The status and challenges of a modern irrigation system in Kenya: A systematic review

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The status and challenges of a modern irrigation system in Kenya: A systematic review

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Abstract

The modernization efforts of the irrigation subsector in Kenya have been hampered by several challenges. This review describes the status and challenges facing irrigated agriculture in Kenya. The results indicated that as of 2018, the developed irrigation schemes covered an area of 222,240 ha, which is 16% of the irrigation potential of 1.34 million ha. Most large-scale irrigation schemes use the furrow system. Private and commercial farms and smallholder irrigation schemes use modern irrigation systems. The major challenges to irrigation development are technical, socio-economic, and institutional. The main technical challenges include poor water infrastructure, water scarcity, and poor water quality. The main socio-economic challenges include the high cost of modern irrigation systems, inadequate credit facilities, and market inaccessibility. The institutional challenges include the existence of a pluralistic legal framework, inadequate participation by farmers, including women farmers, and poorly organized irrigation water user associations. However, the future of irrigation development is bright through climate change adaptation strategies such as solar-powered irrigation systems and rainwater harvesting.

KEYWORDS

climate change resilience, drip irrigation, irrigation policy, smallholder irrigation scheme, water scarcity

Résumé

Les efforts de modernisation du sous-secteur de l'irrigation au Kenya ont été entravés par plusieurs défis. Cette revue décrit la situation et les défis auxquels est confrontée l'agriculture irriguée au Kenya. Les résultats ont indiqué qu'en 2018, les périmètres irrigués développés couvraient une superficie de 222.240 ha, soit 16% du potentiel d'irrigation de 1,34 million ha. La plupart des systèmes d'irrigation à grande échelle utilisent le système de sillons. Les exploitations agricoles privées et commerciales et les petits périmètres irrigués utilisent des systèmes d'irrigation modernes. Les défis majeurs du développement de l'irrigation sont d'ordre technique, socio-économique et

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institutionnel. Les principaux défis techniques comprennent la médiocrité des infrastructures hydrauliques, la rareté de l'eau et la mauvaise qualité de l'eau. Les principaux défis socio-économiques comprennent le coût élevé des systèmes d'irrigation modernes, l'insuffisance des facilités de crédit et l'inaccessibilité des marchés. Les défis institutionnels comprennent l'existence d'un cadre juridique pluraliste, une participation insuffisante des agriculteurs, y compris des agricultrices, et des associations d'usagers de l'eau d'irrigation mal organisées. Cependant, l'avenir du développement de l'irrigation est prometteur grâce à des stratégies d'adaptation au changement climatique telles que les systèmes d'irrigation à énergie solaire et la collecte des eaux de pluie.

MOTS CLÉS

résilience au changement climatique, irrigation goutte à goutte, politique d'irrigation, système d'irrigation à petite échelle, pénurie d'eau

1 | INTRODUCTION

Agriculture is the backbone of Kenya's economy, contributing one-third of the gross domestic product and providing 75% of industrial raw materials and 60% of export earnings (Government of Kenya (GOK), 2019a). Approximately four-fifths of the land in Kenya is arid and semi-arid. Interestingly, 80% of the population relies on the agricultural sector for their livelihoods (Oguge & Oremo, 2018). Agriculture in Kenya is mostly rainfed (GOK, 2019a), despite it being largely arid and semi-arid land (ASAL).

Rainfed agriculture is a risky enterprise because of poor spatial and temporal distribution of rainfall, which has been further aggravated by climate change. Indeed, crop performance in Kenya is linked to rainfall availability, with lower yields when there is less rainfall as witnessed during the 2009 drought (Food and Agriculture Organization of the United Nations (FAO), 2015). During the 2017 drought, maize and tea yields declined by 6% and 7%, respectively (GOK, 2018). Thus, irrigation is necessary to ensure the stability of yields and to prevent crop failure. Irrigation is important in improving the resilience of farmers to climate shocks (Mwangi & Crewett, 2019). Despite its importance in yield stability and building climate change resilience, irrigation in Kenya accounts for only 1.7% of the land area under agriculture (GOK, 2019a).

The Government of Kenya is increasing irrigation development by adopting modern irrigation technologies and strategies, especially on ASAL, as a way of addressing the country's food insecurity (National Irrigation Board (NIB), 2019). Modern irrigation technology is defined as on-farm irrigation systems that use sprinkler or trickle irrigation in addition to piped water distribution systems and the use of treadle- and power-driven pumps to draw water (Kay, 2001).

Irrigation development in Kenya has been plagued with challenges for several decades. A review by Ngigi (2002) highlighted a number of factors affecting irrigation development in Kenya, such as high investment costs, lack of access to credit facilities by farmers, lack of a clear irrigation policy, weak coordination between sectors, water inadequacy, and a lack of support systems. Monteiro et al. (2010) did a comparative review on the adoption of irrigation technologies in Kenya and South Africa and focused on low-cost irrigation technologies that had been developed and promoted in the first decade of the 2000s. Since then, there has been policy progress in the irrigation subsector—for example, the Constitution of Kenya 2010, which ushered in a devolved system of government, and various reforms in the agricultural and water sector as enshrined in Vision 2030, the amended Water Act of 2016, and the Irrigation Act 2019, among others. To the best of our knowledge, no recent analysis on the status and challenges facing the irrigation sector in Kenya. Therefore, given the climate change threats and renewed state-sponsored irrigation development, this review describes both.

The rest of the review is structured as follows: First, the methodology is described. Second, we describe the status of modern irrigation, including the governance framework and the technical, socio-economic, and legal and institutional challenges. Third, a discussion of the literature that has been reviewed will be presented. Finally, in our conclusion we will discuss current research gaps.

2 | METHODOLOGY

The information was sourced from online databases including Scopus, Web of Science, Google Scholar, and Directory of Open Access Journals (DOAJ) and databases of organizations such as the Food and Agriculture organization (FAO) and the World Bank for peer-reviewed articles, books, and grey literature. The search strategy was executed using the Boolean operators "AND" and "OR" using strings of words and phrases such as "traditional irrigation," "modern irrigation," "climate resilience," "Kenya," and "agricultural water management." The literature was assessed in two stages, first by title, then by abstract and keywords.

The inclusion and exclusion criteria were guided by the SPICE (Setting, Perspective, Intervention, Comparison, and Evaluation) framework (Booth, 2006). Thematic analysis (Braun & Clarke, 2006) was used to generate the challenges facing the adoption and development of modern irrigation in Kenya. The authors categorized the challenges into technical, socio-economic, and institutional and legal as guided by irrigation performance indicators outlined in Kamwamba-Mtethiwa et al. (2016). The challenges were ranked according to how frequently they occurred in the literature.

We categorized irrigation schemes in the same way as they were defined by the Irrigation Act of 2019 (GOK, 2019b). In this case, large-scale irrigation schemes are defined as those that cover more than 1,200 ha of land and which are developed and managed by the National Irrigation Authority (NIA) or private organizations. Medium-scale irrigation schemes comprise between 40 ha and 1,200 ha of land, managed either by the NIA, county governments, state agencies, or private entities. Finally, small-scale irrigation schemes cover less than 40 ha. Irrigation schemes can also be categorized in terms of ownership, such as community-based smallholder irrigation schemes, private irrigation schemes, and public irrigation schemes. The difference between smallholder irrigation schemes and small-scale irrigation schemes is that the latter are managed by the NIA or county governments or private entities, while the former are developed, owned, and managed by the community or by individual farmers. Public-owned irrigation schemes are owned and managed by the NIA and government institutions (FAO, 2015).

3 | RESULTS

3.1 | Literature sources

A total of 206 sources were gathered from online databases, of which 57 were included in the qualitative analysis (Figure 1). Nineteen sources discussed the status of irrigation in Kenya, while 38 covered technical, socio-economic, and institutional challenges facing the adoption of modern irrigation systems.

3.2 | Status of modern irrigation in Kenya

Irrigation development in Kenya is buttressed by smallholder farming. Of the total area under irrigation, as of 2010, smallholder irrigation schemes accounted for 53.4%, private irrigation schemes for 36.6%, and large-scale public irrigation schemes for 10% (Table 1).

The Kenyan government's efforts to alleviate food insecurity saw the area under irrigation increase by 57% to 222,240 ha in 2018 (Table 2). This represented 16% of the irrigation potential of 1.34 million ha which is based on surface and underground water resources including water harvesting and storage.

Modern irrigation is used on 30% of the total area under irrigation, with sprinkler irrigation systems accounting for 22% (31,200 ha) and localized (drip irrigation) contributing only 8% (11,400 ha) (FAO, 2015). This means that 70% of the irrigated area uses surface irrigation methods. Public irrigation schemes practice traditional irrigation methods such as the furrow method (Kosgei, 2018) and the flood/basin method for rice. This may change once the NIA completes the food security programmes on the Big Four Agenda, such as the ongoing installation of centre pivots and drip irrigation systems in the Galana–Kulalu irrigation scheme (https://irrigation.go.ke/projects/flagship-projects/galana). Private irrigation schemes utilize modern irrigation technologies and produce high-value horticultural (vegetables, flowers, and fruits) crops for local and export markets (GOK, 2019a). Large-scale and medium-scale private irrigation schemes use centre pivots and pressurized drip irrigation systems, while smallholder irrigation farmers use sprinkler and drip irrigation systems (FAO and International Finance Corporation [IFC], 2015).

3.3 | Governance in irrigation schemes: Legal and institutional frameworks

The Irrigation Act of 2019 (GOK, 2019b) provides the legal framework for the development, management, and regulation of the irrigation sector in Kenya through the establishment of the following key institutions (Figure 2):

1. *A ministry responsible for water affairs*: formulates policies, regulates the different sectors and coordinates

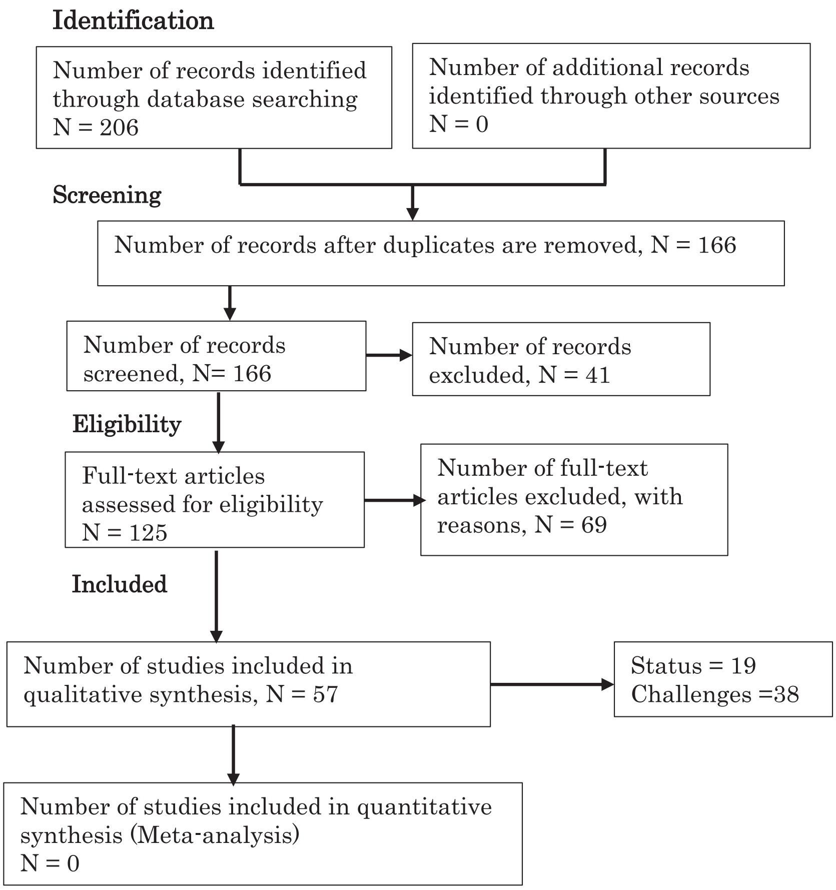

FIGURE 1 Systematic review flow chart based on PRISMA chart

TABLE 1 Irrigation schemes in Kenya in 2010

	Large scale		Small scale		Private		Total	
Catchment	**No.**	**Area (ha)**	**No.**	**Area (ha)**	**No.**	**Area (ha)**	**No.**	**Area (ha)**
Lake Victoria North	1	363	37	1,327	1	186	39	1,876
Lake Victoria South	2	1,800	45	10,225	5	1,193	52	13,218
Rift Valley	2	774	217	5,791	236	3,022	455	9,587
Athi	0	0	185	13,524	780	31,374	965	44,898
Tana	4	11,200	278	14,823	1,167	38,402	1,449	64,425
Ewaso Ng'iro North	0	0	309	6,233	54	1,663	363	7,896
Total		**14,137**	**1,071**	**51,923**	**2,243**	**75,840**	**3,323**	**141,900**

Source: GOK, 2013.

with them, and promotes the use of efficient irrigation systems;

2. *National Irrigation Authority (NIA)*: develops and rehabilitates the infrastructure for national irrigation schemes, provides irrigation support services (in consultation with county governments) for private, medium, and smallholder irrigation schemes, and facilitates the strengthening of water user associations;
3. *County Irrigation Development Unit (CIDU)*: formulates and implements the county irrigation strategy in line with national policies. It provides capacity building and support to irrigation farmer associations and irrigation water user associations. It is also responsible for setting up measures to mitigate and adapt to climate change;
4. *Scheme Management Committee*: responsible for the management of irrigation schemes;
5. *Irrigation Water Users' Association (IWUA) and Irrigation Farmers' Association (IFA)*: responsible for the operation, maintenance, and management of irrigation schemes. At a catchment level, the IWUA is a

member of the WUA established under the Water Act of 2016. The IFA and IWUA also serve as fora for conflict resolution regarding irrigation water use;

6. *Dispute Resolution Committee*: established by the IWUA and IFA to resolve disputes relating to irrigation and drainage development, management, water allocation, operation, and maintenance.

There are other institutions which were established by other legislation and are relevant to the irrigation sector (Figure 3). The Water Act of 2016 established the Water Resources Authority (WRA), whose mandate includes water abstraction rights, determining water use charges, and formulating strategies for water harvesting and storage, among other water-related functions (GOK, 2016b). The act also established the National Water Harvesting and Storage Authority (NWHSA) to develop water storage structures to enable irrigation and climate change adaptation strategies. Land rights are fundamental to irrigation development and thus the National Land Commission and the county governments provide the right to land with respect to private- and community-owned land, respectively (GOK, 2019b).

TABLE 2 Area under irrigation in Kenya in 2018

Category	Area under irrigation (ha)
Public irrigation scheme	24,240
Smallholder irrigation scheme	110,000
Private irrigation schemes	88,000
Total	**222,240**

Source: GOK, 2019a.

4 | CHALLENGES FACING THE DEVELOPMENT OF MODERN IRRIGATION SYSTEMS IN KENYA

The challenges facing the adoption and development of modern irrigation technologies in Kenya can be categorized thematically into technical, socio-economic, and institutional (Table 3).

4.1 | Technical challenges

4.1.1 | Water scarcity

Kenya is a water-scarce country with a current per capita water demand of 647 m^3 (GOK, 2018). The water situation in Kenya has been worsened by climate change coupled with deforestation, low water storage capacity, increasing water demand from industrial, domestic, and agricultural use, and having to share half of the rivers, lakes, and aquifers with neighbouring countries (GOK, 2018). Therefore, water availability remains a key challenge in the irrigation sector. Water unavailability affects most drainage basins, with the exception of the Lake Victoria basin, which enjoys abundant relative irrigation water supply as reported by Muema (2018). The Athi River basin had a water deficit of 76% in 2010 (Kibiiy & Kosgei, 2018). In the Tsavo subcatchment in the Tana basin, only 30% of respondents felt that they had adequate water (Oremo et al., 2019). Similarly, Masya (2016) observed that inadequate water was one of the main factors that contributed to the failure of many irrigation projects in Kibwezi, Makueni County. Kulecho & Weatherhead (2006a) found that majority of farmers cited an unreliable water supply as the main

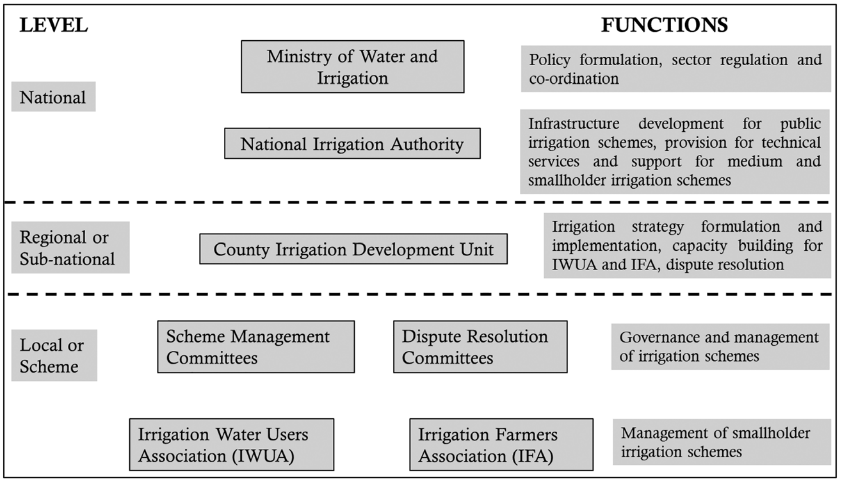

FIGURE 2 Institutional framework in irrigation sector in Kenya as conceptualized in Irrigation Act 2019

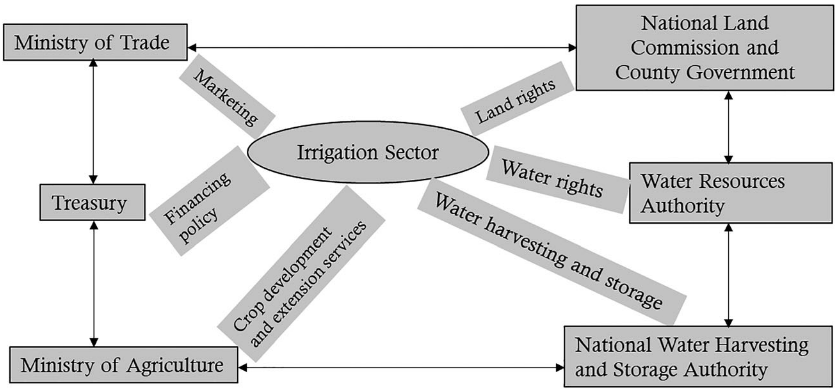

FIGURE 3 Other key enablers for irrigation development in Kenya

TABLE 3 Ranking of challenges facing irrigation development in Kenya

Challenge		Frequency (%)
Technical	Water scarcity	26
	Water quality	26
	Irrigation infrastructure	11
	Technical support services	11
Socio-economic	High cost of irrigation system	11
	Access to credit	18
	Access to markets	13
	Extension services	24
Legal and institutional	Pluralistic legal framework	5
	Weak institutions	5
	Inadequate participation	15
	Weak regulation enforcement	5

hindrance to the adoption of low-cost drip irrigation. Mboi & Kidombo (2018) reported that water availability influenced the sustainability of smallholder irrigation schemes in Kirinyaga County, a part of the Tana River basin. The distance to water sources affects the adoption of modern irrigation systems because of its impact on the cost of installing irrigation infrastructure such as pipe distribution systems. Mwangi & Crewett (2019) found that a 1-km increase in the distance to a water source decreases the likelihood of irrigation adoption by 85%. In the Rift Valley basin, inadequate water has been cited as one of the main problems affecting the Perkerra irrigation scheme (Lumumba, 2018). Small-scale irrigation schemes in the Turkwel River basin in the Rift Valley drainage basin suffer from water scarcity due to the arid climate (Hirpa et al., 2018).

4.1.2 | Water quality

Water used for irrigation can vary in quality depending on its source, which may affect the performance of modern irrigation systems. Kulecho & Weatherhead (2006b) found that most farmers in Kenya use water directly from rivers or wells, which has been found to be saline or contain sediment. In the Tsavo area, 66% of respondents perceived the water resources to be of bad or fair quality (Oremo et al., 2019). Karuku et al. (2017) noted that most rivers in the Kabete area of Kiambu are polluted with heavy metals, which renders them unsuitable for domestic use and crop production. In Murang'a, Home & Ngugi (2012) reported the clogging of sprinkler nozzles by sediment as a cause of low irrigation efficiency in irrigation schemes. Frequent clogging of emitters because of poor water quality and the corrosion of metal parts in the drip kits due to saline water led to the discontinuation of low-cost drip irrigation kits in many parts of Kenya (Kulecho & Weatherhead, 2005; Nakawuka et al., 2018). Generally, stakeholders in the irrigation sector in Kenya complain of poor water quality that affects irrigation performance (FAO and IFC, 2015).

The challenge of water quality is of great concern in the face of recent developments in wastewater reuse in agriculture in response to water scarcity. Residents in peri-urban areas of Nairobi would reuse wastewater because they had inadequate freshwater sources (Angatia, 2013; Maina et al., 2020b). However, wastewater reuse is hampered by the poor performance of wastewater treatment plants, whose effluents do not meet the discharge standards set by the National Environment Management Authority. Maina et al. (2020a) established that treated wastewater effluent contained high organic loading and traces of heavy metals, such as lead, above the accepted standards. Therefore, wastewater reuse for irrigation should be encouraged, but this should go hand in hand with improvement in the treatment processes, including heavy metal removal.

4.1.3 | Irrigation infrastructure

In sub-Saharan Africa, the common problems hindering adoption of drip irrigation technology are blockage of driplines, problems with water storage systems, and the damage of drip systems by animals such as elephants, hyenas, and rodents (Friedlander et al., 2013). In Kenya, Opar (2016) cited poor installation of drip systems, leaks, and poor lateral designs as the main problems which affect the operation of drip irrigation systems. The problems of poor design and installation could be attributed to a lack of technical support as explained in the next subsection. Kulecho & Weatherhead (2006a) found that the low-cost drip irrigation kits were made of poor materials that reduced their useful life to less than 3 years instead of the minimum 7 years claimed by the manufacturers. Ngigi et al. (2005) cited poor performance of water storage structures, for example, seepage, as one factor hindering irrigation development. Home & Ngugi (2012) noted that the irrigation efficiencies in schemes around Murang'a County were below the design values because of leakages in distribution pipes and the improper layout of sprinkler systems.

4.1.4 | Technical support

Modern irrigation technologies require reliable and consistent technical services in terms of operation and maintenance. A study by Kulecho & Weatherhead (2006a) found that almost a third of the respondents using low-cost drip irrigation technology cited inadequate technical support services, leading to operation and maintenance problems. Masya (2016) established that the majority of farmers in Kibwezi did not receive technical services for their irrigation systems, and consequently the irrigation infrastructure failed because of poor maintenance. Indeed, mechanical and maintenance problems discouraged the adoption of low-cost drip irrigation systems (Kulecho & Weatherhead, 2006b). A lack of knowledge on the repair and maintenance of modern irrigation systems and their accessories, such as pumps, were major constraints facing smallholder farmers in Kenya and East Africa in general (Nakawuka et al., 2018).

4.2 | Socio-economic challenges

4.2.1 | Cost of modern irrigation systems

Modern irrigation systems require large capital outlays that are beyond the reach of smallholder farmers. Karuku et al. (2017) found that a third of tomato farmers in Kiambu County prefer to irrigate with sprinkler and furrow systems since they were considered cheaper than the water-efficient drip irrigation systems. Kiprop (2015) observed that of the farmers in Kerio Valley, Elgeyo-Marakwet County, 35% used sprinklers and only 0.9% used drip irrigation, with the majority (64%) using furrow irrigation because it was cheaper. Smallholder farmers pay 25% more per unit hectare when using drip irrigation systems than large-scale farmers using the same systems (Table 4). The centre pivots used by large-scale farmers are almost three times cheaper than drip irrigation used mostly by smallholder farmers.

Compounding the high cost of irrigation projects is the question of value for money, when projects are implemented regardless of the cost because of inadequate feasibility studies caused by political expediency, in addition to long procurement processes leading to delays, cost overruns, and narrowed scope—as was the case with the Bura irrigation scheme (Kadigi et al., 2013). Leshore & Minja (2019) established that most projects experienced delays in implementation due to budgetary constraints which generally affect every stage of the project. They also cited poor pricing and tendering processes and inadequate contract documentation skills as factors that hindered the implementation of irrigation projects, such as the Galana-Kulalu irrigation project.

4.2.2 | Access to credit

Access to credit is one of the main challenges hindering farmers from adopting modern irrigation systems in Kenya (Ngigi, 2002; Sijali & Okumu, 2002). Oremo et al. (2019) established that the majority of smallholder farmers in Tsavo lacked access to credit facilities. Farmers in Kiambu could not increase the area under

TABLE 4 Cost of conventional modern irrigation systems in Kenya

Irrigation method	Irrigation area (ha)	Cost per hectare (USD)
Small drip systems	0.4	7,750
Large drip irrigation system	4	6,225
Small sprinkler movable systems	0.4	4,700
Larger sprinkler movable systems (4 ha)	4	4,150
Centre pivot	> 40	2,750

Source: Food and Agriculture Organization of the United Nations (FAO) and IFC, 2015.

tomato production due to a lack of credit facilities (Karuku et al., 2017). Masya (2016) found that farmers in Kibwezi lacked access to credit because most financial institutions require collateral, which most of the smallholder farmers did not have. In Kirinyaga County, inadequate funding negatively affected the sustainability of smallholder irrigation projects (Mboi & Kidombo, 2018). A lack of access to credit prevents smallholder farmers from buying solar-powered irrigation kits (Holthaus et al., 2017), which jeopardizes the use of those systems as a climate-smart strategy.

4.2.3 | Access to markets

Most farmers using modern irrigation systems grow fresh produce such as vegetables and fruits that are perishable and deteriorate quickly, which means that having a ready market is important. Market inaccessibility for their farm produce was cited as one of the main problems affecting irrigators in most parts of Kenya (Kulecho & Weatherhead, 2006b). In Kiambu County, it was established that market access increases the chances of farmers adopting modern irrigation systems by 17% compared to farmers without access to markets (Mwangi & Crewett, 2019).

Public amenities, such as roads, influence market accessibility. Ngigi (2002) noted that inadequate support infrastructure, such as a lack of roads and electricity, hindered the development of irrigation in Kenya. Mwangi & Crewett (2019) established that access to a tarmac road increases the chances of farmers adopting irrigation. Finally, Stöber et al. (2018) found that poor access to markets hinders adoption of low-cost irrigation technologies as farmers are uncertain of the return on investment.

4.2.4 | Extension services

Extension services are especially critical to the adoption of modern irrigation systems in Kenya because the majority of farmers have primarily relied on rainfed agriculture and do not have experience with irrigation (Kulecho & Weatherhead, 2006a; Mati, 2008). Indeed, Kulecho & Weatherhead (2005) found that the majority of those who stopped using low-cost drip kits came from Kajiado and were used to a pastoral lifestyle and had no experience with irrigation. Therefore, awareness on water saving irrigation practices needs to be increased in Kenya where the majority of those in the larger ASAL are pastoralists.

Having access to information on irrigation increased the chances of farmers adopting irrigation by 29% in Kiambu County (Mwangi & Crewett, 2019). In Mbeere South, Ireri (2017) established that there was a big knowledge gap among smallholder farmers in terms of irrigation water rights and also regarding guidelines and the rules on using water for irrigation as established by the WRA. Kulecho & Weatherhead (2006a) found that extension staff from the government did not have enough knowledge themselves to be able to educate the farmers using low-cost drip irrigation kits, and this hindered their adoption. Monteiro et al. (2010) attributed the lack of knowledge among extension service officers to a lack of resources and training on the field applications of irrigation technologies. Further Kulecho & Weatherhead (2006b) noted that a government extension policy on small-scale irrigation technologies was either nonexistent, unclear, or weak. According to Macharia et al. (2018), properly using irrigation technologies and extension workers is important to the adoption of irrigation technology by smallholder farmers.

The design of information strategies should consider gender and cultural norms; it should ensure that women are not left behind in adopting irrigation technology. Njuki et al. (2014) established that women lacked information about irrigation pumps, which are used in conjunction with drip irrigation, because of the strategies employed by the sales agents and promoters of pumping technology which favoured men over women.

4.3 | Legal and institutional challenges

The legal framework established several institutions charged with the development, operation, management, and maintenance of irrigation schemes in Kenya (Figure 2). Some of these institutions are weak since they have little experience in modern irrigation systems. Small-scale irrigation schemes managed by the IWUA face challenges of governance and are still at the early stages of development (GOK, 2019a). Participation in the WUA does not guarantee the right to water access by smallholder farmers. For instance, smallholder farmers in the WUA in the Likii subcatchment in the Ewaso Ngiro North catchment were actually disadvantaged as the WUA limited their water accessibility and increased water charges disproportionately compared to large-scale farmers (Kemerink et al., 2016).

The existence of a pluralistic legal framework in the water sector is a challenge. Gartner (2015) explained that a lack of convergence between customary and statutory institutions affects water accessibility, water distribution, water allocation, and decision-making in the management of smallholder irrigation schemes.

Inadequate participation by farmers in decision-making is a common feature in the majority of irrigation schemes in Africa, which removes their sense of ownership and responsibility in the management of water in the scheme and ultimately affects their motivation to invest in modernizing irrigation systems (Mutambara et al., 2016). According to Swallow et al. (2007), inadequate participation in decision-making led to a collapse of irrigation schemes in the Nyando basin. In their study, it was established that farmers in the scheme managed by the National Irrigation Board (the predecessor to the NIA) were considered to be only "tenants," with little tenure security, and thus they had less incentive to invest in developing irrigation facilities. In the Yatta irrigation scheme, there was poor participation by stakeholders in water resource management despite the existence of a local WUA (Simitu & Odira, 2008). Inadequate participation by smallholder farmers in water resource management has been cited as one of the institutional failures in Mbeere South (Ireri, 2017). In the West Kano irrigation scheme, K'Akumu et al. (2016) noted that farmers were excluded from determining water use pricing, which is exclusively the mandate of the NIA.

The lack of women's participation is of great concern because of the culture and traditions among communities in Kenya. Njuki et al. (2014) found that decisions about irrigation pumps, which crops to irrigate, and market arrangements are made jointly by men and women but that the final decision rests with the men, thus leaving women at a disadvantage. Gender equality in the management of irrigation schemes is still a mirage in Kenya. A study by K'Akumu et al. (2016) found that all members of the management of the WUA in the West Kano irrigation scheme were men. Women are central to water resource use and management, and therefore they must participate at all levels of irrigation scheme management.

The reforms in the water sector which started with the enactment of the Water Act of 2002 and amended the Water Act of 2016 captured the Dublin principles on integrated water resources management where water is to be treated as both a social and economic good. This therefore means that users should pay for water so that they have an incentive to conserve water. However, this has been poorly implemented in some irrigation schemes in Kenya. Njiraini & Guthiga (2013) found that small-scale farmers lacked financial incentives to adopt water saving irrigation technologies, such as drip irrigation, because they do not pay for irrigation water. This was consistent with the findings by Kulecho & Weatherhead (2006a) where the majority of farmers were using water for irrigation which they were not charged for, and thus they could hardly be encouraged to adopt water saving irrigation technologies.

5 | DISCUSSION

The main technical challenges facing irrigation development in Kenya include water scarcity and poor water quality, with 26% of the sources highlighting these issues (Table 3). The socio-economic challenges mentioned most in the literature are inadequate extension services (24%) and lack of credit access (18%). Poor irrigation infrastructure, lack of market accessibility and availability, and the lack of support services as well as prohibitive cost irrigation systems are the key bottlenecks to the adoption of modern irrigation systems. The most important institution and legal challenge was the inadequate participation of stakeholders, including women. This resonates well with the challenges facing the irrigation sector in sub-Saharan Africa. For example, in Ethiopia's Tana basin, Ayele (2011) reported water scarcity as one of the main challenges facing smallholder irrigation farmers. Inadequate participation is a common challenge in irrigation schemes in Ethiopia, South Africa, Tanzania, Zimbabwe, and Mozambique (Mutambara et al., 2016). Mdemu et al. (2017) reported poor irrigation infrastructure and governance challenges as some of the main problems facing irrigation development in Tanzania. In sub-Saharan Africa, participation under the WUA is ineffective due to the inappropriate structure and poor governance (Kadigi et al., 2013). However, the challenges analysed in the present study did not consider a basin-scale approach, and therefore, it would be important to analyse in depth the technical challenges affecting the adoption of modern irrigation technologies at the basin level, as some of the issues, such as water availability and quality, are specific to each basin due to variations in hydrological and hydrogeological characteristics.

The development of modern irrigation systems in Kenya has a bright future which is buttressed by the government's desire to tackle food insecurity problems. The key enabling environment has been revamped through the enactment of the Irrigation Act of 2019 and the Water Act of 2016. These two pieces of legislation are aligned with the Constitution of Kenya, 2010, which brought in a devolved system of governance. The implications of these two acts are (1) increased space for public and stakeholder participation in matters of irrigation water management, (2) strengthening irrigation scheme management through the establishment of the IWUA as a legal entity, (3) the promotion of a private–public partnership in the construction and management of irrigation schemes which will unlock the financing solutions in irrigation development, (4) the establishment of county development irrigation units which will help counties prioritize irrigation needs and ring-fence funds for irrigation development at the local levels, and (5) the establishment of the NWHSA for water harvesting and storage for irrigation purposes which is critical in climate change adaptation. The future of irrigation development is also aided by the drive towards solar water pumping and climate-smart strategies as anchored in the Climate-Smart Agriculture Strategy of 2017–2026 (GOK, 2017).

The adoption of rain water harvesting (RWH) for irrigation is one method of building resilience to the impacts of climate change. The adoption of RWH techniques can provide the opportunity to increase the water supply for irrigation, especially in arid and semi-arid parts of Kenya (Oguge & Oremo, 2018). The Government of Kenya has accelerated water harvesting initiatives through the medium-term plans of the National Adaptation Plan of 2015–2030 as part of enhancing climate change resilience (GOK, 2016a). The establishment of the NWHSA (GOK, 2016b) is important in enhancing climate change adaptation and resilience in irrigated agriculture. The combination of conservation agriculture practices, water harvesting, clean energy, and water saving irrigation systems helps in building resilience to climate change.

6 | CONCLUSION

The findings revealed that traditional surface irrigation methods are still predominant in Kenya, with smallholder farmers and private irrigation schemes driving the adoption of modern irrigation systems. The challenges hindering the development of modern irrigation systems are water scarcity, poor water quality, inadequate irrigation infrastructure, a lack of credit facilities coupled with high investment costs, inadequate participation of farmers in decision-making and inadequate extension services. The prospects of irrigation systems in Kenya are anchored in the government initiatives of the adoption and promotion of clean energy, water harvesting, and conservation agriculture aimed at building climate change resilience. These initiatives, if sustained, could help in addressing some of the challenges hindering irrigation development in Kenya. However, the government needs to further limit its role to policy formulation and sector coordination in the irrigation sector, as has been done in the water and sanitation services, and allow greater participation of farmers and the private sector. This will lead to improved governance and performance in the irrigation schemes. It is also necessary to develop a working policy arrangement between the national and county governments in irrigation development in schemes that span county jurisdictions.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author upon request.

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