# Sustainable water resources management in Kenya: The role of modelling approaches

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## ABSTRACT

Kenya faces increasing challenges in sustainable water resources management due to climate change, water scarcity, population growth, and the uneven distribution of water resources. These challenges have necessitated the development of efficient strategies to support water demand management, allocation, and planning. This paper reviews sustainable water resources management in Kenya, with a focus on water resources modelling. The objectives of the review paper are to: (i) examine the modelling techniques used in water resources management in Kenya; (ii) assess the benefits of water resources modelling; (iii) examine the challenges associated with applying modelling techniques in Kenya; and (iv) explore future prospects for enhancing modelling applications in Kenya's water sector, including the Internet of Things (IoT), Geographic Information Systems (GIS), and remote sensing technologies, which facilitate real-time monitoring and decision-making. The paper adopted a structured literature review design focusing on sustainable water resources modelling and management, drawing on literature from Google Scholar, Web of Science, and ScienceDirect. The literature was critically reviewed and thematically synthesised based on modelling applications, benefits, limitations, research gaps, and emerging opportunities. The findings show that incorporating modelling techniques enhances the understanding of complex water systems, thereby improving planning for socioeconomic purposes. Nevertheless, limited data availability, inadequate technical capacity, and insufficient collaboration among institutions remain significant challenges. The paper concludes that water resources modelling is vital for supporting sustainable water resources management by providing information on hydrological processes, hazard forecasting, water quality, water demand, resource allocation, and planning. Therefore, the paper recommends strengthening water resources monitoring networks, enhancing stakeholder involvement, and promoting collaboration among researchers, government institutions, and academia to improve sustainable water resources management in Kenya.

**Keywords:** Climate Change, Decision Support Systems, Hydrological Modelling, Water Allocation, Water Security

## I. INTRODUCTION

Water is an essential resource for human socio-economic growth as well as for maintaining all life. Nevertheless, an increase in population, industrialization, increased demand for water, climate change, urbanization, and agriculture have intensified pressure on water resources worldwide (du Plessis, 2023). Based on Leader and Wijnen (2018), global water demand is likely to exceed supply by more than 40% by 2030 and by more than 50% in the developing countries, especially in Sub-Saharan Africa. Additionally, estimations indicate that by 2050, 90% of the world's 3 billion inhabitants would come from developing nations and regions with poor access to clean water and sanitary facilities (Reader, 2022).Sustainability guarantees that there is enough clean water to satisfy present demands without jeopardizing the availability of the same resource for future generations(Silva et al., 2025).To achieve Sustainable Development Goal 6 (SDG 6), which aims to guarantee the availability and sustainable management of water and sanitation for everyone, these trends emphasize the critical need for sustainable water resources management(Evaristo et al., 2023).

Kenya is one of the world's water-scarce nations, with an annual per-capita availability of less than 1000 m3 (Mulwa et al., 2021). Over 18 million people today struggle to obtain clean and safe water (Martínez-Santos, 2017).In order to access water that is extremely contaminated and potentially dangerous for human consumption, residents, particularly those living in rural areas, must walk great distances up to eight miles(Mulwa et al., 2021). Kenya, like all other countries, understands how important water is to achieving its development objectives, as the availability of clean water is essential to its economic success and poverty alleviation (Mutschinski & Coles, 2021). Kenya has prioritized sustainable water resources management in its national development program through Kenya Vision 2030 and other national water policies (Njora & Yılmaz, 2021). Additionally, it has also adopted the concepts of Integrated Water



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Resources Management (IWRM), which support the coordinated development and management of water, land, and related resources (Dirwai et al., 2021).

However, there are still many issues facing the water sector, such as population pressure, climate unpredictability and change, frequent droughts and floods, degradation of catchment regions, contamination of water resources, invasion of water catchment areas, and invasive species (Kameri et al., 2021; Kinyili, 2023). Hence, incorporating modelling techniques for sustainable water resource management is useful because these increasingly complex water issues necessitate science-based planning and decision-making (Razavi et al., 2025). In light of this, this review aims to examine how modelling techniques might help Kenya manage its water resources sustainably. The review specifically explores the main modeling techniques used in water resource management, reviews how they are used in Kenya, and highlights the advantages, difficulties, and new trends related to their use. In order to improve evidence-based planning and management of water resources, the evaluation also identifies current knowledge gaps and suggests future research avenues.

### 1.1 Statement of the Problem

Kenya's water resources are under growing pressure from population increase, climatic variability and change, uneven geographical and temporal distribution of water, watershed degradation, pollution, and competing demands from residential, agricultural, industrial, and environmental use (Mulwa et al., 2021; Ngare et al., 2024).These demands make planning , allocation and managing of existing water resources challenging. While integrated water resources management (IWRM) offers a framework for tackling these challenges, reliable data on water availability, demand, quality, hydrological processes, and interactions are necessary for successful implementation(Gallegos et al., 2026).

Hence, water resource modelling provides crucial tool for comprehending ,assessing and decision making water availability, demand quality and allocation. Nevertheless , the application of modelling in Kenya is limited by data availability, quality and limited monitoring networks ,limited technical capacity coupled with coordination challenges among stakeholders and institutions(Kiptum et al., 2025).This limitations constrain the effectiveness of modelling in supporting water resource management and decision-making.

The integration of hydrological, hydraulic, groundwater, water-allocation, and developing digital modelling tools to promote sustainable water resources management in the water sector has not been adequately synthesized in Kenya (Woldeyohanes, 2025).The existing literature mainly focuses on individual modelling techniques and their particular uses, which makes it challenging to understand how the various techniques work together to support water resource planning, allocation, monitoring, and sustainable management.

There is also limited evidence of comprehensive data on benefits, application and emerging trends of water resources in Kenya due to challenges such as data availability, quality and limited monitoring networks ,limited technical capacity (Olago, 2019) .Furthermore, the growing integration of GIS, IoT, smart sensors, remote sensing creates new trends that need to be further synthesized in order to contribute to modelling-based water resources management in Kenya (Mehmood et al., 2020).

Therefore, there is need for a comprehensive review of evidences of water resource modelling approaches in Kenya, their benefits, challenges, applications and examination of emerging trends that enhance the management of sustainable resources management. This review examines existing literature and addresses the conceptual and empirical gaps by highlighting areas that require further research and integration of emerging trends in water resources modelling.

### 1.2 Research Objectives

i. examine the modelling techniques used in Kenyan water resource management
ii. Benefits of Water Resources Modelling
iii. Challenges in Applying Modelling in Kenya and
iv. future prospects for enhancing modelling applications in Kenya's water industry.

## II. THEORETICAL REVIEW

### 2.0 Modelling Approaches in Water Resources Management

### 2.1 Hydrological Models

Hydrological models are used for a various of purposes such as short- and long-term water management, flood forecasting and flow forecasting (Vogeti et al., 2023). These models provide a simple and straightforward depictions of the physical processes occurring within a watershed (Prasad et al., 2020).

#### 2.1.1 SWAT

The Soil and Water Assessment Tool (SWAT) is a comprehensive model that integrates hydrology, ecology, agriculture, and water quality (Kibii et al., 2021). SWAT development began in the early 1990s with the merger of



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SWRRB (Simulator for Water Resources in Rural Basins) and ROTO (Routing Outputs to Outlet), to facilitate the model parameterize for larger basins with a variety of land uses and soil types (Krysanova & White, 2015). Evidence from Literature review show that SWAT was developed to evaluate water resources and forecast how changes in land use and cover, land management techniques, soil erosion, sedimentation, and non-point source pollution affecting watersheds or big river basins (Akoko et al., 2021). Benedict et al. (2018),emphasized how crucial sufficient data is for accurate stream-flow and sediment calculations while Le and Pricope (2017), linked restrictions in the spatial correlation of datasets to poor stream-flow performance.Notwithstanding the difficulties and restrictions, the SWAT model has several benefits. The SWAT model proved superior at simulating medium, dry, and low flows in the Ribb watershed, according to a study comparing hydrological models for the evaluation of water resources in a data-poor area in the Upper Blue Nile River Basin (Tegegne et al., 2017).The precision of the SWAT model can also be effective for assessing the hydrological effects of soil and water conservation and comprehending how sediment movement affects a dam's ability to store water in a semi-arid area (Nyeko, 2015; Zettam et al., 2017). The SWAT model was shown to have good potential for applications in hydrologic/water quality, flood disaster risk management, assessing the costs and benefits of implementing best management practices (BMPs) for sediment control and drought planning and mitigation in areas with limited data (Briak et al., 2016; Lweendo et al., 2017). In Kenya SWAT has been applied to support river basin management in Mara Basin.Showed that further forest conversion to grassland and agriculture could raise peak flows while lowering dry-season flows, which would have an impact on watershed management and water scarcity (Mango et al., 2011). This illustrates the effectiveness of SWAT in assisting catchment-level management decisions and connecting environmental changes to water availability. Overall, the literature review indicates that SWAT is useful for comprehending how land use, climate, and hydrological processes interact. However, in Kenya, its efficacy will depend on bolstering hydrological surveillance, enhancing data quality, and guaranteeing proper calibration and validation.

### 2.1.2 HEC-HMS Model

Hydrologic Engineering Center-Hydrologic Modelling System, a model created by the US Army Corps of Engineers that might be used for numerous hydrological simulations (Odey & Cho, 2025). The model support both lumped and distributed parameter-based modelling and incorporates methods for infiltration base-flow transformation and routing (Sahu et al., 2023). Based on the literature review HEC-HMS is a useful tool for analysis of water quality, sediment transport, erosion and stream -flow forecasting (Belvederesi et al., 2022) The advantage of HEC-HMS is that it is acceptable by.Researchers, consultants, government organizations,and students can all utilize HEC-HMS for free (Ebbersten, 2023).This is because it provides a variety of techniques for base-flow simulation, loss estimates, transform modelling and routing, enabling users to choose strategies suitable for their watershed (Zheng et al., 2025) However When using the HEC-HMS the quality and accessibility of rainfall, stream-flow, land use, soil, and topography data all have a significant impact on model accuracy therefore data gaps may produce inaccurate results(Sahu et al., 2023).As a result, the literature suggests that HEC-HMS is suitable for rainfall-runoff and watershed applications; however, model selection and interpretation should take the catchment's complexity and data quality into account.

## 2.2 Hydraulic Models

Hydraulic modelling,the computer simulation of water flow across both closed and open systems, pipeline networks, river channels, and surface floodplain (Tanim et al., 2024). The model consist of: 1D model which mimics one-way flow along a particular path, such as a river or pipe (Mandair, 2020), 2D. chart multi-directional flow and extensive surface movement throughout floodplains (Mandal et al., 2026) and 3D models studies intricate local depth, turbulence, and structural interaction (Lai et al., 2022).

### 2.2.1 HEC-RAS

HEC-RAS, a readily available 1-D& 2-D hydraulic model with GIS integration, and risk maps of flood inundation are created for various rainfall scenarios (Rangari et al., 2019; Zwirglmaier et al., 2024). The components examined by the HEC-RAS system include:(1)1D steady flow water surface profile computations; (2) 1D and 2D unsteady flow simulation; (3) 1D and 2D computations of quasi-unsteady or fully unsteady flow movable boundary sediment transport; and (4) 1D water quality analysis (Al-Hussein et al., 2022; Zainal et al., 2024).The model also assesses the hydraulic performance of hydraulic structures such as culverts and spillway to help in risk assessment and emergency preparation (Garcia et al., 2020) Nevertheless,Siakara et al.,(2024), reveals that the reliability of HEC-RAS is determined by the accuracy of topographic data, channel geometry, boundary conditions, and other hydraulic inputs. Additionally ,the model is time consuming and labour intensive especially when simulating large river basin due to its preparations such as geometry ,boundary conditions calibration and validation (Crenganis et al., 2025). Therefore ,in Kenya HEC-RAS is a crucial tool for converting hydrological data into spatially explicit flood-risk information for Kenyan water resources management. Its use can help with the development of suitable flood-management strategies, the identification of flood-prone locations, and the evaluation of the possible effects of extreme flows. Still, accurate



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hydrological and spatial data as well as sufficient technological capability are necessary for successful implementation.Thus, the literature review shows that because HEC-RAS focuses more on the hydraulic response and geographical distribution of floods, it is especially significant in flood control.

### 2.2.2 MIKE 11

MIKE 11 is an explicit finite model for one-dimensional unstable flow computation and can be used for quasi-two-dimensional flow simulation on floodplains and looping networks (Chowdhury et al., 2020).

The model has been designed for in-depth river modelling, including particular handling of floodplains, culverts, gate openings, and weirs(Dehkordi & Kashkuli, 2015).MIKE 11 is suitable since it offers precise hydraulic modelling for comprehensive one-dimensional river and floodplain simulation(Andrei et al., 2017).

Based on Gao et al. (2025), Mike 11 is useful for assessing the effects of hydraulic interventions, the river system, and the temporal and spatial fluctuation of flow and water level. Additionally, it has capacity to offer intricate simulations of erratic river flow and fluctuations in water level (Vo et al., 2016) .Nevertheless the reliability of the simulations depends on the availability and quality of hydraulic data (Alaghmand et al., 2012). Therefore, by offering comprehensive data on variations in discharge and water levels along river systems, Mike 11 can help analyse river flow and flood risk in Kenya infrastructure design and the assessment of river management. Overall, Mike 11 offers a thorough one-dimensional simulation of river system behavior, which enhances a more comprehensive hydrological and hydraulic modelling approach (Alaghmand et al., 2012).

## 2.3 Groundwater Model

A groundwater model is a computer based method that approximates an underground water system (Kumar, 2019)They include MODFLOW and FEFLOW.

### 2.3.1 MODFLOW

MODFLOW is the most widely used computational model for simulating interactions between surface water and groundwater (Brunner et al., 2010). According to Alattar et al., (2020), MODFLOW is especially useful for comprehending how groundwater systems react to variations in recharge and obstruction. MODFLOW'S main advantage is its well-established and adaptable framework for simulating groundwater flow processes and evaluating different management scenarios (Pouliaris, 2026). The disadvantages of MODFLOW is it performs best with laminar groundwater flow and therefore it might not accurately replicate turbulent flow conditions, such those found in huge conduits or karst aquifer (Panagopoulos, 2012) .Additionally, it has large data requirement such as recharge rate, hydraulic conductivity and aquifer characteristic which in regions which data gaps the model bring model uncertainty (Akram et al., 2025). MODFLOW offers Kenya, a crucial method for evaluating groundwater resources, especially in regions where rising abstraction and viable recharge raise questions about long-term groundwater availability. The reviewed literature shows that MODFLOW is a useful tool for planning and evaluating groundwater resources; however, the quality of the conceptual understanding of the aquifer system and the data available to represent and calibrate it determine how reliable it is.

### 2.3.2 FEFLOW

FEFLOW, which stands for finite elements subsurface flow simulation systems, it solves the flow mass and heat transport equations in a porous and fractured medium (Koskinen et al., 1996).

FEFLOW provides a unique method for simulating fractured rock medium (Heinze et al., 2025).The most crucial inputs to software is the geometry and hydraulic characteristics of the bedrock structures, which are derived from geological research (D'Affonseca et al., 2020).

Given this, it can be used to address issues with groundwater flow, contaminant transport, and interactions between various subsurface environment components (Liu et al., 2026).

Based on Gdoura et al. (2026), FEFLOW offers a transportable decision-support tool for groundwater management methods resilient to past hydro-climatic variability.

In cases when hydro-geological data is scarce, this level of depiction also raises data and technical requirements, such as geological structure and hydraulic qualities, leading to uncertainties in model findings (Siebert et al., 2024) .In the Kenyan setting, FEFLOW offers a framework for examining intricate aquifer systems and groundwater flow behaviour. As a result, FEFLOW offers a versatile method suitable for modelling intricate groundwater systems.

## 2.4 Water Allocation Models

Water allocation models are techniques used to calculate the optimal distribution of available water among competing users (Chang et al., 2016).



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### 2.4.1 WEAP

It is a computer-based tool for integrated planning of water resources, which offers a thorough, adaptable, and easy-to-use framework for policy analysis (Kracmar, 2021).WEAP addresses what if scenarios that enables planners to investigate the possible effects of changes in water demand, population expansion, climate variability, and different management techniques (Nivesh et al., 2023). WEAP emphasizes the depiction of water supply, demand, allocation, and management choices in an integrated water system (Hamlat et al., 2024).

The advantages of WEAP include demonstrated efficacy in scenario planning across a range of development trajectories, climate scenarios, strengthening collaboration between water managers and other stakeholders (Abbas et al., 2022; Mitiku et al., 2023) . The disadvantages of WEAP are it does not capture complex subsurface flow interactions due to its simplified water balance technique when compared to fully distributed hydrological models (Abera et al., 2021). This restricts its capacity to accurately depict some physical processes in comparison to specialized groundwater or hydrological models (Robles et al., 2026). The implementation of WEAP in Kenya would assist in identifying possible water shortages, assessing strategies for allocation, management scenarios and providing information for decisions pertaining to competing user (Amoo et al., 2025).

### 2.4.2 River-Ware

River Ware is a sophisticated modelling tool for rivers and reservoirs that is used for long-term planning, operational scheduling, and water resource management (Srđević & Srđević, 2026). River-Ware can be used for tasks ranging from short-term scheduling to long-term planning in a variety of river and reservoir systems with various operating goals (Witt et al., 2017). River-Ware's adaptable, graphical policy representation enables shifting policy goals and makes it easier for stakeholders and decision makers to comprehend and communicate policies (Shahbazbegian & Dinar, 2026).

The literature study indicates that river-ware is especially important when managing several reservoirs with conflicting needs and operational limitations (Srđević & Srđević, 2026). River-Ware's main advantage is its capacity to depict the management and operation of water systems, which complements models that mainly concentrate on hydrological processes or overall water distribution (Yaykiran & Ekdal, 2025). River-Ware is important for Kenya because water resources must be distributed among conflicting uses including as energy, agriculture, the environment, and domestic consumption. In general, River-Ware focuses more on the management regulations and the operational behavior of river and reservoir systems.

## III. METHODOLOGY

The review paper employed a structural literature review research design conducted sustainable water resources management and modelling approaches in Kenya.The review focused on Kenya as the study area. Google Scholar, Scopus, Web of Science, and Science Direct were the databases that were searched for publications from 1996 to 2016.WEAP, GIS, integrated water resources management (IWRM), and sustainable management of water resources were the main search terms utilized. In order to provide a more comprehensive conceptual and empirical viewpoint, almost 200 publication both Kenyan and foreign were reviewed. Hydrological, hydraulic ,groundwater ,water allocation, integration of GIS, remote sensing, IOT and Smart sensors was the primary theme examined. Based on modelling applications, benefits, limitations, research gaps, and upcoming prospects, the literature was critically examined and thematically synthesized. The synthesis concentrated on modelling methods utilized in Kenya.The study mainly relied on published scientific data and hence no primary data collection was done. Therefore, there was no direct contact with human participants and there is acknowledgment of the sources cited in the manuscript in the reference section.

## IV. FINDINGS & DISCUSSION

### 4.1 Findings

#### 4.1.1 Benefits of Water Resources Modelling

A wide range of models have proven useful in the hydrological sector for improving comprehension of the system and for recognizing and characterizing the problems and trade-offs associated with basin-scale water planning (Johnston & Kummu, 2012). The advantages of water resource modelling have been the subject of numerous studies and reviews. Nkwonta et al. (2017), conducted a review on water resource yield model. The objective of the research was to efficiently balance the supply of water with anticipated needs, which could include infrastructure expansion and/or water demand control strategies. It was determined that the efficient use of reservoir planning is crucial for water allocation.Candido et al. (2022), researched on allocation models and decision support systems for integrated water resource management with an emphasis on combined water quantity-quality. The decision support systems (DSSs) and basin level models currently in use for public water allocation were examined by the author. The results demonstrated



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that the implementation of IWRM requires a procedure that involves all relevant stakeholders and is supported by an integrated hydrological and economic model that is accessible via DSS. Manetu et al. (2019), investigated on a the geographic modelling of present and projected piped residential water demand in Athi River Town. The study modelled residential water consumption using geographic information systems (GIS), geographically weighed regression (GWR), and ordinary least squares (OLS). The findings showed that home water demand increased by around 22% from an expected 721,899 $m^3$ in 2017 to 880,769 $m^3$ in 2022. Highlighting the findings can help managers and planners of water resources manage current resources effectively and provide baseline data for developing an affordable and dependable water supply for a town's citizens.

### 4.1.2 Challenges in Applying Modelling in Kenya

Despite the many benefits of applying of water resources modelling in Kenya they are still several challenges that strain the fully application and utilization of this models as discussed below. Akoko et al. (2021), studied the Mwea irrigation scheme in Kenya to assess the availability of irrigation water resources and the effects of climate change. The goal of the study was to examine the availability of irrigation water resources both now and in the future using SWAT & CROPWAT in order to improve future water. The author concluded that the study's technical findings were due to hydrological monitoring in dam release stream-flow and river sediment, as well as a lack of data to calibrate the CROPWAT model. In order to lessen the bias in the estimation of total available flow and irrigation water requirement, this data is helpful for both SWAT simulations and CROPWAT data input.

Sungu (2018), evaluated how water distribution affected the sustainable management of water resources in Kenya's Nyando River Basin. According to the assessment using the WEAP model, which revealed that environmental flow requirements (EFRs) are only met between 43% and 94% at the time. The current water allocation system lacks a water allocation plan (WAP), inadequately manages water demand (WDM), has inadequate infrastructure development, and does not involve the community in water resource management. Highlighting the need of IWRM in sustainable management of water resources

Dessu and Melesse (2013), examined the effects and uncertainties of climate change on the hydrology of Kenya's Mara Basin River using SWAT. For the years 2046-2065 and 2081-2100, the data demonstrated a statistically significant rise in the Mara River flow volume at Mara Mines. Despite receiving funding from USAID and the Global Water for Sustainability (GLOWS) program, the project's execution as a project-based intervention may restrict the availability of sustained resources for ongoing hydrological monitoring. This emphasizes the difficulty of obtaining long-term institutional funding for data creation and monitoring networks, which are crucial for hydrological model calibration, validation, and updating.

## 4.2. Emerging Trends

The integration of digital technology with traditional hydrological and water-resource models is becoming important in recent breakthroughs in water-resource management (Marshall et al., 2025) . The Internet of Things (IoT), smart sensors, remote sensing, and geographic information systems (GIS) platforms are some of these innovations. These technologies are moving water-resource management away from methods that rely on sporadic observations and toward more continuous, spatially dispersed, data-driven, and almost real-time monitoring and decision-making (Amanatidis et al., 2025). Their growing use is especially pertinent to Kenya, where frequent droughts and floods, temporal and spatial variability in water availability, and constraints in traditional monitoring networks necessitate more effective methods of data collection and water-resource assessment (Ogembo et al., 2026).

### 4.2.1 Internet of Things (IoT) & Smart Sensors

Internet of things" (IoT) is a uniquely recognizable, interoperable, and linked to radio-frequency identification (RFID) technology (Alaba, 2024). IoT enabled sensors and smart meters gather and log minute-by-minute data on water levels, quality, and usage for a variety of household, commercial, and agricultural applications (Silva et al., 2025). These continuously collect data on water distribution network monitoring and water usage optimization (Velayudhan et al., 2022).

Smart-sensors are self-learning systems having the capability to manage water more efficiently (Gupta et al., 2020) Sensors allow for automatic monitoring, real-time hydraulic data monitoring, and cloud platform warnings in the event of incidents like water leaks or overuse (Palermo et al., 2022). In Kenya, water resources are distinguished by regional and temporal variability, frequent droughts and floods, and constraints in traditional monitoring networks, making digital water management especially promising (Thomas et al., 2020). IoT and smart sensors enable monitoring with hydrological models, data for model validation and calibration could be more readily available, facilitating quicker decision-making (Robles et al., 2026). Despite such advantages, the cost of sensors and communication infrastructure, limited technical capacity, erratic power and internet connectivity, data management needs, and institutional difficulties with data sharing may limit the adoption of digital water technologies in Kenya.



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### 4.2.2 Remote Sensing & GIS Integration

Remote sensing has become a crucial part of water resource management because satellite observations offer spatially data across vast areas (Mashala et al., 2023) Particularly, in Kenya it is relevant in monitoring water supply, watershed conditions, drought, and flood dynamics across various (Ogembo et al., 2026). Al-Khalifa (2023), assessed the vulnerability of small-scale water resource high spatial resolution sensing. The water quality in 60 reservoirs was extrapolated from 2019-July 2022 to examine patterns of water quality over space and time. The results showed Sentinel 2 satellite produced better models of chlorophyll-a (Chl-a)($R^2$=0.66).Highlighting that sentinel support monitoring and planning with the water resources sector.

GIS systems have been considered as one environmental monitoring method because to its data presentation capabilities, ease of use, and accessibility (Le Hoang et al., 2023). Kipkemboi et al. (2023), examined development of a web GIS system for environmental monitoring and conservation of the Muringato catchment in Kenya. The aim of the study was to integrate the existing database with GIS systems for continuous monitoring of the water resource. The results showed that the GIS platform offered a platform with near-real-time data to engage diverse stakeholders for the collaborative conservation with 53% of user acceptance testing responses from 30 selected stakeholders confirming stakeholder willingness for collaborative environmental conservation. This emphasizes the role of GIS in water resource monitoring and management in Kenya.

A study conducted by Gesami and Nunoo (2024), evaluated the risks that climate change poses to these Kenya's blue economy ecosystems and investigate how AI solutions might improve resilience and adaptation. The aim of the research was to explores the use of artificial intelligence (AI) in monitoring and controlling maritime ecosystems. The results showed that adaptation initiatives can benefit greatly from the research's identification of the potential of AI to improve resilience and sustainability in marine ecosystems. However, investigation into particular AI applications suited to Kenya's particular water resource problems is limited. Thus, the emerging trend is shifting from using remote sensing and GIS independently and toward integrating them with hydrological models and ground data (Rabie et al., 2025) .In Kenya, this integration can enhance spatial representation, offer more data for model validation and calibration, and facilitate model output visualization (Ogembo et al., 2025).

## V. CONCLUSION & RECOMMENDATIONS

### 5.1 Conclusion

In Kenya water resource management is vital in supporting sustainable water resource management since it provides data on hydrological cycle, forecasting of hazards, water-quality, water demand, allocation & planning. This review has shown the various types of modelling for each purpose including hydrological, water-quality, water-allocation, ground-water and hydraulic model. Therefore, the models should be selected based water management strategy, data availability, regional and temporal scale, and research objective.

Nevertheless, the research identifies their efficacy in Kenya is limited due to cost of access, data scarcity, inadequate monitoring stations, limited technical capacity and inadequate integration of models in water resource planning. These challenges may undermine the models reliability and results.

Additionally, the review paper identifies emerging technologies such as digital water management, IOT, smart-sensors, remote sensing and GIS provide a platform to improve data availability ,accuracy and early warning system. The integration of these technologies could strengthen water resource monitoring as climate variability increases hence necessitating the need of water managers to address shifting water supply, extreme events, conflicting demands, and contamination to water quality. However, the reviews reveals a continuous gap between modelling technique advancements and their practical use in Kenyan water resource management. To achieve this future water resource management should support community based approaches, advanced modelling that incorporate various data sets and collaborations among researchers, communities and government institutions to enhance technical capacities.

Finally, the effectiveness of modelling in Kenya sustainable water resource management will not only depend on the advanced models but also on the quality of data, results ,scientific based evidence in water resource planning and decision making.

### 5.2 Recommendations

In light of the reviews finding, the following recommendations are suggested: The review paper recommends the strengthening of water resources network systems including hydrological and hydraulic, groundwater and water quality to enhance the availability and reliability to data currently constraint model validation and calibration.

It encourages further studies and collaboration among institutions on integration of models that like hydrological, hydraulic groundwater and water quality together rather than depending on individual model giving a more detailed depiction of how water-resource systems interact. Also, it recommend integration of emerging



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technologies such as IOT, Smart Sensors, GIS and Remote sensing to enhance data availability, spatial coverage, real-time monitoring, forecasting, and decision making. Finally ,it recommend the increased training and capacity building for researchers, government agencies, water resource managers, and other pertinent stakeholders in hydrological modelling, GIS, remote sensing, programming, and digital water technologies.

**Declaration of Interest**

The authors declare that they do not have any known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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