenya: Multi-Barrier and Multilateral Integrated Approach Systems for Sustainable Access to Safe Drinking Water

A Review

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Abstract

Accessibility to clean drinking water is essential to the quality of life of all humans. Water is also important in national development of a country. Kenya is faced with both physical water scarcity and economic water scarcity. Physical water scarcity is due to increased water demand, limited supply of water and low rainfall whereas economic water scarcity is due to lack of sufficient financial capability to support water infrastructure. Depending on the water use, there are various techniques available for removal of harmful bacteria, water softening and removing organic particulates and other contaminants from drinking water. They range from simple to sophisticated technologies. This review focused on the economic water scarcity in Kenya which is a developing country. Aspects reviewed included: water poverty index and effects of economic water scarcity**.** The review methodology tool used was the water poverty index assessment tool (WPI) at which elemental parameters related to water were identified and discussed. The outcome of this research was expected to contribute in the development of affordable and sustainable purification technologies and policies that can be used to deliver safe and clean drinking water.

The assessment using the Water Poverty Index (WPI) found Kenya's WPI to be low in the range of 38-45 %, which is characterised as being severe in regard to the global water stress. Kenya's safe yield of surface water resources and ground water was estimated to be 7.4 BCM per annum and 1.0 BCM per annum respectively. Water abstractions is estimated at 1.6 BCM per annum representing 13-19% of the available water. Challenges identified include: undeveloped water resources, low financial and institutional capacity, limited access and increased demand of water in agricultural activities such as irrigation with a declining total annual renewable water per capita in the last 50 years. Recommendations proposed as solutions that can be adopted to address economic water scarcity and consequently water stress in Kenya, include exploring sustainable low-cost purification technologies, adopting multi-barrier integrated approach system and the use of multilateral economic groups support to address economic water scarcity.

Keywords: drinking water access, economic water scarcity, purification technologies, and sustainability

1. Background

In 2001, the United Nations Population Fund (UNDF) report [1] estimated that by 2025, the total global water use will increase by 40% and 17 % more water will be needed for both agriculture and human consumption in developing countries. As of 2020, 4 billion people which was then two-thirds of the world's population were affected by severe water scarcity for at least a month every year. It was also estimated that this number would increase to 6 billion people by 2050 (UN Water 2020) [2]. Progress has been made to improve on water provision although there are still issues and limitations. Inadequate resources, rapidly growing population coupled with global warming have made it difficult to improve on clean water and sanitation coverage.

Lack of access to clean water is a global threat to humanity and development. According to the United Nations report of 2015 [3], the countries with over 75% coverage and at least the basic drinking water services were 181. Those that had achieved over 75% coverage of basic sanitation services were 154 countries. In Africa alone, the report mentioned that less than 50% coverage had basic hand washing services [4]. In Asia and Africa, 20% of the poorest population group spend 3-11% of their low income on water. Earth's water existence shows that 97% of the earth's water is saline and only 3% is freshwater, of which less than 1% of it is easily accessible for human consumption [5]. The issues are and not limited to water scarcity only, international disputes over water contamination, ecological degradation and unsustainable groundwater usage [6] are some of the other contributing factors. Additionally, there is the cost of managing water and sanitation facilities and long time spent especially by women in collecting water [7].

Sub-Saharan African countries such as Kenya experience a great challenge of inaccessibility to safe drinking water. Most of the freshwater sources are depleting due to climate change and increased demand caused by urbanization and industrialization. Freshwater in Kenya is currently limited to annual renewable rainfall of 600-680 mm. About 80% of the country is arid and semi-arid. The average annual rainfall in Kenya is 630 millimeters (mm) with a variation from less than 200 mm to over 1,800 mm in Northern Kenya and on the slopes of Mt. Kenya respectively. It is estimated that by 2025, 70% of the annual available freshwater will be depleted due to population growth alone [8]. According to the Ministry of water and irrigation report of 2014 [8], it was projected that by 2025 the per capita water availability in Kenya will drop to 235m^3 due to population growth. Figure 1 highlights the geological location of the major water catchment areas in Kenya. The ratio of water demand is projected to increase by the year 2030 by more than 100% [9]. In this regard, Kenya is classified as a water-scarce country.

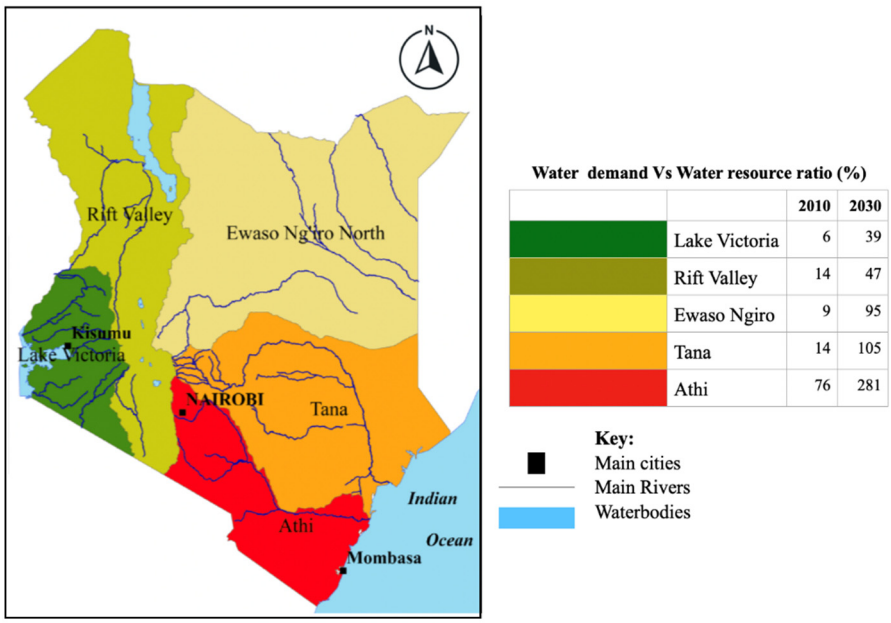

Figure 1. The geological location of the various water sources in Kenya.Source: Kenya Nation Water Masterplan 2030 [9]

The current drinking water sources in Kenya include surface water, groundwater and in some areas treated wastewater is reused for irrigation in agriculture. Surface waters resources in Kenya cover only 2% of the total surface area. Arid and semi-arid lands (ASALS) cover two thirds of Kenya with climate varying from tropical in

the coastal zone to arid in the interior. Surface waters suffer loading , pollution and depletion during droughts.

There are several problems associated with water quality in Kenya. Groundwater is an important source of water for people, livestock, and agriculture. However, the quality of groundwater has become a challenge to its consumption. The issues are still not well understood in the various regions across the country. In most parts of the country, it is mostly saline and contains arsenic contaminants that are harmful to human health. For instance, the ground water in north-western Turkana region, coastal aquifers, and the Merti aquifer and the environs of Isiolo-Marsabit, Garissa and Wajir County [10]. High concentrations of naturally occurring fluoride is another challenge. For example, groundwater from Nairobi Aquifer through most parts of the Rift Valley region. In addition to salinity, there is high nitrate levels due to the infiltration of agricultural runoff and pathogenic contamination caused by poor sanitation systems. For example in shallow aquifers along the coast and near Lake Victoria [10]. Figure 2 below shows the salinity levels of available ground water in the horn of Africa at which Kenya is geographically placed. The groundwater available requires a polishing treatment before consumption. This poses a technical challenge that requires a solution to this water resource.

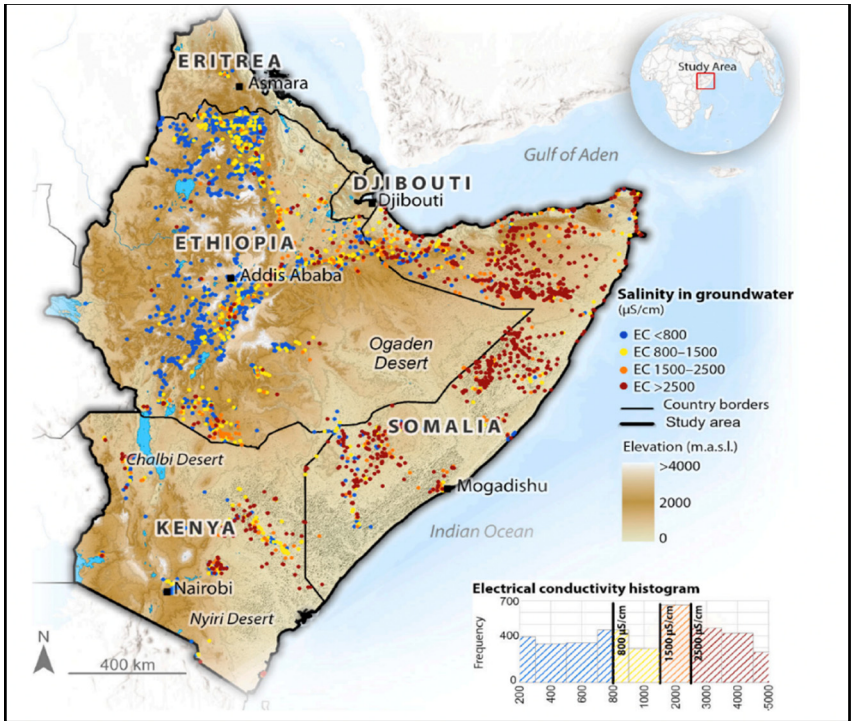

Figure 2. Salinity levels of available ground water in the horn of Africa. Kenya's ground salinity is in the range lower than 800 uS/cm and most of it in the range to > 2500 uS/cm/. Adopted from Environment International, 2023 [11]

The depletion of water sources and industrial and agricultural pollution is also rampant. This is due to discharge of poorly treated industrial effluent and excessive use of agricultural chemicals. The conventional wastewater treatment system of an activated sludge system and stabilization ponds are mostly used for municipal and industrial wastewater. This implies that removal of nitrogen and phosphorus is high but the treatment of biological oxygen demand (BOD), turbidity, microbial contamination, and limited micropollutant removal is still the main concern in its treatment efficiency and treated wastewater reuse.

In developing countries, about 80% of illnesses are associated with drinking unclean water and poor sanitation conditions. Universal access to safe and adequate drinking water with proper sanitation would reduce the global water disease index by approximately 10% [12]. Until 2010, the United Nations General Assembly and human rights council recognized access to safe drinking water as a Human right as a binding international law [13] and proper sanitation access was recognized as a distinct right [14]. The United Nations defines the right to water as "access to safe, sufficient, acceptable and affordable water for personal and domestic use for everyone".

Water scarcity can be defined in terms of physical water scarcity and economic water scarcity. Physical water scarcity is experienced when there is a higher demand of water than the land and nature's ability to provide the needed water. Arid and semi-arid regions of the world are often associated with physical water scarcity. This can

be caused for instance by water being overused and lack of proper water abstraction management systems, leading to water scarcity downstream or in some areas. The presence of several direct implications resulting from situations especially offered by economic water scarcity due to inadequate water infrastructure and extreme climate change effects resulting to long and short term droughts has become a challenge to the access to safe water sources.

Economic water scarcity occurs when a nation does not have the required monetary means to utilize available water sources. It also involves inadequate water infrastructure and unequal distribution of resources due to lack of good governance, political and ethnic conflicts and lack of compassion resulting in continuity of this problem. Most parts of Sub-Saharan Africa experience economic water scarcity, as illustrated in figure 3 below. Despite water being locally available to meet the demand, most of the Sub-Saharan African countries experience this water scarcity due to limited human, institutional and financial capital to facilitate the necessary water infrastructure and technologies [15].

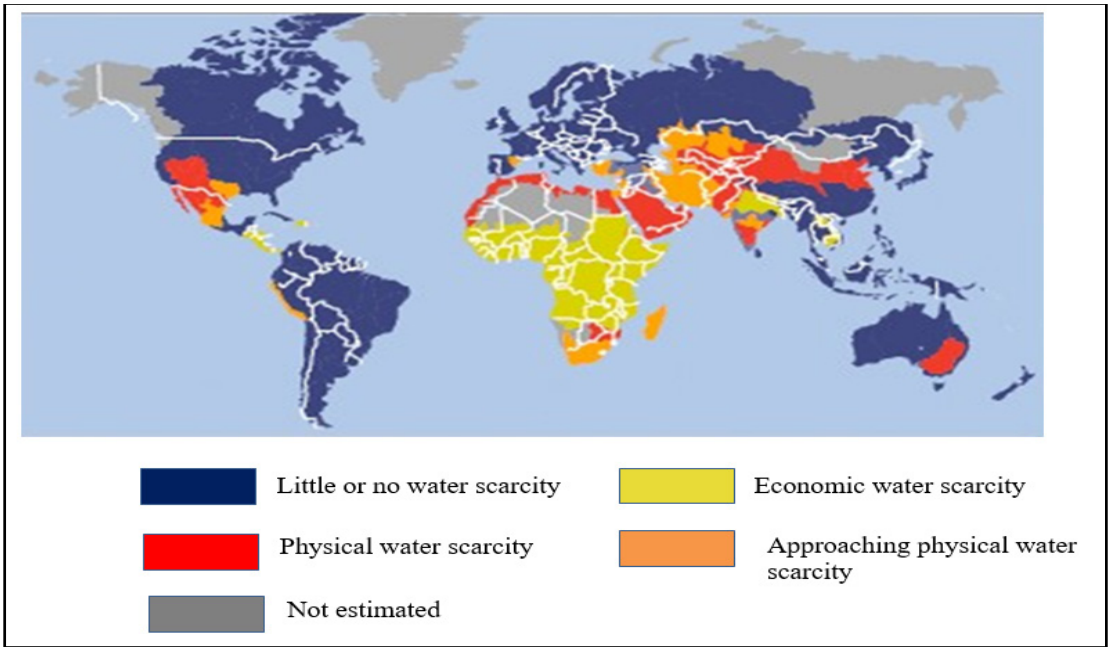

Figure 3. A map showing the global coverage of physical and economic water scarcity in varying degrees of severity. Most countries in Africa experience economic water scarcity besides the physical scarcity in the dry Sub-Saharan regions [16]

The objective of this review paper was to determine the link between financial poverty and water poverty and their contribution to economic water scarcity experienced in Kenya. It also proposed solutions that if adopted can help in reducing economic water scarcity and promoting the sustain development goal 6, " Access to clean water and sanitation for all" in Kenya.

2. Methodology

To review the status of economic water scarcity in Kenya, the link between economic water scarcity and economic poverty was established using the Water Poverty Index (WPI). This is an interdisciplinary tool that analyze water poverty using component elements related to water. These component elements include: Water Resources (R), Environment (E), Access (A), Usage (U) and Capacity(C). For this review, these elements were defined as follows:

- *Resources (R)*: the amount of renewable freshwater that is available per capita. It gives an indication of population's pressure on water resources.
- *Environment (E)*: these are indicators related to the environmental integrity of water resources.
- *Access (A*): This is measure of proportion of the population with access to improved water facilities and water sources. According to WHO-UNICEF Joint Monitoring Programme (JMP) for Water Supply and Sanitation, improved water sources are those that are accessible on premises, contamination free and available when needed.
- *Usage (U)*:This is a reflection of water usage for various purposes. This was determine d by considering demand sites that included: domestic use of rural and urban, irrigation and industry.

- *Capacity (C):*This is an assessment of the financial and social ability in handling water scarcity and water resource management. Financial capacity is the ability to purchase improved water and access water treatment technology while social capacity is an indicator of people's awareness on water related environmental and health issues. It also entails the use of effective management of water resources [17].

WPI tool is a used in assessing the measure of water stress at household and community level. It helps the local authorities and national government manage water scarcity, quality and access problems by considering all the elements mentioned above. It examines physical water availability, attraction, and the well being of the community and ability to utilise the available water resources. Utilisation can range from aspects of quantity, quality, variability, access for both human consumption and non-portable uses, industrial use and water management practices. It evaluates poor water endowments alongside poor adaptive capacity. In some cases, WPI can be calculated as a weighted averaged components, such that each of the elements is in the range of 0 to 100 repressing the lowest and the highest WPI respectively. Low WPI indicate severe drinking water availability whereas high WPI represents sufficient or adequate drinking water availability. WPI is quite a comprehensive tool however its complexity and lack of adequate information especially for the elements required for establishing the average weighted and the indicator on large scale can limit its implementation.

In addition to the WPI analysis, effects pf economic water scarcity in Kenya discussed and lastly, recommendations were made on possible approaches and future technological solutions that can be adopted to be able to successfully and sustainably manage water scarcity in Kenya. The solutions will help water scarcity management and water sector policies and procedures to ensure achievement of SGD 6, access to clean water and sanitation.

3. Results and Discussion

3.1 Water Scarcity in Developing Countries

The level of income determines the development level of a country. Countries in the world have been classified as high, middle or low income country based on its gross national income per capita [18]. World bank which is a multilateral financial institution has the responsibility of providing loans to countries in need. With this regard, it defined and developed a system to characterise a country based on its needs. In the world bank's systems of characterising a country as per the income, a developing country is that whose gross national income per capita is $ 4085 or less [18]. It is good to note that not all developing countries are entirely the same. Each faces its own developmental progress and challenges.

In terms of water access, developing countries experience various issues pertaining water access and water quality. These countries have limited reliable water, which mostly affects poor and marginalised settlement areas [19]. Water scarcity issue in developing countries has been expressed in terms of; poor access to sufficient and clean water supply, poor water productivity in agriculture and poor water resource management by US Agency for International Development, Bureau of Economic Growth, Agriculture, and Trade.

Some of the other challenges faced include water shortage, poor quality of the available water and flooding. Water shortage is as result of growing human population which has increased human water consumption. This has been made worse by depletion of fresh water bodies and groundwater sources, poor ground water quality, and increased water contamination. These conditions have been

intensified by climate change, industrialisation, water loss during distribution and local interventions such as deforestation [20].

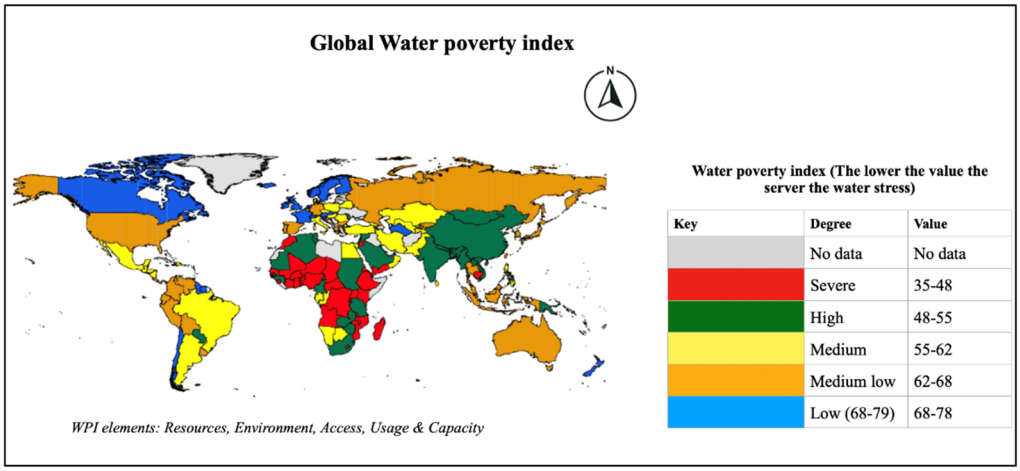

Figure 4. Global water poverty index. Source Centre for Ecology and Hydrology (CEH, 2007) [21]

In figure 4 above of global water poverty index, most developing countries such as Kenya is rated to have water poverty index that is low meaning the level of water stress is severe taking into consideration water poverty elements Resources, Environment, Access, Usage and Capacity.

In some developing countries that have good water infrastructure, seasonal water fluctuations aggravate water shortages. Contrary, for some developing countries, lack of good water infrastructure limit them from accessing the available water resources. These situations impact on production activities and the health of the population affected [22]. With water scarcity, the affected population often does not have the choice of availing good-quality or safe water for consumption. Consuming poor quality water lead to waterborne-diseases ; cholera, hepatitis, typhoon, diarrhoea, typhoid among others. For instance, the global disease burden shows that 1.5 million (~3.6%) deaths that occur globally is due to diarrhoea disease. Unsafe water supply, poor hygiene and inadequate sanitation cause 842,000 deaths annually for low and lower-middle income population margins and 361,000 children under five years [23].

Considering population settlement of rural and urban areas, lack of access to safe drinking water is more pronounced in rural areas compared to urban areas. Moreover, the UNICEF and WHO reported that approximately 2 billion people globally lack basic sanitation, with at least 7 in every 10 living in rural areas and 33% reside in least developed countries [24]. The degradation of water quality has been attributed to pollution from untreated municipal water, agriculture, industrialization, and development infrastructure projects.

As earlier mentioned, economic water scarcity has also largely affected the developing countries. Low income countries do not have the financial capacity for good water supply infrastructure to utilise the available water resources as needed. This can be expressed in two folds drivers as : lack of infrastructure to meet the increasing water demand as a consequence of population growth and industrialisation. Due to the increasing population, urbanization and internal migration is rampant in developing countries. For developing countries urban migration in-particular follows an economic development pattern. Some move to the urban areas due water scarcity and drought in rural areas and some for financial reasons [25].This patterns tends to concentrate the industrialised cities straining its capacity to provide for safe and sufficient water because the water resources easier planned for become overburdened.

Water resource management in developing countries is still poor. The aspects of overconsumption, pollution, exploitation and privatisation of water resources is still a concern. [26], [27, [28]. Activities associated with this include pollution of water resources and ground water depletion. According to [29], [30], it is estimated that 90% of untreated sewage in developing countries is discharged to water bodies which deteriorates the water quality. Privatisation mostly occurs in countries that the government can not afford the needed water infrastructure. It has often been associated with lack of corporate accountability, corruption and weakened adherence to the regulations and policies pertaining water abstraction, supply, quality and and distribution.

3.2 Water Poverty Index of Kenya

To build sustainable water provision system requires that water concern issues are well understood first. It involves integrating the environmental, physical, economic and social aspects. Physical water scarcity is largely attributed to environmental and physical factors whereas economic water scarcity is associated with the socio-economic elements of a population in question. Evaluation of the extent of economic water scarcity can be done using linkage between water provision challenges and financial poverty of a country.

According to Liu and Liu, 2021 [31], sustainability of water access and provision can be derived from linking water poverty and economic poverty in a tool known as Water Poverty Index (WPI). WPI provides a view on the water resource sustainability and its impact on the people. Sullivan (2002) [32] , proposed components of the WPI as Resource (R), Environment (E) Access (A), Capacity (C), and Use (U). A high WPI expressed in percentage indicates better water management performance [33], [34]. WPI was calculated internationally in 2007. As shown in figure 4 above (page 9) most Sub Saharan Africa countries in including Kenya have quite low water poverty index in comparison to other countries. Kenya was rated at 35-48 % , low WPI , which is an indicator of server water stress.

The following is a review of the water related elements mentioned in relation to Kenya.

3.2.1 Under Developed Water Resources (R) and Environment (E)

Freshwater in Kenya is currently limited to annual renewable rainfall of 600-680 mm. The safe yield is currently approximately 40% of the available renewable freshwater in Kenya , meaning it has the potential for development whereas the 60% sustains the flows in water bodies to sustain the ecological systems and a reserve. This shows that Kenya, has an extensive potential for development if optimum utilisation of the available fresh waters is achieved. Currently, the safe yield of surface water resources and ground water in Kenya is estimated to be 7.4 BCM per annum ad 1.0 BCM per annum respectively. Water abstractions is estimated at 1.6 BCM per annum representing 13-19% of the water available for development indicating underdevelopment in the water infrastructure.

The environment that affect the safe water yield of Kenya can be explained in terms of the climatic conditions and the rainfall patterns. The Kenya Ministry of Water and Resources Management and Development estimated the current country's per capita water supply per annum to be at 647 CM (cubic meter). The rainfall patterns are spatially and temporary variable across the various water basins and catchment areas across the country. The high variability affects the annual safe yields.

Another aspect that affects it is the degradation of the catchment areas.This degradation is experienced in occurrences of increased runoff, reduced filtration, erosion, siltation, poor implementation of policies on water abstraction and usage, water allocation and pollution control and flash floods that limit water reservation. As a developing country, other activities that contribute are poor farming methods, deforestation and resettlement due to high growing population. Consequently the degradation of the catchment areas has contributed to the drying up of surface waters. This can be illustrated from the declining annual renewable water of Kenya in figure 5 below.

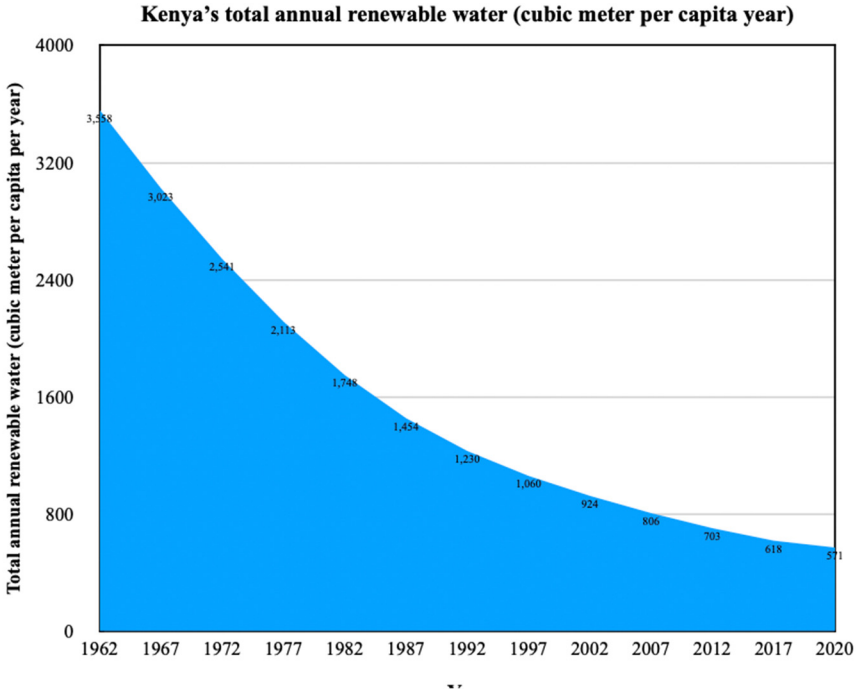

Figure 5. Representation of the declining total annual renewable water of Kenya

The underdevelopment of the water resources in Kenya on water treatment and supply infrastructure is due to inadequate funds for investments. This has limited use of efficient systems of abstraction, distribution systems and developmental utilisation such as in energy generation, agriculture, irrigation, urban, rural and industrial water supply. The water coverage in Kenya is still less than 60 % over the recent years, and sewerage coverage less than 20% as illustrated in figure 6, whereas there is 7% increase in water coverage between 2009 to 2017, it is still quite low in regard to the demand and the population growth.

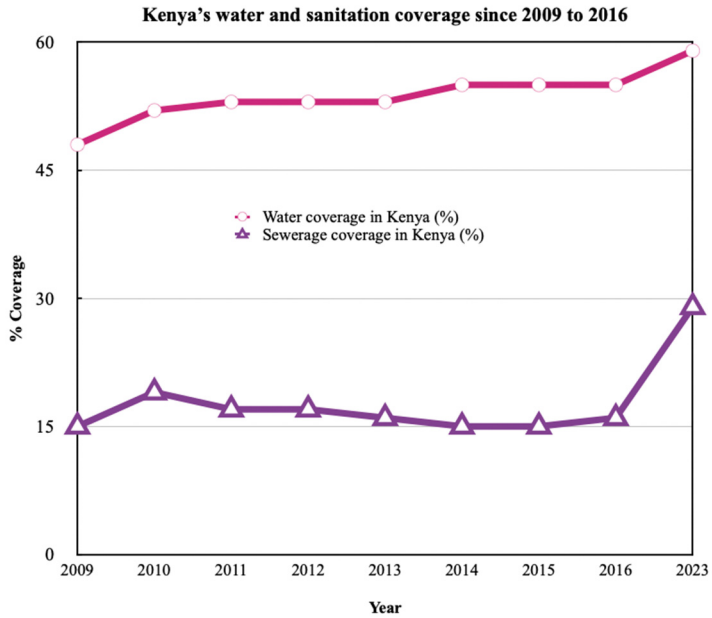

Figure 6. Representation of low coverage of water and sanitation in Kenya. An indicator of underdevelopment in the water infrastructure and sanitation facilities

3.2.2 Water Access

Families in Kenya thrive if there is access to safe and clean water and good sanitation conditions. 2019 census established the population of Kenya at 47.5 Million with an annual growth of 2.6%.The population of Kenya has increased from 5.4 Million in 1948 to 53 Million 2022 as shown in figure 7.

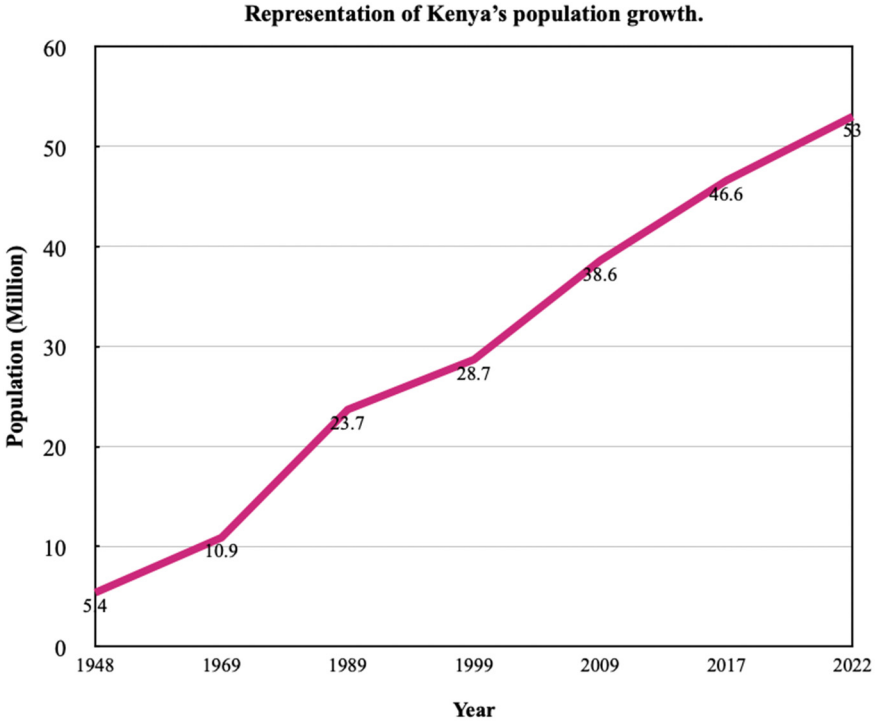

Figure 7. Kenya population growth since 1948 to 2022

Increase in the population has resulted in higher water demand in the country. In 2023, an estimate of 59% of people in Kenya have access to safe drinking water and 29% of people in Kenya have access to improved sanitation facilities. Moreover, in 2023, with the current population at 53 million, about 28 million Kenyans, which is 52.8% lack access to safe water and 41 million equivalent to 77.4% lack access to improved sanitation. This is translated from underdeveloped water coverage and sewerage coverage that is 60% over the recent years as represented in figure 6.

In Kenya's constitution, Article 43 on Rights to Water, water access has been defined in terms of water availability/ sufficiency, affordability, quality and acceptability. Sufficiency means that there is access of 50-100 litres per person per day and a minimum of 20-25 litres per person per day without meeting all needs. Affordability requires that water facilities and services can be acquired and should bot limit a person to pay for other essential needs.

A standard cost for water should not exceed 3% on the household income and not more than 5% if wastewater collection is included. Access to water also requires that all groups of the people in the society ; women, children, men and people with disabilities to access water services and facilities within 1km home radius and collection time not exceeding 30 minutes. Lastly the article reinstates that the water quality on the other hand must acceptable as per public health requirements and World Health Organisation's (WHO) drinking water regulations (WHO). In essence the water should be of acceptable colour, taste and free from microbes, parasites and chemical substances.

To assess water access, the form of population settlement access in Kenya is one factor that provides a quantitative view and statistics. For instance, in 2014, Kenya National Bureau of Statistics carried out an economic survey and stated that 33% of Kenya's population did not have access with rural water access of 62.% and urban water access of 87% with improved water sources nationally. The statistics presented on contrary, showed urban settlements to be performing well with still unequal access in the urban settles considering the formal and informal urban settlement areas. The rural access can be further represented in terns of water provision infrastructure as shown in figure 8 which shows that nearly 43.8% of the rural population and 45% [35] of urban population access water through surface water and unimproved water sources.

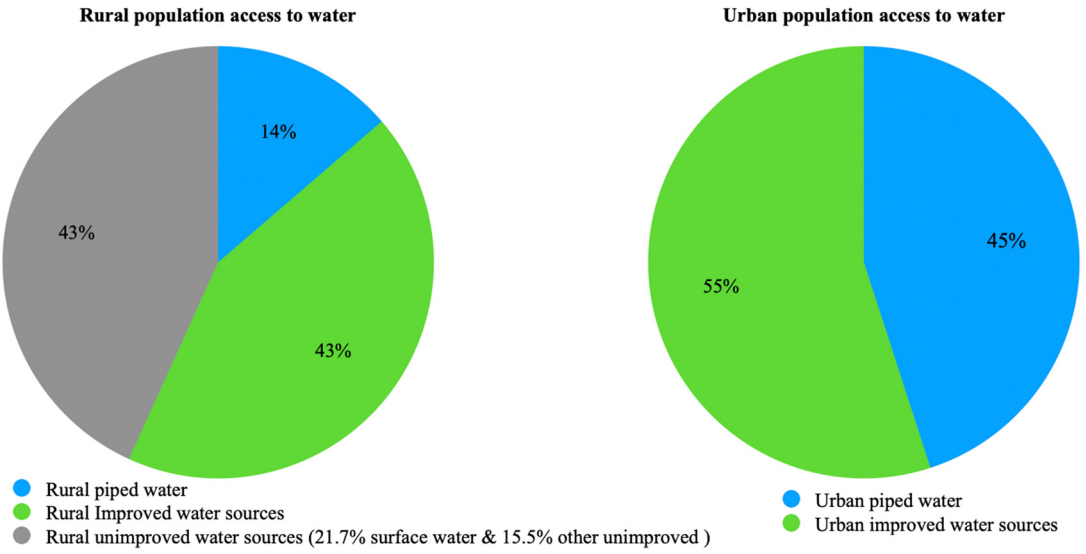

Figure 8. Water access facilities in the urban and rural settlements of Kenya [35]

In figure 8, unimproved water sources include un-protected wells whereas surface waters include streams, rivers, ponds and lakes.

3.2.3 Water Use

Water usage in Kenya can be represented as per the sector development and requirements of agricultural use, industrial, and municipal. Below is the representation of the usage of this sectors in Kenya.

As represented in figure 9 on Kenya's water consumption, domestic and agriculture water usage were considered as the two major indicators of water use in Kenya such that 76 % and 20% and 4% of the water is for agricultural, domestic and industrial use respectively.

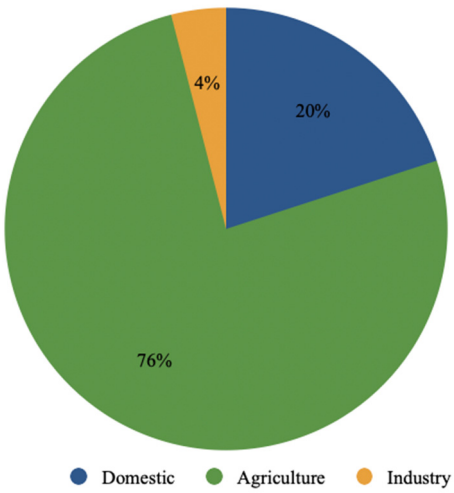

Figure 9. Kenya water consumption per percentage usage of the total available water (2023)

3.2.4 Capacity

A countries' capacity to improve on provision of safe and clean water indicates the degree of existing water resources utilisation and national development. In Kenya , the Ministry of Water, Sanitation and Irrigation (MWSI) has the responsibility to strengthen the water capacity of Kenya. In 2014, for financial years 2015/2016 and 2017/2017, Ksh. 16.2b and Ksh. 31.3b was allocated respectively to strengthen the capacity of the country. 92% of this was used on water and sanitation for infrastructure development. Even with this efforts, there is still room for developing the water

infrastructure based on the current and projected water demands of the country. The chart in figure 10 shows actual expenditure for Financial Year (FY) 2021 and projections to FY2025.

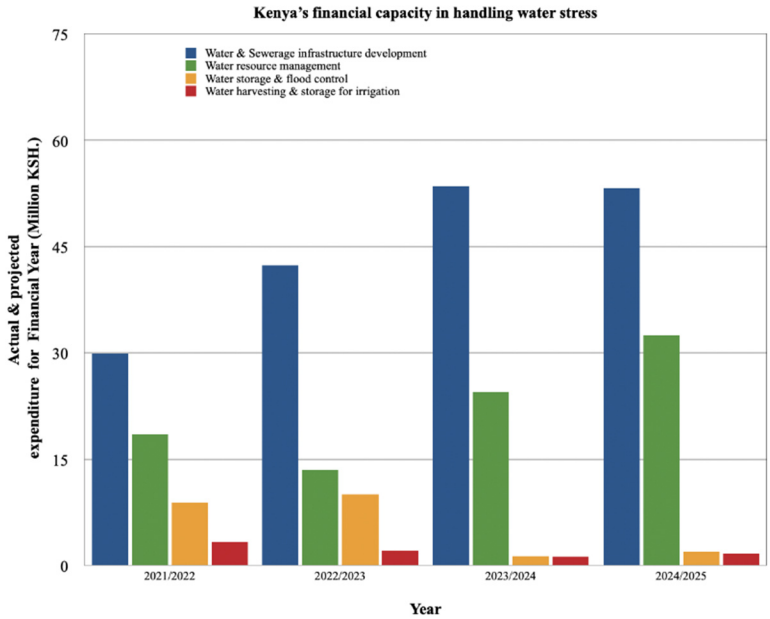

Figure 10. Actual expenditure for Financial Year (FY) 2021 and projections to FY2025

Source: Ministry of Water, Sanitation and Irrigation MWSI and Water Services Regulatory Board (WASREB) [36].

To achieve Kenya's 2030 vision on water access, the National water resources master plan of 2030 in liaison with JICA estimated the funds allocated and required to be Ksh 561.5 billion. The rural areas required an investment of Ksh. 1.3 billion whereas the urban areas require Ksh. 1.1 billion for water supply. This requires that Kenya needs to invest estimated amount of USD 7 billion by 2030 to achieve Kenya's vision 2030 vision on rural water supply and urban water supply. A large percentage of this investment funds are compensated from Official development assistance (ODA) funds and private funds. Although the support from International development agencies and donors to the water and sewerage sector was only about USD 0.5 billion per year in 2017, there is still a large gap between investment needs and available funds for investment.

Regardless of the limitations and setback faced financially, the Ministry of Water, Sanitation and Irrigation (MWSI) set the following goals: To increase percentage people with access to safe water in both urban and rural areas 80% by 2020 and to improve the average operation and maintenance cost average to 150% by 2030.

3.3 Effects of Economic Water Scarcity in Kenya

3.3.1 Public Health

Inadequate water and sanitation are linked to 80% of illnesses in the developing countries. Ground water, untreated surface waters and water from shallow wells forms the major resources of drinking water in Kenya. Moreover, if waste water is treated to the desired quality, it has also been reused in agriculture and for non-portable uses. Article 43 of Kenya's constitution in regard to the public health requirements require that every citizen get clean good

quality water free from microbes and diseases cause pathogens. Boiling is largely used as a form of disinfecting drinking water in both rural and urban areas due to lack of water supply and treatment infrastructure to purify the available freshwaters.

Bacteria, viruses or pathogens present in any drinking water significantly contribute to waterborne diseases. These diseases include cholera, typhoid, bilharzia. Waterborne diseases are rampant in poverty stricken areas, rural and informal urban settlements. Despite the socio-economic status of Kenya, diseases caused by drinking unclean contaminated water are under-reported because most people do not have the financial ability to seek medical attention.

3.3.2 Development

Development of a country depends on its ability to provide the necessary resources needed. Capital, labor and productivity affect development. Water is critical to agricultural production, energy e.g hydropower, transportation, and manufacturing. The changes and shortages in water supply in Kenya affects the sectoral water demand. Kenya's economic driver is agriculture and industrialization is also on the growing trend. Water scarcity in Kenya has affected agricultural activities and production. With water scarcity, agricultural practices which is one of the primary source of global water consumption has to to trade-off with other basic demands such as human consumption [37]. Approximately 80% and 90% of reservoirs and dams in Northern Kenya are drying up. As a result, pastoralists loose livestock, and the communities living adjacent to Lake Turkana, struggle to survive on fishing. These effects have triggered increase in water and food prices. In addition several industries in Kenya depend on water for their operations. Industrial water is used in processing, transportation, cooling, petroleum refineries and production of food, paper and chemical products. Most of them struggle to operate fully due water rationing.

3.3.3 Conflicts

Access to basic needs for a population promotes peace of a country. Water scarcity has been considered a threat to peace amongst communities in Kenya. In some areas especially in Arid and Semi-Arid areas (ASAL) it has evolved to volatile conflicts. These conflicts lead to civil wars, lack or decline in development and socio-economic growth and productivity. Transboundary water resource disagreement threaten the peace and the living of the people in the involved areas. In some areas it has leased to full pledge wars amongst the communities. According to Detges 2016, [38], water scarcity conflicts in Sub-saharan Africa are triggered by poorly developed water infrastructure which if addressed can prevent the conflict and ensure water access.

3.3.4 Women and Girls

Women and girls are disproportionately affected by lack of clean water and sanitation and hygiene (WASH). Clean water and sanitation is important for their sexual and reproductive health, human dignity, physical safety and security and socio-economic development. Poor hygiene caused by lack of poor sanitation conditions and lack of access to clean water puts them at risk of infection. In some areas , they are force to relive themselves in the night at the open fields exposing them to the risk of physical and sexual assaults. The repetitive cycle has caused some to drop out of schools and discontinue with building their careers.

Women are also key in household management, they are mostly responsible for home cleaning and agricultural activities in the home farms. Lack of water limit their productivity and waste time for those that have to fetch water from long distances. Long hours used to fetch water prevents women and girls to focus on their economic autonomy, education and community activities. Though they are key in informing on sustainable water management based on the involvement in water use at times, they are excluded from management and maintain of water supply facilities and ultimately decision making.

3.4 Approaches to Solving Economic Water Scarcity in Kenya

3.4.1 Exploring Sustainable Low Cost Purification Technologies

Water treatment plants meeting minimum health and safety requirements given by the public health in Kenya or World Health Organization (WHO) standards is not enough for drinking water quality. Sustainability in water

treatment and purification technology also involves consideration if its : impact on environment, carbon footprint and increasing access to clean water. Sustainability occurs when an equitable access to water for people and protection of water resources occurs.

Developing countries such as Kenya, not only have pathogenic pollutants in the natural water resources, there are also organic micropollutants that adversely affect the health by causing diseases such as: cancers, nervous systems disturbance and birth defects. Therefore, choosing the right water treatment technology is important. The development and research in water purification technologies suitable for Kenya, or other developing country should not only focus on removal of pathogens but also emerging pollutants such as micropollutants so as to prevent chronic diseases. Filtration at point of use/entry presents an opportunity to treat ingested water. This is because the chances of recontamination is minimized. Many of the POU/POE technologies involve use of reverse osmosis or ultra-violet light to remove or reduce bacterial concentration in water. These technologies are efficient in treatment, however they are expensive to purchase and require high water pressure and steady supply of electricity for continuous treatment. In most developing countries such as Kenya, their availability and use is limited by the economic incapability of most people.

Cost effective, sustainable, ease of operation/maintenance technologies and treatment technologies that use locally available materials are required. Some of the unique, low-cost and sustainable technologies include natural filtration, riverbank filtration, bio sand filtration and solar water disinfection technique. The challenges associated with other technologies especially the current water purification technologies is over reliance on relatively expensive systems and synthetic materials .These technologies are non-sustainable for the poorest communities in water stressed areas.

Concerning the selection of a suitable method for microbial examination. There is no technique with 100% sensitive nor specificity. Each technology is associated with advantages and disadvantages. Thus, different water users may choose appropriate alternative techniques based on the corresponding tests to resources or/and corresponding tests to applications. A sustainable purification technique is that which doesn't use chemicals to purify water, less energy usage, with highly efficiency in microbe and particles removal from water. For instance , solar water disinfection (SODIS) is a common and simplest approach of disinfection. This involves filling clear polyethylene terephthalate (PET) bottles or clear plastic bags for example with water and exposing them to direct sunlight for 6 h [39]. During this exposure period pathogens in the water are inactivated or destroyed. If turbidity is greater than 30 NTU for fed water, a preliminary treatment such as filtration is recommended. The system has been reported to be effective against a wide range of bacteria and viruses [40], [41]. The set back of such systems is that their effectiveness is not clear in terms of improvement water quality standards.

3.4.2 Multi-Barrier Integrated Approach (MBA) Systems

The Multi-barrier integrated approach (MBA) is an integrated multi-step system of processes, procedure and tools that prevent or reduce drinking water contamination. This system acts within the scope from water source to consumer level i.e tap in a house. This prevention or reduction of contamination help in reducing health related risks from drinking unclean water. The MBA is modelled after the multi-step process used by centralized water treatment systems [42]. For instance, the Household Water treatment and Safe Storage system (HWTS) has proven to be effective way to reduce health risks from contaminated drinking water at household level [43]. Each stage for the HWTS is a barrier against waterborne pathogens.

A complete MBA system consist of water source protection, sedimentation, filtration, disinfection and safe water storage. Most of which the last three stages are done or can be done as Household Water treatment and Safe Storage system (HWTS).

For any MBA system to work, the following elements must be accounted for:

a) *Protected water sources:* This involves minimization of pollution at resource point which consequently reduce the degree of treatment required.

b) *Efficient water treatment:* This is to ensure that the right and desired drinking water quality is achieved.

c) *Secured water supply network:* This involves proper maintenance of the system and provision of residual disinfection at extreme points of the network to potent against residual microbial intrusion within the system.

d) *Water quality monitoring plan:* Water quality fluctuation occurs from source to consumer level. These

fluctuations can be traced using water quality monitoring technologies that provide real time or period quality status. This allows for in-time action in the case of contamination and safe drinking water at the human consumption point.

e) *Adverse conditions control measures:* This is often the final barrier at which a response plan is developed and used to protect the general public in the event that contamination occurs.

f) *Stakeholder engagement:*

Both technical and administrative barriers are needed for any MBA approach to be successful, thus stakeholder involvement and engagement is key. Stakeholders of the MBA system include members of the scientific community and others that contribute to system understanding and implementation, regulators, local and national government authorities, landowners, regulators, legislators industry (e.g irrigation) representatives and members of the general public. The initial approach is to present the existing status together with predictions of the consequences of not taking some form of management actions using community outreach, mass media, local communication channels after which the system is developed and implemented. Stakeholder involvement and engagement can be enabled and nurtured by facilitating interaction amongst the full range of stakeholders, dissemination of a broad understanding of the current resource situation, promoting measures that improve the water resource balance, provision of a conducive institutional and legal framework, and setting realistic monitoring progress management targets.

3.4.3 Multilateral Economic Groups Support

Cost estimates of water treatment and distribution to consumers cover those of capital investment, programme delivery, operations, and operations and maintenance including extension services cost to the unserved and costs of maintaining access to those in accesses. Kenya's increasing pressure on its water resources requires major investments. Kenya is no exception in comparison to the global water cost investments which is estimated to increase between years 2000 and 2050 by 55%.

As discussed above on Kenya's capacity to support water infrastructure and development, it is clear that the costs are increasing overtime even though the allocated levels of financing cover basic drinking water, sanitation and hygiene. The current allocated finances are aimed at achieving the basic water and sanitation services as long as needs are met. The finances required to extensively provide safe drinking water and proper sanitation facilities is still a concern. To sustain the coverage and requirements, multiple capital flows are required. It calls for both financial support as well as institutional for effective translation of all the capital investments.

Economic framework specifically for the water provision sector is recommended for Kenya. This framework would seek to determine the use of any investments, identity investors and support, alternative sources of the finances and seek to maximise social welfare of the people in terms of empowerment of both public and private on investments benefits of having water. To allow for multilateral economic groups support in Kenya, the set economic framework can adopt the following:

1) Devising revenue streams

Water users are both beneficiaries and investors. Both public and private benefits are identified and mechanism set to harness revenue collection. This can be supported through user-pay principle, beneficiary-pay principle and polluter-pay principle [44], [45]. For User-pay principle, the user bears the cost of enjoying the benefits from the natural resources, for example property developers can invest in extension services to which the property value gains. Beneficiary-pay principle is for those that use water resources for provision of private gains such as farmers that irrigate their farms. Polluter principle employs fees for those that introduce contaminants to the water resources for example industries. Other opportunities include water and sanitation tariffs, pollution taxes, urban development of wetlands and flood plains, and water abstraction charges. The sustainability of this economic framework relies on equity and address of affordability issues and proportionality of bills and stakeholders pay capacity.

2) Optimization existing and current investments

This involves improving of efficiency for the existing water infrastructure through better operations and maintenance, setting out demand management measures and reduction of water-related risks and investments needs.

In addition, through stakeholder involvement performance for waters services can be defined from the basic physical condition to service quality. It also involves proposer assessment of risks and sustainability opportunities that can aid optimum water usage, maintenance of existing and facilitate or promote new water infrastructure investments.

3) Water resource management

As mentioned earlier in this text**,** challenges associated with water resource and environment in Kenya include physical scarcity, economic water scarcity and weak institutional, policy and regulatory frameworks. Measures are needed on improved governance on the use, allocation, sharing and planning for water resources with integrated and sustainable water resources management. The measures include better policies, stakeholder's involvement in decision-making on water management, strengthening finical capacity, and preservation of freshwater ecosystems. Additionally, adequate and reliable data for all corrective measures is required to enable evidence-based forecasting on dynamic water resources.

4) Water quality

Water quality deterioration in Kenya calls for a scientific intervention. Appropriate and reliable techniques to treat water, to analyse and to monitor water quality is required for the development of sustainable water resource management strategies.Conventional water quality monitoring methods have been widely used due to their accuracy, however they are time-consuming, costly and practically impossible to use at broader scales. Various remote sensing platforms and techniques can be used for assessing and monitoring water quality. The use of remote sensing technology will enhance water quality monitoring, with comparatively accurate information with timely update necessary for water resource management and strategic decision making. High cost and limited availability may be challenges for this technologies, however, with the multilateral economic groups support, this constraint can be addressed.

5) Policy recommendations

For Kenya to sustainable use water resources, there is need for legislation and policy at the national level governing how the country can cooperate and consult in managing shared resources such as water. Policies and measures on water abstraction, ecosystem conservation, pollution mitigation to be considered. Incentives on reducing the amount of unaccounted water lost through leakages, inactive and illegal connections and corruption-fed supply distributions to be developed. Moreover, an overhaul of management by water utility providers in conjunction with the private sector, to be adopted. This can include improved funding for the water sector and behavioural adjustments among all water users.

In addition, water services performance from resources management, infrastructure development and maintenance, service quality, risk assessment and mitigation and sustainability needs to be defined to ensure better alignment of policies and investments. For instance, Kenya's government can support attraction of new investors by enabling risk mitigation measures.

4. Conclusion

Lack of clean water is a global threat to humanity and development. Economic water scarcity is when a nation lacks the necessary monetary means to utilize the available water. It also involves unequal distribution of resources for many reasons, such as lack of financial and social capacity, lack of good governance, political and ethnic conflicts, and lack of institutional and policy frameworks that support water infrastructure.

Demand for adequate and clean drinking water in Kenya is in the rise. Low-cost sustainable technologies presents a solution to the challenges facing drinking water quality and wastewater management in Kenya. The filtration technologies range from simple such as use of natural filters to sophisticated such as use of synthetic filters. Natural filters include sand, activated carbon, cotton, natural ceramics, diatomaceous earth, cellulose, and activated clay

such as kaolinite. Examples of synthetic filters are such as nylon, ceramic filters, polymeric and liquid membranes, i.e. those made from organic and inorganic backbone. Natural filters are locally available in Kenya and if explored can be transformed into low-cost sustainable technologies.

To address water scarcity both physical and especially economic water scarcity, there is need for strategic planning to improve on resource utilisation and management, development of water infrastructure, and efficiency in water treatment to provide clean drinking water. Sustainable development and management is critical and is required. This can be supported through governmental, economic, institutional and techno-scientific frameworks to strengthen the capacity of Kenya in water provision to its populations.

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Authors contributions

Mrs. CJI and Prof. DOM were involved in the design, data collection and analysis whereas Dr. JPOO and Prof. TOM were responsible for data review and revision. CJI drafted the manuscript and Prof. DOM, Dr. JPOO and Prof. TOM did the in house review. All authors read and approved the final manuscript before submission.

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No additional data are available.