<u>*Original Research Article*</u>

STRATEGIES FOR ADAPTING WATER SUPPLY TO CLIMATE CHANGE IN NZOIA RIVER BASIN, KENYA.

ABSTRACT

Climate change is influencing the hydrological cycle on a global scale, and enhancing communities' ability to adapt to these changes is critical for long-term growth and survival. Climate change is expected to have a negative influence on water resources and supply. Other water stresses, such as population expansion, land-use change, growing per capita water demand, and regulatory changes, frequently exacerbate the consequences of climate change. Mitigation will not be enough to minimise the significant repercussions on the water industry, especially in poor nations. Adaptation is a "high priority" for developing countries, according to the "Delhi Declaration," which also calls for "urgent attention and action on the part of the international community." The study adopted a cross-sectional survey design. Three counties were randomly selected from Nzoia River Basin for study with Busia representing the lower catchment, Kakamega middle catchment and Trans Nzoia upper catchment. The study was carried out from May, 2017 to September, 2017.A carefully selected team of water and climate change experts consisting of decision makers, practitioners, managers, scientists, technology adopters and other stakeholders were used to identify the five main climate change challenges affecting water supply management in Nzoia River Basin (water scarcity and drought, flooding, water quality effects, unknown climate change risks and disaster preparedness) and the accompanying strategies and technologies for adapting water supply management to climate change through questionnaires, in-depth expert-interviews, brainstorming sessions, field observations and literature review. The adaptation strategies and technologies identification exercise drew from multiple sources of information including the national context where national development plans were used; adaptation technologies proposed in previous documents; technologies currently in use and supported by national water policy; initiatives in the pipeline under the larger water sector; appropriateness of technologies in the local context and the social acceptability among other sources. Stakeholder engagement helps to foster local ownership and buy-in, which is often necessary for long-term project viability. The study has also assessed the level of implementation for the adaptation strategies and the agencies involved. The adaptation strategies were identified and ranked using the total weighted scores as follows: Water storage, Water efficiency and demand management, Water augmentation, Alternative water sources, Water allocation, Urban storm water management, Riverine flood protection, Hazard and risk assessment, Vulnerability assessment, Disaster response, and Early warning. The Total weighted scores under ranking are very close to each other, implying that all the strategies/technologies listed for adapting water supply management to climate change are good. The results of this study provide valuable information that can be used by national and county governments in adapting water supplies to climate change.

Keywords: Nzoia River Basin, Climate change, Water supply, Adaptation strategies.

1.0 INTRODUCTION

Climate change is expected to have a negative influence on water resources and supply. Additional water stressors, such as population growth and rising per capita consumption, would amplify these effects [1]; thus, significant negative repercussions on the water sector are foreseeable. Adaptation was identified as a key factor in climate change responses in the first and second Intergovernmental Panel on Climate Change (IPCC) assessment reports. Early global climate change negotiations and actions, on the other hand, were nearly entirely focused on mitigation [2]. Adaptation was given more attention and finance at the Conference of the Parties meetings in 2001 and 2002 (COP7 and COP8, respectively). At COP8, the "Delhi Declaration" stated that adaptation was a "high priority" for developing countries, as well as a need for "urgent attention and action from the international community" [3]. Climate change presents several challenges/impacts to water supply management in Nzoia River Basin, and this study seeks to identify adaptation strategies and technologies linked to water quantity and availability. Adaptation strategies and technologies for water quality effects have been proposed for another separate study. Adapting your utility system and operations to the challenges of climate change necessitates thought and strategy.

Adaptation planning, on the other hand, is not necessarily a novel endeavor different from previous utility practices. Adaptation planning can be integrated into existing efforts for emergency response planning, capacity development, capital investment planning, water supply and demand planning, conservation practices, sustainability goals, and infrastructure maintenance because adaptation strategies/technologies often provide multiple benefits. When it comes to adaptation planning, it should be recognized that there is no one-size-fits-all approach for utilities. To design an adaptation plan that fits well with your utility's available resources and priorities, it's critical to start with the utility's climate change challenges/impacts. At a utility, dealing with climate change is a challenging task. Utilities are likely to face numerous issues as a result of projected future climate change. Because utilities must also deal with budgetary constraints, aging infrastructure, and other concerns, adaption strategies that can handle these challenges while also increasing climate resilience are preferable. Climate change adaptation strategies and technologies could result in more sustainable and efficient operations, cost savings, sufficient water supply and quality, and a reduction in greenhouse gas emissions. Every utility has its own set of priorities and resources, and climate change will affect them differently. As a result, it's critical to explore a wide range of options and benefits in order to design a complete adaptation plan that meets utility needs without straining resources. Adaptation planning is not a new or distinct activity in utility management. Utility asset management, permit compliance, emergency response planning, capacity building, and other decision-making processes can all benefit from incorporating adaption strategies/technologies that deliver numerous benefits. Conducting a risk assessment and implementing a decision-support framework is an important aspect of strengthening utility climate change resilience.

This framework should be an iterative process of identifying expected consequences and obstacles, assessing risks associated with these impacts, selecting and executing adaptation alternatives, and revisiting evaluations when new knowledge or more capacity to execute options becomes available. Apart from climate change, additional stressors should be included in the framework (e.g., changes in land use, population and regulatory changes). Adaptation planning entails more than just a look at the many alternatives available to facility owners and operators. Planning requires a number of technical and informational tools. In the determination of flood thresholds and the assessment of adaptation strategies to minimize losses, for example, inundation maps, precipitation forecasts, and flood models may all be required. In the past, utilities have assumed that, while observed temperature and precipitation conditions may vary greatly, the variability and average conditions will be stable in the future. As the climate changes, this assumption, known as stationarity, will be challenged. Many climate models predict that future climatic settings (e.g., precipitation intensity, temperature increases, etc.) would be more variable than in the past; historical data and trends may no longer be reliable predictors of future climate conditions. When deciding which adaptation strategies to adopt, utilities should use a flexible and iterative approach, making sure that strategies and technologies complement capacity building, emergency response activities, capital planning, and sustainability planning. An adaptive approach will lead to sound decision-making and successful operations, regardless of the climate impacts that a utility faces. Apart from the shift away from climate stationarity, utilities are increasingly realising that future energy prices and environmental conditions may not be forecasted based on historical data. These transformations may necessitate utilities changing how they operate and manage their resources in order to adapt and endure these changes. A water utility's sustainability is ensured through methods that fulfill today's needs while also maintaining the long-term supply of clean and safe water. Many sustainable practices offer ways to solve climate-related issues in a socially, economically, and environmentally acceptable manner.

It's critical to address areas of overlap between adaptation and the three categories of sustainable practices: energy management, green infrastructure, and water demand management, when considering utility sustainability. Energy management has the potential to lower operating costs, reduce greenhouse gas emissions, and improve service flexibility. Any activity performed to decrease, optimize, or increase energy efficiency, including service demand reduction or on-site energy generation, is generally considered part of energy management. These methods also allow for long-term engagement with stakeholders, resulting in collaborative partnerships that create a more sustainable community. In terms of adaptation planning, utilities should assess the energy consumption implications of new decisions or operational changes, as well as how alternate or extra options could help to limit any rise in energy needs. Green infrastructure is another sustainable technique that uses natural systems (or manufactured systems that resemble them) to control runoff, absorb storm water, and minimize water consumption. Green roofs, rain gardens, land acquisition, and permeable pavements are all examples of prevalent green infrastructure approaches. Green infrastructure, as an adaptation strategy, can help address both current and future storm water management concerns while also complementing the use of more traditional grey infrastructure. Green infrastructure has the advantage of being able to be phased in gradually, allowing for project adjustments as needed.

When considering the benefits of community-scale implementation, pursuing green infrastructure activities also promotes collaboration with stakeholders and County governments. Water demand management strategies can help to improve the long-term viability and availability of water supplies. Climate impacts, such as rising temperatures and the possibility of extended drought, combined with non-climate impacts, such as population growth, can lead to unsustainable demands on water supplies, raising the risk of water shortages. Water demand management involves both water efficiency and conservation measures and can occur on both the supply and demand sides (i.e., the supply side may involve efforts taken by drinking water utilities to improve the efficiency of supplying water to customers; whereas the demand side may relate to customer actions to reduce the amount of water used in homes and businesses). Water demand management strategies can help a utility meet demand for services while decreasing the need to produce additional source water to increase existing supplies as part of an adaptation plan. Because climate research is constantly evolving, and there is uncertainty about the timing, nature, direction, and scale of associated effects, utilities must constantly review and respond to new risks and opportunities during the adaptation planning process. This iterative process has been defined as part of the Plan-Do-Check-Act approach for water utilities. This method is a project-management cycle that emphasizes progress evaluation and corrective action when necessary in order to promote continual improvement.

2.0 MATERIALS AND METHODS

2.1 Study area

The study area is located in Western Kenya and spans latitudes 1^{0} $30^{'}$ N and 0^{0} $05^{'}$ S and longitudes 34^{0} E and $35^{0}45^{'}$ E. It includes the nine County governments of Elgeyo/Marakwet, West Pokot, Trans Nzoia, Uasin Gishu, Nandi, Kakamega, Bungoma, Busia and Siaya (Figure. 1). The geology of Nzoia River Basin is quite varied ranging from metamorphic basement rocks, volcanic rocks, to quaternary sedimentary rocks. The areas around Mt. Elgon are characterized by tertiary volcanic rocks mainly phonolites and agglomeratic tuffs. The plateau zones including Uasin Gishu and parts of Nandi are also characterized by Tertiary volcanic rocks which consist of phonolites and agglomeratic tuffs. The middle zone within the catchment is covered by metamorphic basement rocks consisting mainly of the gneissic rocks. The Climate of Nzoia River Basin is predominantly tropical humid and is characterized by day temperatures that vary from 16 °C in Cheranganyi and Mt. Elgon areas to 28 °C in the lower semi- arid plains of Bunyala.

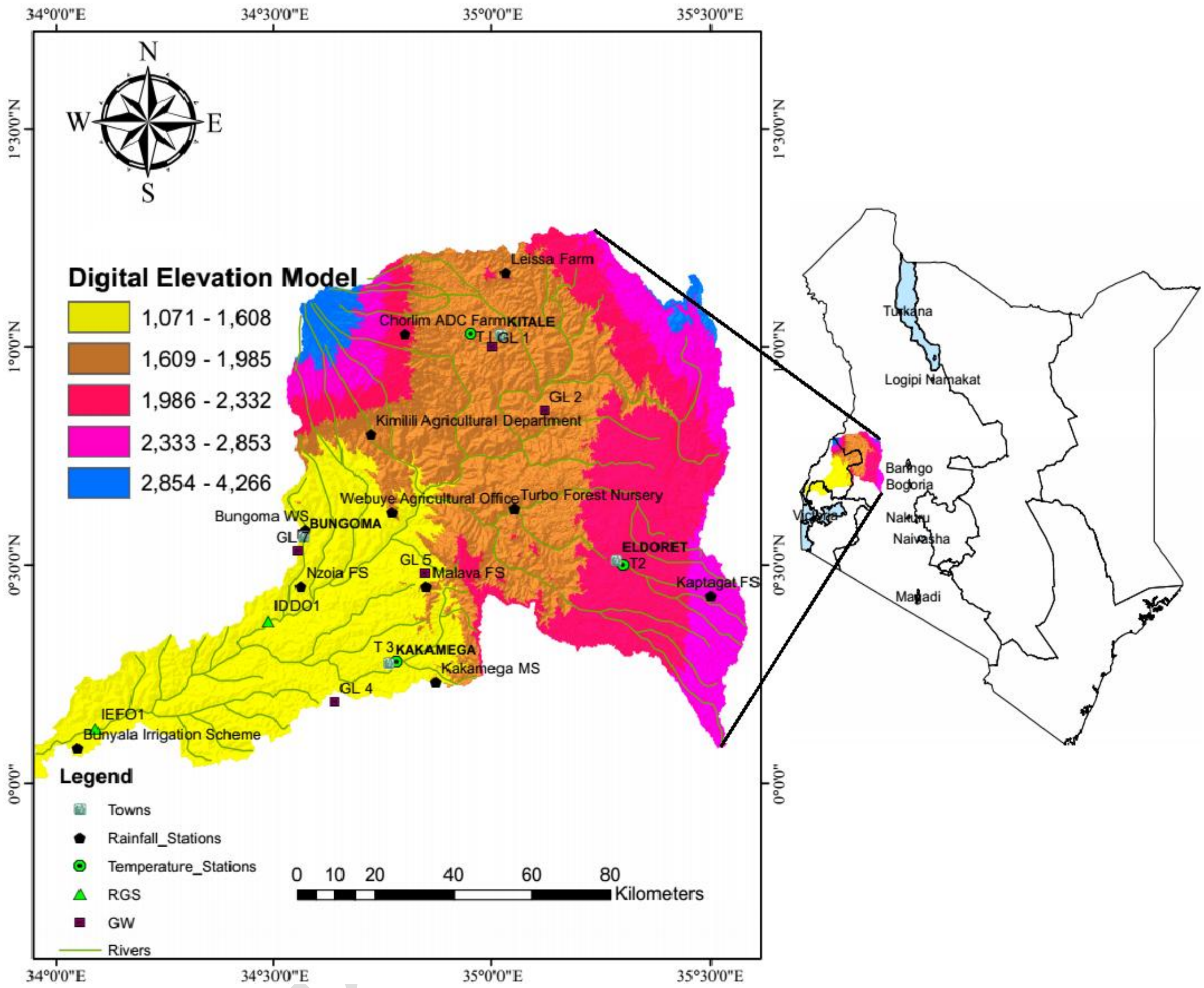

Figure. 1: Map of Nzoia River Basin, Kenya

Night temperatures vary from 4 °C in the highlands to 16 °C in semi-arid lowlands [4]. The highest rainfall ranges from 1100 – 2700 mm annually. Lowest rainfall ranges from 600 – 1100 mm annually [5]. Agriculture is the dominant land use in the region with the main food crops grown as maize, sorghum, millet, bananas, groundnuts, beans, potatoes, and cassava while the cash crops include coffee, sugar cane, tea, wheat, rice, sunflower and horticultural crops. The inhabitants of the basin also practice dairy farming together with traditional livestock keeping.

2.2. Methodology

The study adopted a cross-sectional survey design. Three counties were randomly selected from Nzoia River Basin for study with Busia representing the lower catchment, Kakamega middle catchment and Trans Nzoia upper catchment. A carefully selected team of water and climate change experts consisting of decision makers, practitioners, managers, scientists, technology adopters and other stakeholders were used to identify the five main climate change challenges/impacts affecting water supply management in Nzoia River Basin (water scarcity and drought, flooding, water quality effects, unknown climate change risks and disaster preparedness) and the accompanying strategies and technologies for adapting water supply management to climate change through questionnaires, in-depth expert-interviews, brainstorming sessions, field observations and literature review. The national context, national government development plans, county government development plans, adaptation technologies proposed in previous documents, technologies currently in use and supported by national water policy, initiatives in the pipeline under the larger water sector, appropriateness of technologies in the local context, and social acceptability, among other sources of information were used to identify adaptation strategies and technologies. Stakeholder engagement helps to foster local ownership and buy-in, which is often necessary for long-term project viability.

3.0 RESULTS AND DISCUSSION

3.1 Strategies for adapting Water supply management to Climate change in Nzoia River Basin

The study established the main climate change challenges/impacts affecting water supply management in Nzoia River Basin as shown in Table 1. A carefully selected team of water and climate change experts consisting of decision makers, practitioners, managers, scientists and technology adopters; ranked the severity of the main climate change challenges/impacts affecting water supply management in Nzoia River Basin (water scarcity and drought, flooding, water quality effects, unknown climate change risks and disaster preparedness) across the basin on a scale of 1-3, where, 1.-LOW, 2.-MEDIUM, and 3.-HIGH severity as shown in Table 1. The severity rating for water scarcity and droughts is high across the basin. The rating for flooding is Low in the upper catchment, Medium in the middle catchment and High in Lower catchment. The severity rating for Water quality effects and Unknown climate change risks were Medium all over the basin. The rating for Disaster preparedness was Medium in both upper and middle catchments, and High in lower catchment.

Increased frequency of water scarcity and droughts is projected to occur as a result of shifting rainfall patterns and rising temperatures linked to climate change [6]. Population growth, economic development, and the corresponding increases in per capita water demand, as well as the expansion of agricultural and industrial activities, may exacerbate the danger of water scarcity [7]. Water scarcity is caused by two main factors: natural and human. Natural water scarcity can occur as a result of lower-than-normal precipitation and freshwater flows, resulting in a physical lack of water. Many rivers, for example, have seasonal flow changes, and as a result, flows during the dry season are no longer sufficient to maintain adequate residential water supply and ecosystem activity. In many parts of the basin, this seasonal variability in rainfall is projected to become more common, making dry seasons even drier and wet seasons even wetter. Water scarcity can also be caused by unsustainable resource use. Water shortage is a regular occurrence in many locations due to competing demand, over-abstraction of groundwater and surface water, and poorly co-ordinated development. In the dry season or during droughts, communities are required to sustain their livelihoods and socioeconomic activities while at the same time maintaining a sufficient supply of water. To accomplish this, adaption technologies that can help maximize the use of scarce resources while at the same time reducing demand must be planned for and implemented.

Table-1: Severity Rating for the Main Climate change challenges/impacts affecting Water supply management in Nzoia River Basin

Climate change challenges/impacts affecting Water supply management	**Severity Rating across the Basin**		
	Upper Catchment	**Middle Catchment**	**Lower Catchment**
Water scarcity and drought	HIGH	HIGH	HIGH
Flooding	LOW	MEDIUM	HIGH
Water quality effects	MEDIUM	MEDIUM	MEDIUM
Unknown climate change risks	MEDIUM	MEDIUM	MEDIUM
Disaster preparedness	MEDIUM	MEDIUM	HIGH

Rainfall intensity is predicted to rise as a result of climate change, as is the variability of the seasonal distribution of rain. As the temperature rises, the atmosphere's ability to hold moisture increases, resulting in higher possible rainfall volumes and, as a result, increased flood risks. Flooding has already become more frequent and severe in several parts of the Nzoia River Basin. Flood impacts on water supply will be influenced by both climatic and non-climatic variables [8]. The entire global hydrological cycle is being influenced by climate change, and rising temperatures have a direct impact on water quality. Apart from temperature rises, other factors that contribute to water quality degradation include the increased frequency of floods and droughts, as well as the effects of human activities. Human activity continues to be the primary source of degradation. As temperatures and precipitation intensity rise, many types of water pollution will become worse. Nutrient pollution from agricultural operations is a significant water resources management issue and one of the most serious risks to water quality. Increasing nutrient leakage leading to eutrophication of water bodies is as a result of increased rainfall intensity caused by climate change. Controlling nutrient leaks, adopting better land management and agricultural techniques can help offset these dangers. Extreme weather events such as floods and droughts are becoming more common, contributing to water contamination. Increased rainfall and floods raise the risk of combined sewer overflows, which drain contaminants from sewers into neighboring water supplies. Similarly, over-abstraction from aquifers during dry spells and droughts can result in salinization and water quality degradation. The quality of surface water is also impacted by rising air temperatures, with the possibility for thermal pollution.

All water managers and investors in adaptation technologies face inherent risks and uncertainties which are exacerbated by climate change. They can, however, be decreased by introducing adaptation technologies that help better assess and analyze the effects of climate change on a river basin's water resources. Through a better understanding of the impacts and their distribution, the most effective adaptation strategies and technologies may be found. Hazard and risk assessments and Vulnerability assessments are the two major adaptation solutions for dealing with risk and uncertainty in the water industry. Many communities around the world are already dealing with the risks of various climate-related concerns. Seasonal floods, for example, are a natural feature of many river basins' hydrological cycle. Climate change, on the other hand, is expected to worsen these problems by increasing the intensity and unpredictability of seasonal water flow fluctuations, as well as the distribution and severity of extreme weather events. Any water management must first understand these developing and growing hazards, as well as assess the level of danger they pose to communities, in order to identify and design the best feasible adaptation strategies, as well as acquire funding for their implementation. A well-designed climate change Hazard and risk assessment helps to establish linkages between regional climate change and its impacts at the local level, and identifies the specific risks to the water resources sector that need to be addressed. This includes effects on the availability and quality of water resources, as well as the identification of areas and communities that are particularly vulnerable to extreme occurrences. Essentially, hazard and risk assessments try to estimate the effects of climate change on water resources and their expected geographical and temporal distribution, based on historical patterns and the best known research at the time. Vulnerability assessments, on the other hand, consider how climate change impacts interact with the features of the place, economic activity, ecosystem, or community of interest. Vulnerability thus becomes a function of the potential impacts of climate change (exposure) and that of the characteristics of the system (sensitivity to the changes) and the ability of the system to deal with the impacts (adaptive capacity) [9]. This also means that vulnerability is a less static element, and can change over time. Implementing appropriate adaptation technologies can reduce it.

Hydrological disasters account for the majority of natural disasters today, resulting in thousands of deaths and billions of dollars in economic losses each year. Floods affect more people than any other disaster on the planet [10]. Climate change is predicted to worsen these losses by increasing the frequency of floods and droughts. Natural disasters have the greatest impact on middle- and low-income countries with little adaptive capabilities [10]. Hydrological disasters interrupt critical infrastructure such as power plants, schools, and medical facilities, as well as water supplies. Recovery is difficult for the most vulnerable members of society, who often lack the financial resources to rebuild after losing their livelihoods and property.

3.1.1 Strategies for Adapting Water supply management to Water scarcity and droughts in Nzoia River Basin

The study sought to identify strategies and technologies for adapting water supply management to Water scarcity and droughts.

3.1.1.1 Strategies for adapting Water supply management to Water scarcity and droughts through Water storage

The strategies and technologies for adapting water supply management to Water scarcity and drought through Water storage in Nzoia River Basin are shown in Table.2. Water storage is one of the most important adaptive response options for managing water scarcity, given the expected future changes in the length and intensity of dry and rainy seasons.

Table.2: Adapting Water supply management to Water scarcity and drought through Water storage in Nzoia River Basin

Climate change challenge/ impact	Adaptation strategy	Technologies	Status of adaptation Technology implementation		
			Agency	Location	% Preference under strategy
Water scarcity and drought	Water storage	Construction of surface water reservoirs and multipurpose dams	Ministry of Water, Kenya Power & Lighting Company, Communities	All over the basin, a number of surface water reservoirs and multipurpose dams are planned on Nzoia river and its tributaries.	37
		Rainwater harvesting for storage	Institutions, Communities	All over the basin, Institutions and Communities capture rainwater.	33
		Conservation of natural wetlands	National and County Governments, Communities	All over the basin joint efforts are being made to restore the original hydrology and topography of the wetlands.	30

Some locations in the basin may have a decrease in precipitation, while others may see an increase in precipitation but with more heavy rain and shorter periods of time, extending dry spells. This will need adaptation strategies that rely on water storage to keep water supplies stable during the dry season. Surface reservoirs are man-made water storage facilities that aid in water security. Reservoirs come in all shapes and sizes, from natural water bodies dammed for storage to ground excavation in low-lying plains fed by rainwater or diverted rivers. Water supply, irrigation, hydropower generation, and flood control are all possible uses for stored water in reservoirs. Multipurpose dams are hydro infrastructure projects that integrate two or more functions of standard single-purpose dams into one. A multipurpose dam may be used for flood control, power production, navigation, runoff storage, and water discharge regulation in addition to storing and delivering water for irrigation, industry, and human consumption [6].

Ex situ water harvesting is the process of collecting rainwater for storage. This is a method of collecting rainwater and storing it for later use. Rainwater can be collected directly from roofs, soil surfaces, or highways and stored in open storage systems. Tanks are the most frequent storage systems for rainwater collection. Wetland ecosystem services are utilized for climate advantages when natural wetlands are conserved. It covers operations such as wetland restoration and conservation (avoided degradation). The re-establishment of a degraded wetland is known as wetland restoration. The goal of restoration interventions is to restore the wetland's original hydrology and topography so that natural processes and ecosystem functions that include water storage and regulation can continue.

3.1.1.2 Strategies for adapting Water supply management to Water scarcity and droughts through Alternative water sources

The strategies and technologies for adapting water supply management to Water scarcity and drought through Alternative water sources in Nzoia River Basin are shown in Table.3. Under Inter-basin transfers, water is transferred from a watershed with a surplus (donor basin) to a watershed with a deficiency (recipient basin).

Table.3: Adapting Water supply management to Water scarcity and drought through Alternative water sources in Nzoia River Basin

Climate change challenge/ impact	Adaptation strategy	Technologies	Status of adaptation Technology implementation		
			Agency	Location	% Preference under strategy
Water scarcity and drought	Alternative water sources	Inter-basin transfers	Ministry of Water, WRMA, County Governments	No inter-basin water transfers carried out	0
		Groundwater prospecting and extraction by boreholes	Ministry of Water, WRMA, Water sector development agencies.	All over the basin, groundwater prospecting and extraction by drilling boreholes.	100
		Water recycling and reuse	None	There are no agencies carrying out water recycling and re-use.	0
		Solar water distillation	None	There are no agencies carrying out solar water distillation.	0

The water is transported across great distances using sophisticated pipeline and canal systems, largely to ease water scarcity in the recipient area. Prospecting for groundwater and extracting it through boreholes entails a variety of techniques for locating adequate quality and quantity groundwater for extraction. Prospecting for and extracting groundwater can both be used as part of broader water resource management initiatives to boost supplies or respond to climate change-induced water scarcity or unpredictability. Hydrogeological investigations, geophysical surveys, remote sensing assessments, and the more straightforward way of analyzing existing well sites in the area, as well as their depths and features, are among the methods used. Water recycling and reuse necessitates the use of technologies for collecting, treating, and reusing wastewater, mostly from municipalities, industry, and agriculture. If properly treated, recycled water can be used for irrigation, industrial applications, and even home consumption. In other circumstances, treated wastewater is used for drinking purposes in an indirect manner, such as by injecting it into groundwater aquifers to enhance capacity and reduce saltwater intrusion. Solar water distillation is a method of separating freshwater from salts or other impurities by harnessing the energy of the sun. Solar water distillers are simple and inexpensive technology that provide freshwater alternatives in water-stressed locations. Solar water distillers are typically intended for single-family homes, though larger systems can be set up for shared use as well.

3.1.1.3 Strategies for adapting Water supply management to Water scarcity and droughts through Water allocation

The strategies and technologies for adapting water supply management to Water scarcity and drought through Water allocation in Nzoia River Basin are shown in Table.4. Improved Water allocation agreements are essential for making optimal use of limited resources and better coordinating resource development, lowering the danger of over-abstraction and environmental degradation.

Table.4: Adapting Water supply management to Water scarcity and drought through Water allocation in Nzoia River Basin

Climate change challenge/ impact	Adaptation strategy	Technologies	Status of adaptation Technology implementation		
			Agency	Location	% Preference under strategy
Water scarcity and drought	Water allocation	Seasonal water rationing	Ministry of Water, Water service provision companies, WRMA	All over the basin, carried out to ensure equitable distribution of available water resources	30
		Water re-allocation	Ministry of Water, Water service provision companies, WRMA	All over the basin, carried out to ensure equitable distribution of available water resources	70

Water allocation as a climate change response strives to adopt technology and build mechanisms for equitable sharing of current resources among users, with maximum benefits for all, including the environment [11]. This applies to all freshwater sources, including surface and groundwater. Understanding inputs and abstractions in relation to the overall river basin or water body in issue, including quantification of supply and demand for various users, as well as the value that varied uses provide for society, is a key precondition for efficient water allocation. This data can help you make the best allocation recommendations. Given how often compromises must be reached among conflicting uses and users, stakeholder dialogues should be included in all water allocation schemes. Seasonal water rationing is a method of regulating water use rates among various users depending on seasonal water supply and socioeconomic priorities. Water consumption limitations for certain uses, at specific times, or in specific places are examples of rationing. Throughout the year, the goal is to ensure equitable use among diverse consumers as well as high levels of water productivity. Water reallocation, on the other hand, is the transfer of use rights between users who have been allocated a certain amount of water (through formal or informal water use rights or entitlements) after it has been determined that the initial allocation is physically impossible or socioeconomically unfavorable. Resource re-allocation can assist adjust to unforeseen events (for example, acute water shortages during the dry season), reduce stress on renewable water supplies, and maximize the advantages of water use. It can be both voluntary and non-voluntary.

3.1.1.4 Strategies for adapting Water supply management to Water scarcity and droughts through Water efficiency and demand management

The strategies and technologies for adapting water supply management to Water scarcity and drought through Water efficiency and demand management in Nzoia River Basin are shown in Table. 5. When resources are limited, it's critical to manage not only the available supply but also the demand that frequently causes water shortages [12]. Through enhanced technologies and better control of water usage, water efficiency and demand management strategies assist reduce inefficient use and waste of freshwater. In many communities, addressing high per capita water usage, system losses, and inefficient use can make a significant difference in reducing water demand and use. This can be accomplished through a variety of methods, including improved technology, increased incentives for water conservation, and regulatory regulations that establish standards for acceptable water consumption limitations. When compared to other adaption strategies, these frequently use low-cost technologies. However, successful implementation necessitates widespread participation from all stakeholders, including the general people. As a result, increasing awareness and providing education are frequently significant factors in the successful implementation of such strategies. Water tariffs under progressive pricing are an economic tool for managing water demand and helping to reduce excessive water consumption by creating a financial disincentive [12]. Progressive pricing means that as the amount of water used increases, the price per unit of volume rises. As a result, the largest water customers pay higher rates for water consumed above a specific threshold. Shifting water use from peak to off-peak periods is a water demand management strategy aimed at reducing or rescheduling peak water withdrawals or consumption from surface or groundwater while prioritizing the most beneficial and strategically important water uses. Enforcing water efficiency in manufacturing is a combination of behavioral, operational, and technological changes aimed at increasing water efficiency in industrial production. This includes better leak detection and pipe repair, as well as the use of innovative and more efficient technology (e.g. pipes, smart dosage systems, timers, higher efficiency cleaning systems, water monitoring systems).

Table.5: Adapting Water supply management to Water scarcity and drought through Water efficiency and demand management in Nzoia River Basin

Climate change challenge/ impact	Adaptation strategy	Technologies	Status of adaptation Technology implementation		
			Agency	**Location**	**% Preference under strategy**
Water scarcity and drought	Water efficiency and demand management	Implementing water tariffs under progressive pricing	Ministry of Water, Water service provision companies	All over the basin. These water efficiency and demand management measures are carried out by all Water service provision companies.	40
		Shifting the timing of water use from peak to off-peak periods			
		Enforcing water efficiency use in manufacturing industries			
		Implementing water metering			
		Conducting public water conservation campaigns			
		Reducing system water losses and leakages			
		Carrying out hydrological zoning	Ministry of Water, WRMA	All over the basin, carried out by WRMA to protect water sources.	16
		Enforcing water licencing and permits	Ministry of Water, WRMA	All over the basin, carried out by WRMA to keep track of how much water is used, where and by whom.	21
		Enacting legislation on water savings requirements in building codes	National and County Governments.	Legislation in process.	23

Water use among workers can be reduced by raising awareness and modifying behavioural patterns. Industrial water efficiency can be supported on a regulatory level by setting tariffs as a water conservation incentive. Implementing water metering is a strategy that enables customers account for water consumption rates that are frequently linked to pricing costs per unit utilized, as well as the necessary equipment. Frequently used as part of public water resource management to track and eventually reduce water consumption. It can also be used to detect and locate system leaks (water generated vs.

water metered at the end point), as well as supply utilities with data on consumer behavior that can be used in water conservation efforts. Conducting public water conservation programs attempts to enhance water use efficiency by altering people attitudes and behavior. Education and awareness campaigns about the social and environmental benefits of water conservation and various conservation strategies are included.

Traditional and social media, as well as direct communication such as workshops, presentations, stakeholder dialogues, and so on, are all examples of communication methods. Economic incentives can also be used, such as free water meter installation. Hydrological zoning is a method of dividing land into separate zones depending on its hydrological characteristics. Each sort of zone usually has its own set of land use and development regulations. By controlling land use activities based on the designated hydrological zones, the goal is to safeguard local water sources from over-abstraction, land salinization, groundwater pollution, and waterlogging. Irrigation may be restricted to reduce nutrient loading and sediment flow into watersheds, but other activities such as industrial discharge and water abstraction from surface or groundwater sources may also be restricted. Reducing system water losses and leaks is one way to boost distribution system efficiency and reduce wasteful draws. The amount of water lost between the supplier and the user is described as "real" water losses, whereas "apparent" water losses are defined as those caused by erroneous consumption assessments by the consumer or utility. Leak detection systems, pressure control, meter maintenance, and unauthorized use management are all strategies that can assist decrease both real and apparent water losses (also known as non-revenue water). Water licensing and permits are a water demand management tool that requires private landowners, or in some cases, specific potential water users, to apply for (or purchase) a license or permit for water-use or water-affecting activities (e.g. construction, diversion, artificial recharge) in the watershed. Authorities and watershed managers can use water licensing to keep track of how much water is used, where it is used, and by whom, and impose timely limits when necessary. A legislative method to improving water consumption efficiency in commercial and residential buildings is to enact legislation on water savings requirements in building codes. Building codes may require the installation of modern technologies such as water pressure control, faucet aerators, leak detectors, water-saving toilets to maximize efficiency, but they may also require the installation of internal water recycling systems or infrastructure to provide alternative water sources, such as rainwater harvesting tanks.

3.1.1.5 Strategies for adapting Water supply management to Water scarcity and droughts through Water augmentation.

The strategies and technologies for adapting water supply management to Water scarcity and drought through Water augmentation in Nzoia River Basin are shown in Table. 6. Conjunctive use of surface and groundwater refers to the use and development of both surface and groundwater at the same time. It seeks to improve total water supply resilience by combining both sources of water, especially in towns and basins where water fluctuation is considerable throughout the year. It frequently emphasizes the benefits of groundwater for water storage, distribution, and treatment (through biological processes). Regulations (e.g., water allocation quotas, water quality compliance regulations), compensation schemes (e.g., payments to industrial or agricultural users to reduce use of pollutants or extraction volumes, payments for ecosystem services schemes), or conservation measures in the upstream watershed are all examples of source water protection measures. Measures to sustain appropriate water recharge and infiltration in upstream areas are among them. In situ water harvesting is another term for rainwater harvesting for infiltration.

Table.6: Adapting Water supply management to Water scarcity and drought through Water augmentation in Nzoia River Basin

Climate change challenge/ impact	Adaptation strategy	Technologies	Status of adaptation Technology implementation		
			Agency	Location	% Preference under strategy
Water scarcity and drought	Water augmentation	Conjunctive use of surface and groundwater	National and County Governments, Communities.	This is practiced all over the basin.	35
		Source water protection	National and County Governments, Communities.	National and County Governments and Communities are encouraged to practice source water protection.	10
		Rain water harvesting for infiltration	National and County Governments, Communities.	This is practiced all over the basin.	25
		Urban green spaces	Urban/Town councils, Community	All over the basin. Golf fields, recreational gardens and agricultural farms in the towns' neighborhood.	15
		Managed aquifer recharge	National and County Governments, Communities.	National and County Governments and Communities are encouraged to practice managed aquifer recharge	15

Rainwater uptake in soils is boosted through the soil surface, roots system, and groundwater in this method. Soil works as a storage agent, increasing water holding capacity and fertility while lowering the danger of soil loss and erosion. Terracing, pitting, and conservation tillage are among examples. Urban green spaces are areas in urban settings that are covered with vegetation (e.g. grass, bushes, or trees) that help to absorb and permeate water, reducing runoff rates, which typically include excessive amounts of pollutants. As a result, the demand on water drainage systems and treatment facilities is reduced. Because of their high water retention capacity, vegetation plays a significant role in flood mitigation, storm water management, and groundwater recharge.

Managed aquifer recharge is a water management strategy for maximizing natural storage and increasing water supply system resilience under low flow and high seasonal fluctuation. Aquifers are artificially replenished during these times in order to recover water. A managed recharge means that the process is under control and that health and environmental concerns are kept to a minimum.

3.1.2 Strategies for adapting Water supply management to Flooding in Nzoia River Basin

The study sought to identify strategies and technologies for adapting water supply management to flooding.

3.1.2.1 Strategies for adapting Water supply management to Flooding through Urban storm water management

The strategies and technologies for adapting water supply management to Flooding through Urban storm water management in Nzoia River Basin are shown in Tables.7. Increases in impermeable surfaces are a result of growing rates of urbanization and density of land developments. When combined with aged, or non-existent, storm water infrastructure, these variables generate an urgent need for improved urban storm water management measures to adapt to climate change. Due to its fast onset and the exposure of huge populations and assets to dangers in a relatively smaller region, urban flooding can be deadly and destructive. Sewer overflows which occur in cities where storm water collection systems are combined with domestic sewage and industrial wastewater systems pose greater risks under pluvial floods. During severe rain events, the huge amount of storm water can cause sewers to overflow, posing water pollution and public health issues in neighboring water bodies.

Infrastructure developed in urban contexts to promote storm water runoff and decrease urban floods and storm water overflow threats includes permeable pavements and parking lots [11]. They're designed to take advantage of the ecosystem services supplied by soil, such as water capture and infiltration. The porous surfaces allow for more water absorption. Before refilling the groundwater, the water is infiltrated and cleansed to some extent. Runoff rates are reduced as a result of the retention, and demand on urban storm water systems is reduced. Urban Green spaces in cities are vegetated regions (e.g. grass, bushes or trees). Storm water is redirected and filtered using Bioswales, which are vegetated strips. In an urban setting, a typical bioswale is a long, linear strip of plant used to absorb runoff water from large impermeable surfaces like roadways and parking lots. They provide a similar purpose to gutters. The benefit of employing bioswales is that the vegetation and soil slow down and collect water, allowing it to infiltrate the soil and filter contaminants. Runoff control structures for temporary rainwater storage are structures that absorb runoff during peak flows and can also serve as temporary storage sites. Typically constructed with a discharge component to slowly release water into a neighboring canal to prevent the storage basin from overflowing.

Table.7: Adapting Water supply management to Flooding through Urban storm

water management in Nzoia River Basin

Climate change challenge/ impact	Adaptation strategy	Technology	Status of adaptation Technology implementation		
			Agency	Location	% Preference under strategy
Flooding	Urban storm water management	Construction of permeable pavements and parking lots	No agency	This is a strategy/technology that is ripe for most of the major towns.	0
		Establishment of urban green spaces	Urban/Town councils, Community	All over the basin. Golf fields, recreational gardens and agricultural farms in the towns' neighborhood.	15
		Establishment of Bioswales to redirect and filter storm water.	Community	All over the basin. Vegetative fences to homesteads and agricultural farm lands in towns and its neighborhood.	14
		Construction of runoff control structures to temporarily store rainwater	No agency	This is a strategy/technology that is ripe for most of the major towns.	0
		Upgrading Hydro-meteorological monitoring networks.	Kenya Meteorological Department, WRMA	All over the basin. Each County has a meteorological officer. WRMA upgrading stations.	21
		Enacting Water adaptation to climate change legislation	National and County Governments, Water sector NGOs.	All over the basin. Each County has finalized County Water Policy and Bill.	16
		Allocating adequate funds for climate adaptation	National and County Governments, Water sector NGOs.	All over the basin. Each County has Climate change Programmes in Approved Budgets.	18
		Implementing Intergrated water resources management	National and county governments, Water sector, NGOs.	All over the basin. National Government through WRMA implementing IWRM strategies.	16

Can be constructed artificially, such as by excavating a big area to make it lower than the surrounding ground. Wetlands and other green places can also be used as temporary runoff storage structures. Upgrading hydro-meteorological monitoring networks, enacting water adaptation to climate change legislation, allocating adequate funds for climate adaptation, and implementing integrated water resources management are all activities that, if carried out, will help the Nzoia River Basin adapt water supply management to climate change.

3.1.2.2 Strategies for adapting Water supply management to Flooding through Riverine flood protection

The strategies and technologies for adapting water supply management to Flooding through Riverine flood protection in Nzoia River Basin are shown in Table.8. A green infrastructure concept that focuses on reducing barriers along the river's borders is re-connecting sections of the river with its floodplains. This permits the river to re-establish its original path over time, eventually linking to or establishing a new floodplain. Levees may be removed or put back, a deeply carved riverbed may be raised, or a river's bank may be expanded. Manually restoring (by digging) the river to its natural form and constructing human-made links between the river and its native floodplain wetlands are both faster solutions. Construction of flexible buildings and infrastructure that can accommodate flooding is a design of infrastructure that can endure the impact of flooding occurrences, limiting socio-economic damages and allowing for successful climate change adaptation [12].

Flood resistant designs, which keep floodwater out completely, and flood resilient designs, which minimize structural restoration costs and time if it is inundated, are two examples of accommodation strategies. Both new designs and retrofitting existing structures are included. Ecological restoration of a river system to its natural state entails ecological, spatial, and physical management approaches to return a river to its native state (or close to it). Reconnecting rivers with floodplains, restoring the river's meandering nature with no barriers along its banks, and stabilizing surrounding soil to decrease sedimentation and erosion are all common restoration strategies. Due to their propensity to naturally expand their banks and flood onto floodplains, restored rivers have greater water retention capacity, making them more effective for flood risk management. In flood plain areas, zoning and land development restrictions are a method of dividing metropolitan areas into zones with varied degrees of development limits based on flood risk. In high-risk regions, such as floodplains, construction or reconstruction is frequently forbidden, although in other areas, limited development is permitted as long as specific building requirements are met. Dams, dikes, locks, and levees are examples of flood protection infrastructure that are used to control river floodwater flow and protect settlements from the costly effects of inundation. A permanent structure placed at a specific location along the path of a river to contain water on one side of the barrier. Hard infrastructure includes structures like dams, dikes, locks, and levees.

Table.8. Adapting Water supply management to Flooding through Riverine flood protection in Nzoia River Basin

Climate change challenge/ impact	Adaptation strategy	Technologies	Status of adaptation Technology implementation		
			Agency	**Location**	**% Preference under strategy**
	Riverine flood protection	Re-connecting sections of Nzoia river and its tributaries with floodplains	Ministry of Water, Communities.	Busia County- Nzoia river in Budalang and Sio river in Nambale and Samia Sub-counties.	12
		Construction of flexible buildings and infrastructure that can accommodate flooding	All Water sector implementing agencies.	All over the basin, Communal water points (Hand dug wells, Water springs, Boreholes), Piped water supply intake pump stations are constructed in a manner to accommodate flooding.	25
		Ecological restoration of river system back to its natural state	Ministry of Water, Communities.	Re-connecting sections of Nzoia river and its tributaries in Budalang and Sio river and its tributaries in Nambale and Samia Sub-Counties.	10
		Zoning and land development limitations in flood plain areas	Ministry of Agriculture, Water, Lands, WRMA, NEMA	All over the basin, Keep farming activities and construction of buildings away from flood prone areas. Ensure controlled and approved developments within flood prone areas.	10
		Construction of structural barriers to flooding such as dams, dikes, locks, and levees	Ministry of Water, Kenya Power and Lighting Company, WRMA	All over the basin, a number of dams are under planning stage on Nzoia river and its tributaries. Dikes have been constructed on Nzoia river in Budalang.	22
		Construction of multi-purpose dams	Ministry of Water, Kenya Power and Lighting Company, WRMA	All over the basin, a few multipurpose dams are under planning stage on Nzoia river and its tributaries.	21

Multipurpose dam construction is a method of combining two or more functions of traditional single-purpose dams into a single hydro infrastructure project [11].

3.1.3 Strategies for adapting Water supply management to Unknown climate change risks in Nzoia River Basin, Kenya

The study sought to identify strategies and technologies for adapting water supply management to Unknown climate change risks.

3.1.3.1 Strategies for adapting Water supply management to Unknown climate change risks through Hazard and risk assessment

The strategies and technologies for adapting water supply management to Unknown climate change risks through Hazard and risk assessment in Nzoia River Basin are shown in Table.9.

Table.9: Adapting Water supply management to Unknown climate risks through Hazard and risk assessment in Nzoia River Basin

Climate change challenge/ impact	Adaptation strategy	Technologies	Status of adaptation Technology implementation		
			Agency	Location	% Preference under strategy
Unknown climate risks	Hazard and risk assessment	Drought risk assessment and mapping	National and County Governments, Universities, Climate change Research Institutions, Communities.	Drought risk assessment and mapping studies are conducted by Universities and Researchers on Climate change in the Country	40
		Flood hazard assessment and mapping	National and County Governments, Universities, Climate change Research institutions, Communities.	Flood hazard assessment and mapping studies are conducted by Universities and Researchers on climate change in the Country	40
		Downscaling of climate model projections	National and County Governments, Universities, Climate change Research institutions, Communities	Downscalling of Climate projection studies are conducted by Universities and Researchers on Climate change in the Country	20

Drought risk assessment and mapping is an important part of drought management because it helps communities identify the areas most vulnerable to droughts, allowing them to plan, prepare for, and reduce the effects. Drought risk is calculated as the probability of negative impact caused by interactions between hazard (probability of future drought events occurring based on past, current and projected drought conditions), exposure (scale of assets and population in the area) and vulnerability (probability of assets and population being affected by droughts in the area). Drought risk is frequently assessed using hydro-meteorological or hydrological indicators. Flood hazard assessment and mapping is a method of identifying flood-prone locations and, as a result, improving flood risk management and disaster preparedness.

Flood hazard assessment and mapping is a method of identifying flood-prone locations and, as a result, improving flood risk management and disaster preparedness. Typically, depending on numerous situations, assess the projected extent and depth of flooding in a specific location (e.g. 100-year events, 50-year events, etc.). Flood hazard evaluations can be expanded to analyze specific hazards that take into account the socioeconomic characteristics of the exposed areas (e.g. industrial operations, population density, land use). Downscaling climate model forecasts is a technique for evaluating local-scale climate change consequences using data from regional and global climate models. Modeling and comprehending future climate impacts on water supplies is critical. Due to the high level of uncertainty in, particularly, local scale results, it is usually combined with other sources of information and models.

3.1.3.2 Strategies for adapting Water supply management to Unknown climate change risks through Vulnerability assessment

The strategies and technologies for adapting water supply management to Unknown climate risks through Vulnerability assessment in Nzoia River Basin are shown in Table. 10. The purpose of a climate change vulnerability assessment is to determine the extent to which a changing climate will influence the system under consideration. Vulnerability assessment methods go beyond the immediate hazards stemming from changes in temperature and rainfall (exposure), assessing also the characteristics of the system itself (sensitivity), as well as its ability to deal with the anticipated impacts (adaptive capacity). Vulnerability assessments in the context of water resource management are primarily concerned with the climate risks associated with fulfilling rising water demands in a changing environment and preparing for growing climate variability (including extreme events such as floods and droughts). There are many frameworks and methodologies for vulnerability assessments, and the optimal method should be chosen based on locally relevant criteria such as the objective, availability of information, costs, assessment priorities, and so on. Socio-economic scenarios are a collection of models that depict expected changes in major socio-economic factors. The scenarios are intended to characterize the social and economic dynamics driving climate change, as well as project socioeconomic systems' vulnerability and/or adaptation capability to climate change impacts. They aid in the identification of intervention priorities and, when combined with hydrological and climate assessments, give more depth to risk assessments and quantification, as well as climate impacts and viable adaption strategies.

Table.10: Adapting Water supply management to Unknown climate risks through Vulnerability assessment in Nzoia River Basin

Climate change challenge/ impact	Adaptation strategy	Technologies	Status of adaptation Technology implementation		
			Agency	Location	% Preference under strategy
Unknown climate risks	Vulnerability assessment	Climate change vulnerability assessments	National and County governments, Universities, Climate change research institutions, Communities.	Vulnerability assessment studies are conducted by Universithes and Researchers	60
		Socioeconomic scenarios	National and County governments, Universities, Climate change research institutions, Communities	Vulnerability assessment studies are conducted by Universithes and Researchers	40

3.1.4 Strategies for adapting Water supply management to Disaster preparedness in Nzoia River Basin, Kenya

The study sought to identify strategies and technologies for adapting water supply management to Disaster preparedness.

3.1.4.1 Strategies for adapting Water supply management to Disaster preparedness through Early warning

The strategies and technologies for adapting water supply management to Disaster preparedness through Early warning in Nzoia River Basin are shown in Table.11. Flood forecasting systems aid in the prediction of probable flooding disasters. Forecasts give the public more time to prepare and evacuate, and also aid in providing a sufficient response to reduce flood damage. The forecasting systems use data from simulation tools and models that anticipate precipitation amounts and stream flow, as well as hydrometric stations that measure water levels at specific sites along a river or other water body, to estimate projected water level rise. Drought forecasting systems employ models supplied by climatic and atmospheric data (historical/seasonal weather patterns, real-time meteorological monitoring, and weather forecasts) to anticipate the likelihood of a drought developing in the future in a region or area of interest (up to approximately three months). Drought forecasting systems are an important aspect of early warning systems because they give planners enough time to respond to threats, reducing the danger of drought impact. The basic goal of early warning systems is to send out alerts when a flood is about to happen or is already happening.

Table.11: Adapting Water supply management to Disaster preparedness through Early warning in Nzoia River Basin

Climate change challenge/ impact	Adaptation strategy	Technologies	Status of adaptation Technology implementation		
			Agency	Location	% Preference under strategy
Disaster preparedness	Early warning	Flood and Drought forecasting systems	Kenya Meteorological Department, WARMA, Communities.	Data collection being done all over the basin	25
		Early warning systems for Floods and Drought	National and County Governments, Universities, Climate Change Research Institutions, Communities.	Flood Early warning system developed in Budalang	40
		Landslide and mudflow warning systems	National and County Governments, Universities, Climate Change Research Institutions, Communities.	Not developed for the basin	10
		Decentralized Community run Early warning systems	National and County Governments, Universities, Climate Change Research Institutions, Communities.	Decentralized Community run Early warning system for floods developed in Budalang	25

The system gives a forecast of the impending flood's size, timing, location, and anticipated damages as part of the warning. To forecast a future flood occurrence, the system collects data from sensors to assess water levels at crucial sites in local water basins (rivers, lakes) or flood defenses (dikes, dams, embankments). The fundamental goal of a drought early warning system is to alert local communities when a drought is imminent, enhancing preparedness and lowering the risks of crop and food loss. Drought monitoring, employing appropriate drought indicators, meteorological data and predictions, a warning signal, public awareness and education, institutional cooperation, and data sharing procedures are all required for effective warning systems. An early warning system combined with the slow start of a drought can provide local decision-makers enough time to prepare for drought concerns, such as by securing emergency food supplies, establishing water harvesting programs, or implementing enhanced dry-land farming initiatives.

Landslide and mudflow warning systems offer alerts when a landslide or mudflow event is imminent, helping to improve disaster preparedness and reduce event risks. Rain gauges and slope-movement sensors on site provide real-time or periodic monitoring data to the systems. To evaluate the risk of a landslide or mudflow, the data is combined with data from mathematical models calibrated with local topography, geophysical properties, land usage, and anticipated weather data. Decentralized community-run early warning systems are low-cost technology used by local residents to improve disaster preparedness. Members of the community employ modest technology to forecast natural disasters like as floods, landslides, and droughts, as well as a communication/dissemination system to alert other inhabitants of imminent dangers.

3.1.4.2 Strategies for adapting Water supply management to Disaster preparedness through Disaster response

The strategies and technologies for adapting water supply management to Disaster preparedness through Disaster response in Nzoia River Basin are shown in Table.12. Flood Disaster Preparedness Indices are used to assess a community's preparedness to deal with flooding. The Flood Disaster Preparedness Index (FDPI) is made up of eight indices, each of which is linked to a distinct component of flood disaster preparedness. The indices are: state of infrastructure, mitigation plans, mitigation systems, evacuation plans, recovery plans, information and education, collaboration, and community strength. They are based on self-evaluation, with respondents answering a series of questions about each aspect. Disaster response and mapping using social media applications uses social media applications to spread information during and after a disaster, allowing persons affected by the disaster to communicate with disaster relief agencies, friends, and family.

Table.12: Adapting Water supply management to Disaster preparedness through Disaster response in Nzoia River Basin

Climate change challenge/ impacts	Adaptation strategy	Technologies	Status of adaptation Technology implementation		
			Agency	Location	% Preference under strategy
Disaster preparedness	Disaster response	Flood Disaster Preparedness Indices	National and County Governments, NGOs, Communities.	Flood Disaster Preparedness Indices for the basin not developed	35
		Social media applications for disaster response and mapping	National and County Governments, NGOs, Communities.	Social media applications for disaster response and mapping not developed	35
		National and community disaster management plans	National and County Governments, NGOs, Communities.	National and community disaster management plans not developed	30

Emergency workers can utilize the information supplied through these apps to estimate the scope of the disaster and locate precise locations in affected areas. It can also be used to immediately alert a large number of people to distribution sites, shelter areas, evacuation zones, and other important information. To improve disaster risk management governance from the state to the local level, national and community disaster management plans are developed. National disaster management plans combine disaster risk management into national policy and develop a framework that clearly defines the tasks of the institutions/committees responsible. Community disaster management plans can be fine-tuned based on local threats, allowing for a more specific and detailed strategy customized to local circumstances.

3.1.5 Shortlist of strategies for adapting Water supply management to Climate change in Nzoia River Basin

Tables 1 to 12, show the five identified climate change challenges to adapting water supply management to climate change (water scarcity and drought, flooding, water quality effects, unknown climate change risks and disaster preparedness); the identified

Table.13: Shortlist of strategies for adapting Water supply management to Climate change in Nzoia River Basin

S/no.	Strategy	Implementation Technologies
1.	Water efficiency and demand management	Water efficiency in industry; water metering; reducing system water loss and leakages; public water conservation campaigns; progressive pricing; hydrological zoning; water licencing and permits; shifting the timing of use; and water savings requirements in building codes.
2.	Water allocation	Seasonal water rationing and water re-allocation.
3.	Water storage	Surface reservoirs; multipurpose dams; natural wetlands; and rainwater harvesting for storage.
4.	Alternative water sources	Solar water distillation; interbasin transfers; groundwater prospecting and extraction, boreholes; and water recycling and reuse
5.	Water augmentation	Rainwater harvesting for infiltration, urban green spaces; conjuctive use of surface and groundwater; managed aquifer recharge; and source water protection.
6.	Urban storm water management	Urban green spaces, permeable pavements and parking lots; bioswales, and runoff control structures to temporarily store rainwater
7.	Riverine flood protection	Structural barriers to flooding - dams, dikes, locks, and levees; re-connecting rivers with floodplains; accommodation of flooding (flexible buildings and infrastructure); ecological river restoration; multipurpose dams; and zoning and land development limitations
8.	Hazard and risk assessment	Downscaling of climate model projections; flood hazard assessment and mapping; and drought risk assessment and mapping
9.	Vulnerability assessment	Socio-economic scenarios; climate change vulnerability assessments.
10.	Early warning	Flood and drought forecasting systems; early warning systems for floods and droughts; landslide and mudflow warning systems; decentralized community run early warning systems.
11.	Disaster response	Flood disaster preparedness indices (FDPI); social media applications for disaster response and mapping; and national and community disaster management plans.

adaptation strategy to each climate change challenge; the technologies for use under each adaptation strategy; and the implementation status in terms of Agencies/stakeholders involved, sites/location of implementation works and stakeholder preference of the strategy/technology. These climate change challenges, adaptation strategies and technologies were identified as detailed under study methodology. Table 13 shows a shortlist of strategies for adapting water supply management to climate change and the respective implementation technologies for Nzoia River Basin. Further screening of these strategies and technologies was carried out by the Researcher and the team of water-climate change experts with the discussions focusing on the likely future scenarios of climate change impacts in Nzoia River Basin; expert knowledge and pre-screening criteria as prescribed in the Technology Needs Assessment (TNA) Handbooks of UNFCCC technology transfer framework as; (i) technical potential of the technology; (ii) contribution to improve climate resilience; (iii) cost of the technology and (iv) coherence of the technology with national development strategy and policies [13]. Thus, this study established the strategies for adapting water supply management to climate change in Nzoia River Basin as:

i. Water efficiency and demand management
ii. Water allocation
iii. Water storage
iv. Alternative water sources
v. Water augmentation
vi. Urban storm water management
vii. Riverine flood protection
viii. Hazard and risk assessment
ix. Vulnerability assessment
x. Early warning
xi. Disaster response.

3.2 A Framework for adapting Water supply management to Climate change in Nzoia River Basin

According to the definition used by the IPCC, “adaptation is any adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities”[14]. Adaptation should thus reduce the sensitivity to potentially damaging impacts, but also enhance the capability to capture any benefits of climate change. Climate change impacts often exacerbate existing pressures or threats. This implies that adaptation does not necessarily require the development of new measures or technologies, but can consist in the appropriate application of existing instruments. Adaptation can also be a side-benefit of sustainable water management practices addressing current problems (generating for instance an increase in resilience). On the other hand, planned adaptation initiatives are often not undertaken as stand-alone measures, but embedded within broader sectoral initiatives such as water resource planning, coastal defence and disaster management planning. This study has established 11 No. adaptation strategies based on the 5No. identified climate change challenges/impacts affecting water supply management in Nzoia River Basin as elaborated in Tables 1 to 13. Some of these adaptation strategies and technologies are based on reactive (response to past or current events) versus anticipatory or pro-active adaptation, autonomous and planned/policy-driven adaptation, purposeful and unintentional adaptation.

For every climate change challenge/ impact (water scarcity and droughts, flooding. unknown climate risks and disaster preparedness); there is a broad range of potential adaptation strategies and technologies. The Researcher engaged in lengthy brainstorming sessions and making consultations with other sector experts, in an effort to develop a framework for assessing adaptation strategies outlined in Table 13; so that the most appropriate intervention (or portfolio of interventions) is chosen for a specific climate change challenge/ impact within Nzoia River Basin. The team finally agreed on an evaluation criteria based on a number of considerations such as the specific climate change challenges/impacts; effectiveness of adaptation (mainly adaptation function, robustness to uncertainty and flexibility; side-effects [mainly no regret, win-win (or win-lose)? and spill-over effects]; efficiency/ costs and benefits (mainly low-regret); framework conditions for decision making (equity and legitimacy, feasibility of implementation, alternatives and priority and urgency). The evaluation criteria is explained in detail here below;

i) Effectiveness of adaptation strategies

The first criterion for assessing the adaptation strategies/technologies should be their effectiveness. Strategies/technologies can effectively deliver adaptation if they contribute to reducing the impacts, reduce exposure to the impacts, or enhance resilience of a system. A key criterion in this respect is if they are able to deal with uncertainties. Adger et al. [15] identify robustness to uncertainty and flexibility to change in response to altered circumstances as key indicators for the effectiveness of adaptation strategies/technologies. While “robust” would mean that strategies/technologies have a low sensitivity to uncertainty, i.e. will work under different scenarios, “flexible” would denote the ability of a strategy/technology to be adjusted later to new developments and trends. Similar concepts have been developed by the European Environment Agency-ESPACE project which recommends that for managing uncertainties, a mix of policies and strategies/technologies should be used that i) pay off immediately under current climate conditions, ii) have multiple benefits that contribute to climate adaptation, iii) are low-cost but have potentially large benefits under climate change, and iv) are flexible and resilient [16].

ii) Side-effects of adaptation strategies

Side-effects of adaptation strategies/technologies can be a criterion for decision-making. A strategy/technology that contributes to solving existing water supply management problems and enhances adaptive capacity in the future should be prioritized (no-regret strategy/technology). Similarly, strategies/technologies may entail side-benefits for other objectives of sustainable development, or they might negatively affect the delivery of other policy objectives. Finally, potential spill-over effects should be taken into account in decision-making. For instance, a water management strategy/technology planned for adaptation purposes might affect the adaptive capacity of other sectors or agents, or it may cause or exacerbate other environmental pressures. In the context of side-effects, interaction between climate change mitigation and adaptation should be considered. Generally, impact assessment procedures may be used to make sure that all relevant impacts and side-effects are taken into account. Examples for robust no-regret strategies/technologies: climate change will enhance water scarcity problems with negative impacts on water quality and aquatic ecosystems. In many regions, adaptation to climate change will be closely linked with adaptation to water scarcity. Measures that reduce water consumption and increase efficiency will be essential elements of adaptation strategies/technologies in these cases, and will often be robust in the sense that they will bring benefits independent of the magnitude of the changes.

iii) Efficiency/ costs and benefits of adaptation strategies

Full cost-benefit assessments may not be feasible in all cases; data may be scarce in particular with regard to the valuation of benefits; however, cost considerations certainly need to play a role in the appraisal of adaptation strategies/technologies and the identification of good practice. The main question to ask in this context is how the benefits the strategies/technologies will bring relate to the costs for implementing it. Adger et al. [15] point out that as far as possible, also distributional effects should be considered, for instance the balance between public and private costs as well as non-market values.

iv) Framework conditions for decision-making on adaptation technologies

When making decisions about adaptation strategies/technologies, additional factors relating to the wider framework conditions for implementation may also play a crucial role. One of them is the equity and legitimacy criterion brought forward by Adger et al. [15]. Not only the strategy/technology itself is important, but also the governance structures and decision-making processes underlying its implementation. Whether decision-making and adaptation strategies/technologies are perceived as fair and legitimate may also be influenced by potential distributional impacts that may result from the climate change impacts themselves or from the adaptation strategies/technologies. Stakeholder involvement is an essential element of adaptive management. For water managers and decision-makers, the feasibility of the implementation of an adaptation strategies/technologies may also play a key role. The complexity of the issues in terms of technical, social and institutional complexity is used as an indicator for the implementation barriers. While the technical complexity may generally not found to be very large, social complexity for instance in terms of the number of stakeholders and diversity of interests involved, and institutional complexity as determined by conflicts between regulations and the degree of necessary changes in current administrative arrangements (e.g. degree of co-operation) required may play an important role. Whether a strategy/technology can be considered as good practice, and whether a strategy/technology should be implemented for adaptation, also depends on the alternatives that are available.

When faced with a decision-making problem, and in particular if the assessment of a certain strategy/technology has revealed major potential shortcomings, water managers will most likely look for alternatives to the envisaged adaptation strategies/technologies that might be less costly or would have fewer negative side-effects. Finally, in a situation where limited financial resources have to be allocated to several adaptation projects, it may be helpful to assess the relative priority and urgency of the adaptation needs: how severe are the climate impacts the adaptation strategies/technologies would address relative to other impacts? When are the climate change impacts expected to occur, and at what timescales does action need to be taken? The evaluation criteria shown under (i), (ii), (iii) and (iv) is based on a number of considerations. Selecting the most appropriate intervention (or portfolio of interventions) for a specific climate change challenge/ impact (water scarcity and droughts; flooding; unknown climate risks and disaster preparedness) is a daunting task amidst the complexity of water interactions across a number of sectors, as well as the wide spectrum of users and stakeholders that rely on water and water ecosystem services. Reconciling these diverse needs while ensuring the adaptation strategies/technologies addresses the actual climate change impact on water requires robust approaches to evaluating and prioritizing the adaptation strategies/technologies. This study hopes to carry out the process using the evaluation criteria elaborated under (i), (ii), (iii) and (iv). This will involve evaluating all the identified strategies and technologies for adapting water supply management to water scarcity and droughts, flooding, unknown climate risks and disaster preparedness in Nzoia River Basin as shown in Tables 13. Then, the best performing strategy/technology, or set of strategies/technologies, in all the chosen criteria (or at an aggregate level) is selected for implementation. Robust and well thought through criteria, and the weight given to each criterion/sub-criterion according to its importance in the set is key for prioritizing strategies/technologies for adapting water supply management to water scarcity and droughts, flooding, unknown climate risks and disaster preparedness in Nzoia River Basin.

Table 14: Framework for adapting Water supply management to Climate change in Nzoia River Basin

Adaptation strategy technologies	Criterion cartegory…..Indicators / Sub-criteria or Specific criterion…….Questions to be asked											Total weighted score
	Effectiveness of adaptation			Side-effects			Efficiency/ costs and benefits	Framework conditions for decision making				
	Adaptation function	Robustness to uncertainty	Flexibility	No regret	Win-win (or win-lose)?	Spill-over effects	Low-regret	Equity and legitimacy	Feasibility of implementation	Alternatives	Priority and urgency	
	Does the measure provide adaptation in terms of reducing impacts, reducing exposure, enhancing resilience or enhancing opportunities?	Is the measure effective under different climate scenarios and different socioeconomic scenarios?	Can adjustments be made later if conditions change again or if changes are different from those expected today?	Does the measure contribute to more sustainable water management and bring benefits in terms of also alleviating already existing problems?	Does the measure entail side-benefits for other social, environmental or economic objectives? E.g. does it • contribute to closing the gap between water availability and demand? • Does it affect (e.g. river flow)? • create synergies with mitigation Does it lead to decreased GHG emissions)?	Does the measure affect other sectors or agents in terms of their adaptive capacity? Does the measure cause or exacerbate other environmental pressures?	Are the benefits the measure will bring high relative to the costs? (If possible, consider also distributional effects (e.g. balance between public and private costs), as well as non-market values and adverse impacts on other policy goals)	Who wins and who loses from adaptation? Who decides about adaptation? Are decision-making procedures accepted by those affected and do they involve stakeholders? Are there any distributional impacts of the climate change impacts or of the adaptation measures?	What barriers are there to implementation? • Technical • Social (number of stakeholders, diversity of values and interests, level of resistance) • Institutional (conflicts between regulations, degree of cooperation, necessary changes to current administrative arrangement	Are there alternatives to the envisaged adaptation measure that would e.g. be less costly or would have fewer negative side-effects?	How severe are the climate impacts the adaptation measure would address relative to other impacts expected in the area/river basin/country? When are the climate change impacts expected to occur? At what timescales does action need to be	

																	s)				taken?		
Water efficiency and demand management	5	12	5	10	4	7	3	10	4	10	4	8	5	10	4	10	4	8	5	7	4	8	4.29
	0.60		0.50		0.28		0.30		0.40		0.32		0.50		0.40		0.32		0.35		0.32		
Water allocation	3	12	4	10	4	7	4	10	4	10	4	8	4	10	5	10	5	8	4	7	3	8	4.02
	0.36		0.40		0.28		0.40		0.40		0.32		0.40		0.50		0.40		0.28		0.28		
Water storage	5	12	5	10	4	7	4	10	5	10	5	8	5	10	5	10	5	8	4	7	5	8	4.76
	0,60		0.50		0.28		0.40		0.50		0.40		0.50		0.50		0.40		0.28		0.40		
Alternative water sources	4	12	5	10	4	7	3	10	4	10	4	8	4	10	4	10	5	8	4	7	3	8	4.04
	0.48		0.50		0.28		0.30		0.40		0.32		0.40		0.40		0.40		0.28		0.28		
Water augmentation	4	12	4	10	4	7	3	10	4	10	5	8	4	10	5	10	4	8	4	7	5	8	4.16
	0.48		0.40		0.28		0.30		0.40		0.40		0.40		0.50		0.32		0.28		0.40		
Urban storm water management	3	12	4	10	4	7	3	10	5	10	4	8	4	10	5	10	5	8	3	7	5	8	3.99
	0.36		0.40		0.28		0.30		0.50		0.32		0.40		0.50		0.32		0.21		0.40		
Riverine flood protection	5	12	4	10	3	7	3	10	4	10	5	8	4	10	3	10	3	8	4	7	4	8	3.85
	0.60		0.40		0.21		0.30		0.40		0.40		0.40		0.30		0.24		0.28		0.32		
Hazard and risk assessment	4	12	3	10	3	7	3	10	4	10	4	8	4	10	5	10	5	8	3	7	4	8	3.84
	0.48		0.30		0.21		0.30		0.40		0.32		0.40		0.50		0.40		0.21		0.32		
Vulnerability assessment	4	12	5	10	3	7	3	10	5	10	3	8	3	10	3	10	4	8	4	7	5	8	3.83
	0.48		0.50		0.21		0.30		0.50		0.24		0.30		0.30		0.32		0.28		0.40		
Early warning	4	12	4	10	3	7	3	10	4	10	4	8	5	10	5	10	3	8	3	7	2	8	3.72
	0.48		0.40		0.21		0.30		0.40		0.32		0.50		0.50		0.24		0.21		0.16		
Disaster response	3	12	4	10	4	7	5	10	5	10	3	8	2	10	4	10	5	8	3	7	4	8	3.81
	0.36		0.40		0.28		0.50		0.50		0.24		0.20		0.40		0.40		0.21		0.32		

3.2.1 Ranking of the adaptation strategies

The study sought to score the identified 11 NO. adaptation strategies of (water efficiency and demand management; water allocation; water storage; alternative water sources; water augmentation; urban storm water management; riverine flood protection; hazard and risk assessment; vulnerability assessment; early warning and disaster response) against the evaluation criteria of effectiveness of adaptation (adaptation function, robustness to uncertainty and flexibility; side-effects [no regret, win-win (or win-lose)? and spill-over effects]; efficiency/ costs and benefits (mainly low-regret); framework conditions for decision making (equity and legitimacy, feasibility of implementation, alternatives and priority and urgency) as shown in Table.14. A group of carefully selected stakeholders consisting of decision makers, practitioners, managers, technology adopters, etc. deliberated and agreed on a simplified scoring tool where strategy options were scored on a scale anchored at 1 (lowest score) and 5 (highest score) based on the expected merits of the technology. The scoring scale had: 1- Very Low, 2-Low, 3-Medium, 4-High, 5-Very High. During scoring, the outcome and performance of each strategy/technology was evaluated against each criteria. The scoring team had to build consensus around a particular score for each strategy/technology on the respective criterion. The scoring scale run from 1 to 5, using 1 as the least preferred strategy/technology and 5 as the most preferred strategy/technology and each strategy/technology was evaluated against all criterion/ sub-criteria or specific criterion. The group of experts discussed before reaching a consensus on the score for each strategy/technology against each criterion. The results of the strategy/technology scores are shown in Table.14.

3.2.2 Assigning weights to each criteria

The study sought to assign weights to each evaluation criterion adopted for assessing the merits of strategies/technologies for adapting water supply management to climate change in Nzoia River Basin (effectiveness of adaptation (adaptation function, robustness to uncertainty and flexibility; side-effects [no regret, win-win (or win-lose)? and spill-over effects]; efficiency/ costs and benefits (mainly low-regret); framework conditions for decision making (equity and legitimacy, feasibility of implementation, alternatives and priority and urgency); and the results are shown in Table.15. When all technology options have been scored against all criteria, the scores still can't be compared because preference of one criterion does not necessarily equal the preference on another criterion.

Therefore, each criterion needs to be assigned a weight to reflect the weight of importance that stakeholders assign to each of the specific criterion. When the criteria have been weighted, the scores against all criteria can be compared. Weighting may be done as follows: First, arrange the final list of criteria in declining order of relative importance. Then assign a weight between 1 and 100 to each criterion, making sure that the sum of all weights totals 100. In the decision matrix where all technology options have been scored, it is expanded to include the weighted scores. In the space where technology option has been scored, the weight for each criterion is added, and the weighted score is calculated for each scoring point.

Table.15: Assigning weights to evaluation criteria adopted for assessing the merits of strategies for adapting Water supply management to Climate change in Nzoia River Basin

Evaluation criterion cartegory	Sub-criteria/specific criterion	Weight (%)
Effectiveness of adaptation	Adaptation function	12
	Robustness to uncertainty	10
	Flexibility	7
Side-effects	No regret	10
	Win-win (or win-lose)?	10
	Spill-over effects	8
Efficiency/ costs and benefits	Low-regret	10
Framework conditions for decision making	Equity and legitimacy	10
	Feasibility of implementation	8
	Alternatives	7
	Priority and urgency	8
Total		**100**

For example if Technology 1 (Water efficiency and demand management) has a score of 5 and the weight for Criterion A (adaptation function) is 12, then the weighted score of Technology 1 for Criterion A is 5*12% = 0.6. It is possible to assign zero weight to the criteria and henceforth treat all criteria equally. See Table.14.

2.1.1 Combining weights and scores

Under this step, all the weights assigned to criteria and technology scores are combined to derive an overall value called the weighted score. All weighted scores under a given technology are added up to get a total weighted score as shown in Table.14.

Table.16: Total weighted scores and ranking of the strategies for adapting Water supply management to Climate change in Nzoia River Basin

Strategy/technology	Total weighted scores	Ranking
Water storage	4.76	1
Water efficiency and demand management	4.29	2
Water augmentation	4.16	3
Alternative water sources	4.04	4
Water allocation	4.02	5
Urban storm water management	3.99	6
Riverine flood protection	3.85	7
Hazard and risk assessment	3.84	8
Vulnerability assessment	3.83	9
Disaster response	3.81	10
Early warning	3.72	11

The total weighted score of each technology option are calculated for each technology by multiplying its relative score for each criterion by the corresponding weight given to that criterion. This will result into a list of ranked technologies prioritized according to their scoring against the criteria and weights given to each criterion as shown in Figure.2. Table.16 shows summarized information on total weighted scores and ranking of the strategies/technologies. The technology scoring the highest total relative weighted score can be ranked as the most preferred technology, whereas the one with the lowest relative score are ranked as the least preferred option. The ranked list of technologies combines all criteria on the same relative scale, and presents the overall preference for technologies. The prioritized list of technologies and the final refinement shown in Table. 16 was carefully examined by the Researcher and a selected team of water-climate change experts to see if the ranks were logical. It was also ensured that the scores given to different criteria were consistent and reflective of the technological merits. The study concluded the ranking order priority of strategies/technologies for adapting water supply management to climate change in Nzoia River Basin, Kenya as;

(i) Water storage
(ii) Water efficiency and demand management
(iii) Water augmentation
(iv) Alternative water sources
(v) Water allocation
(vi) Urban storm water management
(vii) Riverine flood protection
(viii) Hazard and risk assessment
(ix) Vulnerability assessment
(x) Disaster response
(xi) Early warning.

The Total weighted scores under ranking are very close to each other, implying that all the strategies/technologies listed for adapting water supply management to climate change are good.

4.0 CONCLUSION

Climate change has an impact on the quality, quantity, and availability of water supplies, according to academia, national, and county government officials in the Nzoia River Basin. However, climate change is merely one of several factors affecting the basin's water supplies. It cannot always be viewed as a stand-alone element, but rather as an exacerbating factor for other factors such as population increase, rising per capita demand, changes in land use, and regulatory changes in water utilities. The main climate change challenges/impacts in the basin have been identified as, water scarcity and droughts, flooding, water quality effects, unknown climate change risks and disaster preparedness. Water supply availability and quality have been impacted by changes in precipitation. Reduced precipitation levels, particularly in the middle and lower catchments, have reduced the availability of both surface and groundwater resources in some portions of the basin. Increased rainfall intensity and flooding, as shown at a number of rainfall stations throughout the basin, can overwhelm existing drainage systems. Larger sediment loads may result in faster sedimentation of storage reservoirs, limiting storage capacity. High-intensity precipitation may exacerbate erosion. Increases in precipitation may put strain on urban drainage systems, whereas sewerage systems may become more difficult to operate and maintain if precipitation levels and discharge reduce. Increases in long-term rainfall in some regions of the basin may raise groundwater levels, reducing the efficacy of natural purification processes and raising the danger of infectious disease and harmful chemical exposure.

Water supply availability and quality will be impacted by changes in temperature. Warmer temperatures may increase biochemical treatment processes in some cases, notably in cold places or seasons; yet, if critical thresholds are exceeded in other cases (particularly in warm areas), the effectiveness of these processes may be diminished. Increased temperatures may reduce surface water availability by reducing runoff and increasing evaporation from lakes and reservoirs. Increased water temperatures reduce dissolved oxygen capacity, which could lead to hypoxia, harmful algal growth, and the spread of waterborne infections. Due to decreased soil moisture and increased evapotranspiration demand, higher temperatures may increase agricultural water demand. Floods and periods of extreme heat and cold can compromise the structural integrity of basic water infrastructure. Increased flood intensity may lead to contamination of water sources, as well as a rise in the occurrence of waterborne and water-related diseases. Droughts will become more frequent and intense, resulting in lower surface discharge and declining groundwater levels, which can lead to increased source water contamination and well dryness, expanding the distances that must be traveled to gather water.

Based on the identified main climate change challenges/impacts of water scarcity and droughts, flooding, water quality effects, unknown climate change risks and disaster preparedness; this study has identified and ranked in order of priority strategies and technologies for adapting water supply management to climate change in Nzoia River Basin as; Water storage, Water efficiency and demand management, Water augmentation, Alternative water sources, Water allocation, Urban storm water management, Riverine flood protection, Hazard and risk assessment, Vulnerability assessment, Disaster response, and Early warning. Additional water storage infrastructure, such as reservoirs or storage tanks, can be built to offer buffers against rising seasonal and annual fluctuation in precipitation and runoff. Changing infrastructure designs and bringing flexibility into water system operations can help to improve resilience to changing climatic variables including changes in precipitation seasonality and flood return periods. Diversifying water supply sources, such as the combined use of surface and groundwater, reuse and recycling, and household-level water sources like roof water harvesting, can reduce the impact of weather-related disruptions on the water supply system. Flood protection infrastructure can help safeguard water supply sources and treatment plants from contamination. Water storage can help with downstream flood management in some instances.

Increasing the coverage of community water supply infrastructure can improve resiliency in the face of changing climatic patterns. Green roofs, street trees, wetlands, and porous paving can all help to reduce storm water runoff and demand on wastewater treatment plants. Upstream of water consumers, the preservation of riparian wetlands can improve water quality and quantity while also providing flood protection during times of high-intensity or long-duration precipitation. Separating storm water and sanitary sewers reduces the risk of overburdening collection systems and water treatment facilities during heavy rains. In the face of climate change, integrated water resource management within river basins can help to enhance the allocation and management of finite water resources. Water demand can be reduced by promoting efficient water use through programs, incentives, and technologies for water conservation and recycling. Water service delays can be mitigated by having a well-prepared disaster response strategy, especially for vital services like water and sanitation. Water authorities and stakeholders will be better able to respond to the effects of climate change if they have enough data, knowledge, and expertise. This study provides adaptation strategies and technologies identified from multiple sources of information which include the national context (development plans), adaptation technologies proposed in previous documents; technologies currently in use and supported by national water policy; initiatives in the pipeline under the larger water sector; appropriateness of technologies in the local context and the social acceptability, etc. The results of this study provide valuable information that can be used by national and county governments in adapting water supplies to climate change.

COMPETING INTERESTS DISCLAIMER:

Authors have declared that no competing interests exist. The products used for this research are commonly and predominantly use products in our area of research and country. There is absolutely no conflict of interest between the authors and producers of the products because we do not intend to use these products as an avenue for any litigation but for the advancement of knowledge. Also, the research was not funded by the producing company rather it was funded by personal efforts of the authors.

5.0 REFERENCES

[1] Kundzewicz, Z.W., L.J. Mata, N.W. Arnell, P. Döll, P. Kabat, B. Jiménez, K.A. Miller, T. Oki, Z. Sen and I.A. Shiklomanov. Freshwater resources and their management. Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden and C.E. Hanson, Eds., Cambridge University Press, Cambridge, UK, 2007; 173-210.

[2] Pielke, R.A. Jr, Prins, G., Rayner S., and Sarewitz, D. Lifting the taboo on adaptation. Nature, 2007; 445:597–98

[3] UNFCCC. The Delhi Ministerial Declaration on Climate Change and Sustainable Development, 2002.

[4] Odwori, E.O. Temperature variability and trends in Nzoia River Basin, Kenya. Asian Journal of Geographical Research, 2021; 4(4): 17-37.

[5] Odwori, E.O and Wakhungu, J.W. Analysis of Rainfall Variability and Trends Over Nzoia River Basin, Kenya. Journal of Engineering Research and Reports, 2021; 21(4): 26-52, 2021.

[6] UNFCCC. United Nations Framework Convention on Climate Change Climate Change Technologies for Adaptation in the Water Sector. TEC Brief .5, United Nations Framework Convention on Climate Change, 2014.

[7] IPCC. Climate change 2014: Impacts, adaptation, and vulnerability. Part A: Global and sectoral aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovermental Panel on Climate Change (Field CB, Barros VR, Dokken DJ, Mach KJ, Mastrandrea MD, Bilir TE, Chatterjee M, Ebi YL, Estrada YO, Genova RC, Girma B, Kissel ES, Levy AN, MacCracken S, Mastrandrea PR, White LL (eds)). Cambridge University Press, Cambridge, UK and New York, USA, 2014; pp 1–32.

[8] IPCC. Summary for Policymakers. In: Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change (ed. by S. Solomon, D. Qin, M. Manning, Z. Chen, M. Marquis, K. B. Averyt, M. Tignor & H. L. Miller), 1–18. Cambridge University Press, UK, 2007.

[9] GIZ. A Framework for Climate Change Vulnerability Assessments. New Delhi : Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH, India, 2014.

[10] UNISDR. Making Development Sustainable: The Future of Disaster Risk Management. Global Assessment Report on Disaster Risk Reduction. Geneva, Switzerland : United Nations Office for Disaster Risk Reduction, 2015.

[11] UN, CTCN and UNEP. Climate change adaptation technologies for water: A practitioner’s guide to adaptation technologies for increased water sector resilience. UN Environment. DHI Centre on Water and Environment, Climate Technology Centre and Network (CTCN) and the UNEP DTU Partnership, 2016.

[12] EPA. Combined Sewer Overflows (CSOs), 2016; 22 October.

[13] UNFCCC. United Nations Framework Convention on Climate, Change Climate Development and transfer of technologies for adaptation to climate change, United Nations Framework Convention on Climate Change, 2010.

[14] IPCC. IPCC, Working Group, Climate Change .The Scientific Basis, *Contribution of* Working Group I to the Third Assessment Report of the IPCC, Cambridge University Press, 2001.

[15] Adger, W. N. Vulnerability. Global Environmental Change, 2005*;* 16: 268-281.

[16] ESPACE. Planning in a Changing Climate; Final project strategy. ESPACE Partnership, 2007.