Financing Irrigation Development: Global Experiences and Policy Options for Kenya

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ABSTRACT
Agricultural production in many developing countries remains predominantly rain-fed and increasingly vulnerable to climate variability, undermining food security and rural livelihoods. Irrigation development is widely recognized as a critical climate adaptation strategy; however, financing constraints continue to limit its expansion, particularly in Sub-Saharan Africa. This study examines global experiences in irrigation financing and draws policy-relevant lessons for Kenya. Using a qualitative, review-based methodology guided by PRISMA principles, the study synthesizes empirical evidence on five irrigation financing models: public sector–led financing, public–private partnerships (PPPs), blended finance, farmer-led and user-financed irrigation, and climate and green financing instruments. The findings show that sustained and predictable public investment remains foundational for irrigation development, while complementary financing models can enhance efficiency, scale, and sustainability when aligned with institutional capacity and farmer affordability. No single financing model is universally optimal; successful irrigation outcomes depend on coherent integration of financing instruments within broader agricultural and food system policies. In Kenya, the study finds that irrigation constraints are primarily institutional and financial rather than technical, reflecting fragmented financing, weak cost recovery, and limited private participation. The study recommends that Kenya should adopt a diversified and integrated irrigation financing framework anchored in strong public leadership, strategic use of PPPs, catalytic blended finance, support for farmer-led irrigation, and expanded access to climate finance. Such an approach is essential for accelerating irrigation development, strengthening food security, and enhancing climate resilience.

KEYWORDS: Irrigation Financing; Food Security; Climate Resilience; Climate Adaptation; Public–Private Partnerships; Blended Finance; Farmer-Led Irrigation Development; Climate Finance; Sustainable Agriculture; Sub-Saharan Africa; Kenya.

1. INTRODUCTION

Agriculture is the backbone of many economies, contributing nearly a quarter of Gross Domestic Product and providing livelihoods for nearly 3 billion people in developing nations [1]. According to the Intergovernmental Panel on Climate Change [2], agricultural production in developing economies remains predominantly rain-fed, and climate change has affected the predictability of weather patterns. Irrigation remains a key adaptation to climate change and is necessary to enhance climate change resilience in food systems, particularly in developing economies. However, investment in irrigation infrastructure in many countries remains inadequate and not commensurate with the scale required to strengthen climate change adaptation and build resilient food systems [1,3].

Irrigation enables year-round food production, increasing cropping intensity, and supporting diversification into high-value agriculture that would leapfrog the achievement of sustainable development goal on poverty reduction and enhanced food security [3]. Available studies show that countries with water security remain more food secure, and countries with food deficits that are dependent on food imports have low sustained investment in irrigation infrastructure [1]. According to ADB & FAO [4,5], despite possessing large tracts of underutilized arable land, Sub-Saharan Africa spends an estimated USD 35–50 billion annually on food imports reflecting structural constraints in agricultural productivity and irrigation development. This has resulted in overdependence on rain-fed agriculture, which accounts for 80 percent of sub-Saharan Africa's cultivated land. Irrigation infrastructure development is capital-intensive, posing financing challenges for the national government and farmers alike.

In Kenya, agriculture contributes 25% of Gross Domestic Product and another 27% indirectly, while credit to farmers is low, with agriculture accounting for only 3% of banks' loan portfolio [3]. Investment in agricultural technology, agricultural financing systems and well-managed irrigation systems can create a more resilient food system [3,6]. Kenya can leverage critical

lessons from some countries in East and South Asia (China, Vietnam, India and Pakistan) that have aggressively expanded irrigation to support food self-sufficiency [7]. According to Rosegrant *et al*. [6], countries such as China, India, Israel, Egypt, and the United States have achieved food security through sustained public and private investment in irrigation infrastructure. In addition, countries with the highest proportion of arable land under irrigation (Egypt - 90 percent, India - 50 percent, and China - 45 percent) have demonstrated greater resilience to climatic shocks and more stable food supply systems [1]. This shows that there is a strong positive relationship between irrigation coverage and food security outcomes.

Irrigation development has been financed through a diversified mix of financing models, reflecting differences in institutional capacity, fiscal space, and agricultural structure, including public sector financing, Public–Private Partnerships (PPPs), blended finance and development partner funding, concessional finance, donor financing and private capital through user irrigation financing/Farmer Led Irrigation Development [3,6]. According to Shah and You *et al*. [7,8], in Bangladesh and India, farmer-led and user-financed irrigation has played a significant role in expanding small-scale irrigation driven by private investment in shallow wells, pumps, and micro-irrigation technologies. According to the World Bank [3], climate-resilient irrigation and water-efficient technologies have emerged in countries such as Morocco and Ethiopia as climate and green financing instruments designed to enhance adaptation to climate change while promoting sustainable water use.

The choice of irrigation financing models is strongly influenced by institutional capacity, fiscal space, farmer affordability, and governance frameworks [1,3]. As illustrated in Table 1, high food security outcomes in Europe and North America are achieved not only through extensive irrigation coverage, but through a combination of favorable agro-climatic conditions, high agricultural productivity, strong institutions, well-integrated markets, income security, and strategic use of international trade [9]. In contrast, East and South Asia and the Middle East and North Africa (MENA) rely more heavily on irrigation as a compensatory mechanism for climatic and structural constraints; however, irrigation expansion alone has proven insufficient to guarantee high food security in the absence of complementary institutional and economic factors [1,6].

In Sub-Saharan Africa, low irrigation coverage and low food security are mutually reinforcing outcomes of chronic under-investment in irrigation infrastructure, weak financing and governance structures, high climate vulnerability, low agricultural productivity, and widespread poverty [4,5]. Unlike regions where irrigation development complements strong institutions and efficient markets, irrigation in Sub-Saharan Africa remains constrained by systemic failures that limit both its expansion and its potential contribution to food security and rural transformation [3].

Table 1: Regional Comparison of Irrigation, Food Security and Investment.

Region	Population (Millions, 2025)	Total Arable Land (Million ha)	Irrigated Land (% of arable land)	Food Security Index	Estimated Investment in Irrigation (USD billion, 1980–2025 total)
East & South Asia	3,800	450	40–50	65–75 (Moderate–High)	1,800 – 2,250
Sub-Saharan Africa	1,200	240	5–7	45–55 (Low)	225 – 450
Middle East & North Africa (MENA)	520	90	35–60	60–70 (Moderate)	450 – 675
Europe	450	210	15–20	75–85 (High)	675 – 900
North America	370	180	20–25	80–90 (Very High)	900 – 1,125
Latin America & Caribbean	650	300	15–20	65–75 (Moderate–High)	450 – 675

Source: Author's compilation based on FAO [1,5]; World Bank [3]; African Development Bank [4]; and OECD [9].

The purpose of this study is to examine various financing models for irrigation development and to recommend policy options for Kenya. As summarized in Table 1, regions such as Europe and North America have achieved high food security despite relatively lower irrigation coverage, East and South Asia and the Middle East and North Africa (MENA) have moderate irrigation coverage and moderate food security. Sub-Saharan Africa exhibits both low irrigation coverage and low food security, reinforcing outcomes of under-investment. These regional contrasts highlight that the central policy challenge is not whether to invest in irrigation, but how irrigation is financed, governed, and integrated within broader agricultural and food system strategies.

This evidence provides a compelling rationale for examining global experiences in irrigation financing and distilling policy-relevant lessons for countries such as Kenya, where irrigation expansion is increasingly viewed as a cornerstone of food security and climate-resilient agricultural transformation.

2. LITERATURE REVIEW

2.1. INTRODUCTION

The relationship between irrigation development and food security has been widely analyzed within the broader literature on agricultural investments, climate adaptation, and food security. According to FAO [10], food security is commonly conceptualized as comprising four pillars: availability, access, utilization, and stability. Irrigation contributes primarily to food availability and stability by reducing dependence on rainfall, increasing cropping intensity, and lowering yield variability. However, utilization of irrigation infrastructure is affected by access to finance and farmers' level of knowledge. According to Barker & Molle [11], irrigation infrastructure is a quasi-public good, especially due to the establishment of intakes, wayleaves, canals, and pipes to farmers, requiring high upfront capital costs, long payback periods, and positive externalities that limit private sector incentives to invest independently. These characteristics have resulted in various approaches to enhance irrigation infrastructure development, and several models for increasing irrigation development and enhancing climate change adaptation strategies in agriculture have been adopted.

Empirical studies consistently show that irrigated agriculture exhibits lower yield variability and higher average productivity compared to rain-fed systems, particularly in ASAL areas [6]. However, scholars caution that irrigation-based adaptation is highly context-specific and depends on water availability, energy costs, institutional capacity, and environmental sustainability. Poorly planned irrigation investments may exacerbate groundwater depletion, increase fiscal burdens, and generate limited food security gains if not aligned with complementary inputs and governance reforms [1]. In Kenya, the role of the Water Resource Authority is to balance irrigation development with domestic, industrial, ecological, and climate resilience needs, thereby safeguarding long-term water security, allocate, and protect water resources through catchment-based planning, water abstraction permitting, monitoring, and enforcement.

This chapter identifies financing constraints as one of the most persistent barriers to irrigation development using already published studies. Traditional reliance on public budgets has proven insufficient, particularly under conditions of fiscal stress and competing development priorities [3]. As a result, scholars are increasingly emphasizing the need for diversified financing models, including PPP, blended finance, and FLID. According to AfDB [4], irrigation development in Sub-Saharan Africa is low and with the majority of these countries having food insecurity mainly due to inadequate financing resulting from national budgets, inadequate donor and development partners support, low credit uptake from the private sector due to institutional capacity, governance quality, cost-recovery mechanisms, and farmer affordability [1].

However, lessons from East and South Asia highlight the role of sustained public investment combined with gradual institutional reform in expanding irrigation and improving food availability [6]. In contrast, evidence from Sub-Saharan Africa reveals persistent under-investment, fragmented financing, and governance failures as key explanations for low irrigation uptake and weak food security outcomes [3,7]. These contrasting experiences provide valuable lessons for countries seeking to design context-appropriate irrigation financing strategies.

2.2. PUBLIC SECTOR–LED IRRIGATION FINANCING

Available empirical literature demonstrates that public sector–led financing has been central to large-scale irrigation expansion, with public investment being channeled to public goods such as reservoirs, canals, and command-area development, which has significantly increased irrigated area, cropping intensity, and staple food production, particularly in India and China [3,6,12]. Empirical evaluations indicate that public irrigation investments generate high social returns through improved food availability, rural employment, import substitution effects, increased tax revenue generated by economic activities and price stabilization, despite low financial cost recovery [11,13]. However, evidence also highlights inefficiencies linked to governance and management, leading to operation and maintenance that is not optimal, limited farmer participation, and fiscal burdens when public investment is not accompanied by institutional reform [14,15]. Cross-country analyses confirm that public financing remains essential where irrigation exhibits public good characteristics, but its effectiveness depends on governance quality and complementary investments in productivity-enhancing inputs [1,16].

A study by Otieno *et al*. [17] on the role of irrigation development in Kenya and whether it's a solution to food security problems shows that Kenya, like many countries, irrigation development is largely dependent on national budg*et al*locations for establishment of water harvesting and storage structures commonly small dams and water pans or rehabilitation of existing water storage structure or construction of new irrigation projects and irrigation schemes. The study further establishes that irrigated agriculture could increase maize production by between 100 and 400 percent, depending on other factors. Financing

challenges due to upfront capital costs and limited cost recovery for existing irrigation projects have led to massive investment in irrigation, with low private-sector investment in irrigation development.

A study by Ammani [18], covering 94 small-scale irrigated maize and tomato farmers in Kaduna State, Nigeria, established that irrigated crop production yields positive net returns and benefit-cost ratios of 1.49 for maize and 1.40 for tomato, revealing that both social and economic benefits exceed production costs under publicly supported irrigation settings. The findings also show that economically viable outcomes for smallholder farmers are achieved despite high production costs driven largely by fertilizer and energy (fuel for irrigation pumps), underscoring the importance of public investment in irrigation infrastructure to lower entry barriers and production risks for smallholders. However, the results also show that high dependence on public sector financing reduces the uptake of irrigation development expansion among smallholder farmers, calling for more innovative irrigation financing.

2.3. PUBLIC–PRIVATE PARTNERSHIPS (PPPs) IN IRRIGATION FINANCING

There is a growing recommendation of utilization of Public–Private Partnerships (PPPs) in irrigation infrastructure development, with cost recovery expected from the offtake of water and food production [3]. Case studies from Morocco, Brazil, Mexico, and Peru show that PPPs have improved scheme efficiency, reduced fiscal pressure on governments, and enhanced service delivery where regulatory frameworks are robust [19,20]. Studies by Rey *et al*. [21] and OECD [9] found that private participation has been most successful in irrigation operations, maintenance, and bulk water delivery rather than in initial infrastructure construction. However, lessons from some empirical literature from Hall & Lobina [22]; FAO [1] on PPPs show that the structuring of these projects should consider tariff affordability, risk allocation, and offtake guarantees during modeling for the successful implementation of PPPs. According to the World Bank [3], available evidence from Sub-Saharan Africa shows that financial close from majority of PPP irrigation projects often struggle due to weak institutional capacity and limited farmer willingness to pay, challenges of offtake guarantees and poor public risk-sharing mechanisms [4].

A study by Dayu Irrigation Group [23] on the Yuanmou High-Efficiency Water-Saving Irrigation Project in China also provides strong empirical evidence of PPPs as an effective and innovative financing mechanism for irrigation development. The project, jointly financed by the government, private investors, and farmers, successfully irrigated 7,600 hectares using modern drip irrigation and smart water management systems. Empirical outcomes included increased cropping intensity [from one to three or four crops annually], higher farm incomes, improved water-use efficiency, and financially sustainable operation and maintenance. The study demonstrates that PPPs can overcome traditional public-sector financing constraints by integrating investment, technology, and management expertise while aligning incentives across stakeholders.

A study by the World Bank [19] on Public–Private Partnerships in Irrigation and Drainage provides comparative empirical evidence from Morocco, Brazil, Peru, and India on the effectiveness of PPPs in irrigation financing and management. The study finds that PPP arrangements ranging from concession and lease contracts to management agreements enabled governments to mobilize private capital and technical expertise for irrigation infrastructure while reducing long-term fiscal obligations. Empirical outcomes across the case studies include improved service-delivery reliability, higher water-use efficiency, enhanced cost recovery, and better operation and maintenance performance compared with traditional publicly managed schemes. The study concludes that PPPs are particularly effective where risks are clearly allocated, tariffs are partially cost-reflective, and public support is targeted at capital investment rather than recurrent costs, thereby enhancing financial sustainability and farmer productivity.

A study by FAO and the World Bank [24] that reviewed irrigation PPP models in Morocco and Egypt provides empirical support for PPPs as a viable approach to improving irrigation efficiency and scheme sustainability. Focusing on the Guerdane Irrigation Project in Morocco and selected irrigation schemes in Egypt, the study shows that private sector participation in financing, construction, and management led to improved water delivery efficiency, reduced system losses, and more sustainable operation and maintenance. Empirical evidence indicates that farmers benefited from more reliable irrigation services, which enabled crop diversification and higher agricultural returns, while governments benefited from reduced fiscal pressure and improved asset performance. The study emphasizes that successful irrigation PPPs require strong regulatory frameworks, credible public counterparts, and alignment between water pricing, farmer affordability, and long-term sustainability objectives.

A study by Ammani [18] on small-scale irrigated crop production in Kaduna State, Nigeria, provides empirical justification for innovative financing approaches such as Public–Private Partnerships [PPPs] in irrigation development. The study found that irrigated maize and tomato farming generated positive net returns with benefit–cost ratios of 1.49 and 1.40, respectively, despite high production costs driven by energy and input expenses. These findings indicate that irrigation is economically viable but constrained by high upfront and operational costs that smallholders cannot bear alone. The study supports PPP-based financing by demonstrating that public investment in core irrigation infrastructure, combined with private sector efficiency in input provision and water delivery, can enhance the profitability and sustainability of irrigated agriculture.

A study by FAO, UNIDO, and partners [25] under the Jowhar Offstream Storage Programme (JOSP) in Somalia empirically illustrates how PPPs can address chronic public-sector limitations in irrigation scheme management. The pre-feasibility study documents deteriorated irrigation infrastructure, low functionality (25–65%), and weak cost recovery under purely public and community-managed systems. It finds that PPP arrangements, particularly for operation, maintenance, and water service delivery, offer a viable financing and governance model by mobilizing private capital, improving efficiency, and introducing structured cost-recovery mechanisms. The study concludes that PPPs are critical for sustaining rehabilitated irrigation assets, especially in fragile contexts where public fiscal space and institutional capacity are limited.

A study by the World Bank [26] on the Guerdane Irrigation Project in Morocco provides strong empirical evidence that Public–Private Partnerships [PPPs] can serve as an effective and innovative financing mechanism for irrigation development. The study evaluates a concession-based PPP arrangement in which a private operator was responsible for financing, constructing, and managing a bulk water conveyance system supplying irrigation water to commercial farmers. Empirical findings show that private sector participation significantly improved service reliability, water delivery efficiency, and operational sustainability, while reducing the fiscal burden on the government. Farmers experienced increased agricultural productivity, higher-value crop diversification, and improved income stability due to a reliable water supply. The study further demonstrates that the success of the Guerdane PPP was driven by clear risk allocation, government support through capital cost sharing and demand guarantees, and a commercially viable tariff structure. Overall, the findings confirm that well-structured irrigation PPPs can mobilize private capital, enhance efficiency, and deliver sustainable irrigation services when aligned with sound governance and farmer demand.

Examining the Galana Kulalu Irrigation Project in Kenya provides critical empirical insights into both the potential and risks of PPPs in irrigation financing [27]. While the project was conceived as a flagship PPP to mobilize private capital and technical expertise, the study finds that weak feasibility analysis, politically driven scope inflation, and poor risk allocation undermined performance. Nevertheless, the authors emphasize that these shortcomings reflect implementation failures rather than flaws in the PPP model itself. The study concludes that well-structured PPPs anchored in realistic project scoping, phased investment, strong governance, and enforceable contracts remain a viable and innovative financing pathway for large-scale irrigation development in Kenya and similar contexts.

2.4. BLENDED FINANCE AND DEVELOPMENT PARTNER–SUPPORTED IRRIGATION

A growing empirical literature highlights the role of blended finance, combining public funds, concessional loans, grants, and private capital, in expanding irrigation investment in developing countries. Studies from Sub-Saharan Africa and South Asia demonstrate that blended finance has enabled irrigation projects that would otherwise be commercially unviable, particularly smallholder and climate-resilient schemes [1,28]. Evidence from Kenya, Ethiopia, and Ghana shows that development partner–supported irrigation investments have improved water access, yields, and incomes when aligned with national strategies and farmer support services [3,4]. However, empirical evaluations also reveal limitations, including donor dependence, fragmented project implementation, and sustainability challenges once external financing ends [7,16]. The literature consistently emphasizes that blended finance is most effective when it catalyzes long-term domestic financing and strengthens institutional capacity rather than substituting for it [1,9].

A study by the World Bank [26] on Maximizing Finance for Development in Water and Irrigation also provides empirical evidence that blended finance instruments, i.e., combining public funds, concessional loans, guarantees, and private capital, can significantly improve the financial viability of irrigation investments. Drawing on case studies from India, Morocco, and Brazil, the findings reveal that blending public and donor finance with private investment reduced sovereign fiscal exposure while improving service delivery and operational efficiency. The results show that public resources were most effective when used to de-risk projects and crowd in private capital, rather than fully financing irrigation infrastructure, thereby supporting long-term sustainability and scalability.

A study by the World Bank and IFAD [19] on Blended Finance for Smallholder Irrigation in Sub-Saharan Africa empirically demonstrates that development partner support is critical in lowering entry barriers for smallholder irrigation adoption. Using evidence from Ethiopia, Kenya, and Tanzania, the study finds that combining donor grants with concessional credit and farmer contributions increased uptake of irrigation technologies, improved farm productivity, and enhanced climate resilience. The study concludes that blended finance is particularly effective in addressing market failures in agricultural credit and risk perception, making irrigation investments bankable for both farmers and financial institutions.

A study by IFAD [29] on Innovative Financing for Smallholder Irrigation provides empirical insights from Rwanda, Senegal, and Mali, showing that blended finance models combining grants, public funding, and private finance improved irrigation access and scheme sustainability. The study finds that donor-supported financing reduced capital costs, strengthened farmer organizations, and enabled cost recovery mechanisms to function more effectively. Evidence indicates that irrigation schemes

supported through blended finance achieved higher productivity and better maintenance outcomes than those financed solely through public budgets.

A study by the African Development Bank [4] on Boosting Irrigation through Blended Finance in Africa empirically assesses irrigation projects in Kenya, Morocco, and Burkina Faso. The study shows that blending concessional finance, public investment, and private sector participation improved project bankability and accelerated implementation. Findings indicate that development partner support played a catalytic role in mobilizing private capital, improving governance structures, and enhancing long-term operational sustainability of irrigation schemes.

A study by FAO [30] on Financing Climate-Smart Irrigation Systems provides empirical evidence from East Africa that blending climate finance with public and donor funds enhances irrigation efficiency and climate adaptation outcomes. The study finds that development partner–supported irrigation projects achieved significant water savings, improved resilience to climate shocks, and reduced environmental risks. The results highlight that blended finance enables irrigation investments to address both productivity and sustainability objectives, which are often unattainable under purely public financing models.

A study by the World Bank [19] on Reducing the Fiscal Burden of Irrigation through Blended Finance presents empirical findings from India and Peru, demonstrating that combining public subsidies with donor finance and private investment improves cost recovery and reduces long-term public expenditure. The study shows that blended finance arrangements allowed governments to shift from recurrent funding of irrigation schemes toward targeted support for capital investments and risk mitigation, resulting in more financially sustainable irrigation systems.

A study by IFAD [31] on Small-Scale Irrigation and Blended Finance Models examines donor-supported irrigation programs in Kenya, Ethiopia, and Niger. The study finds that blended finance improved access to irrigation for smallholders, strengthened water user associations, and enhanced institutional capacity for scheme management. Empirical evidence suggests that combining grants, concessional loans, and farmer contributions led to higher scheme utilization rates and improved maintenance compared to fully subsidized irrigation projects.

2.5. FARMER-LED AND USER-FINANCED IRRIGATION DEVELOPMENT

Empirical studies provide strong evidence that farmer-led and user-financed irrigation has been a major driver of irrigation expansion, particularly in South Asia. Research from India, Bangladesh, Nepal, and Pakistan documents rapid growth in privately financed shallow wells, pumps, and micro-irrigation systems, largely funded by farmers themselves [8,32]. These studies show that farmer-led irrigation is highly responsive to local demand, relatively low-cost, and closely linked to productivity gains and poverty reduction [12]. However, empirical evidence also highlights risks related to groundwater depletion, energy subsidies, and inequitable access, particularly for poorer farmers [1,15]. In Africa, farmer-led irrigation remains limited, but emerging evidence suggests significant potential if supported by access to finance, markets, and extension services [3,7].

A study by Woodhouse *et al*. [33] provides extensive empirical evidence on farmer-led and user-financed irrigation development across Ghana, Kenya, Tanzania, and Ethiopia. The study finds that smallholder farmers independently finance irrigation expansion through investments in pumps, shallow wells, water storage, and on-farm distribution systems, often without direct public subsidies. Empirical results show that farmer-led irrigation expands more rapidly and flexibly than state-led schemes, driven by market incentives and household investment decisions. However, the study cautions that while farmer-financed irrigation enhances productivity and incomes, it requires supportive public policies to address water governance, environmental sustainability, and equitable access.

A study by Xie *et al*. [34] conducted under the World Bank, empirically demonstrates that farmer-led irrigation is the dominant source of new irrigated area in Sub-Saharan Africa. Using multi-country data, the study shows that user-financed investments in small pumps and groundwater abstraction account for the majority of irrigation growth, outperforming publicly financed large-scale schemes. The findings highlight that low entry costs, farmer control over water use, and rapid returns on investment make user-financed irrigation attractive to smallholders. The study concludes that public policy should shift from direct scheme construction to facilitating farmer investment through access to finance, infrastructure, and regulation.

A study by Merrey and Lefore [35] examines the performance of farmer-managed and user-financed irrigation systems and finds that such systems are often more cost-effective and adaptive than centrally managed irrigation schemes. Drawing on empirical evidence from Africa and South Asia, the study shows that farmer-led irrigation requires significantly lower public capital expenditure while delivering comparable or superior productivity outcomes. The authors argue that user-financed irrigation benefits from local knowledge, flexible management, and strong ownership incentives, but emphasize the need for public support in areas such as groundwater regulation, extension services, and conflict resolution.

A study by Lefore *et al*. [36] provides empirical evidence from Kenya and Ethiopia on how smallholder farmers finance irrigation development through household savings, remittances, informal credit, and cooperative arrangements. The study finds that farmer-led irrigation significantly increases cropping intensity, enables dry-season production, and raises household incomes. However, the authors note that access to finance, land tenure security, and water availability remain binding

constraints, suggesting that user-financed irrigation performs best when complemented by enabling institutional and financial frameworks.

A study by the World Bank [26] on Revitalizing Irrigation in Sub-Saharan Africa empirically documents the rise of farmer-led and user-financed irrigation alongside traditional public schemes. The study finds that privately financed irrigation systems are more responsive to farmer needs and market signals, leading to higher utilization rates and better maintenance outcomes. It concludes that public investment should prioritize regulatory oversight, bulk water infrastructure, and financial services rather than direct ownership of on-farm irrigation assets.

A study by IWMI [37] synthesizes empirical evidence on farmer-led irrigation development across Africa and finds that user-financed irrigation accounts for the majority of new irrigated area over the past two decades. The study highlights that farmer investments are driven by profitability, climate risk management, and access to markets. However, it also identifies emerging challenges, including groundwater depletion and inequitable access, underscoring the need for public intervention in water governance and sustainability.

A study by Lefore *et al*. [38] analyzes the policy and investment implications of scaling farmer-led irrigation and finds that targeted public support can significantly enhance the effectiveness of user-financed systems. Using empirical case studies, the study demonstrates that combining farmer investment with supportive policies—such as access to credit, extension services, and water regulation—improves productivity while mitigating environmental risks. The study concludes that farmer-led irrigation should be recognized as a central pillar of irrigation development, complemented rather than replaced by public investment.

2.6. CLIMATE AND GREEN FINANCING FOR IRRIGATION DEVELOPMENT

Recent empirical literature examines climate and green financing instruments as emerging mechanisms for irrigation investment. Studies from Morocco, Ethiopia, and Vietnam show that climate-resilient irrigation projects financed through climate funds and green bonds have enhanced water-use efficiency, reduced climate risks, and supported adaptation objectives [1,3]. Evidence suggests that integrating irrigation investment with climate finance improves project bankability and aligns agricultural development with environmental sustainability [2,28]. However, empirical assessments caution that access to climate finance remains limited by complex accreditation requirements, weak project preparation capacity, and uncertain revenue streams [3,4]. The literature concludes that while climate finance offers significant potential, it must be embedded within broader irrigation financing frameworks to achieve scale and long-term impact [1,9].

A study by the Green Climate Fund [40] on Climate-Resilient Irrigation Financing demonstrates the role of blended climate finance in scaling irrigation development in Africa and Asia. The study drew portfolio-level data and project evaluations across multiple GCF-funded irrigation and water projects, including Kenya, and found that GCF-supported irrigation projects, financed through a mix of grants, concessional loans, and co-financing from governments and development partners, improved adaptive capacity to climate shocks, enhanced water conservation, and stabilized agricultural production. The findings highlight that climate finance reduces investment risk for irrigation projects while enabling governments to pursue adaptation objectives without imposing excessive fiscal burdens.

A study by FAO [30] on Financing Climate-Smart Irrigation Systems provides empirical evidence that climate and green financing significantly enhance the sustainability and resilience of irrigation investments. Drawing on case studies from East Africa, the study finds that irrigation projects financed through climate funds and concessional green finance achieved higher water-use efficiency, reduced vulnerability to drought, and improved agricultural productivity. These findings were attributed to the ability of climate and green financing to lower upfront investment costs for farmers, de-risk adoption of climate-smart technologies, and enable long-term planning and maintenance of irrigation systems. Farmers, with assistance from climate financing, were found to deploy water-efficient technologies such as drip and sprinkler systems, promote energy-efficient pumping solutions, and strengthen institutional and farmer capacity for water management. In addition, climate finance frameworks required projects to integrate climate risk assessments, environmental safeguards, and sustainability indicators, ensuring that irrigation investments were aligned with drought resilience and resource conservation objectives. Together, these mechanisms improved water-use efficiency, reduced climate vulnerability, and translated productivity gains into more sustainable and resilient irrigation outcomes. Therefore, climate finance is most effective when integrated with modern irrigation technologies, institutional strengthening, and farmer capacity building, thereby aligning productivity gains with long-term environmental sustainability.

A study by the World Bank [41] on Climate Finance for Water and Irrigation provides cross-country empirical evidence that integrating climate finance into irrigation investments improves project bankability and sustainability. The study shows that climate-focused concessional finance and guarantees lower perceived climate risks, attract additional financing, and support long-term operation and maintenance of irrigation infrastructure. Empirical outcomes include improved system reliability, reduced climate-related disruptions, and better alignment of irrigation investments with national climate adaptation strategies. A study by IFAD [31] on Scaling Climate-Resilient Irrigation for Smallholders presents empirical findings from Sub-Saharan Africa and South

Asia, demonstrating that green and climate finance improve smallholder access to irrigation while enhancing resilience to climate variability. The study finds that climate-financed irrigation interventions increased cropping intensity, diversified livelihoods, and reduced exposure to rainfall shocks. This improvement was achieved because climate and green financing reduced the high upfront costs that typically constrain smallholder investment in irrigation, while also lowering climate and production risks associated with rainfall variability through the provision of climate information services. However, the study emphasizes that climate finance must be complemented by strong institutions, water governance, and farmer participation to avoid environmental degradation and ensure equitable outcomes.

A study by the African Development Bank [4] on Green and Climate Finance for Agricultural Water Management empirically assesses irrigation projects financed through green bonds and climate funds across Africa. The study finds that green financing instruments supported investments in water-saving technologies, improved environmental outcomes, and strengthened irrigation governance frameworks. The results indicate that climate and green finance can play a catalytic role in modernizing irrigation systems while advancing climate mitigation and adaptation objectives.

2.7. SYNTHESIS OF LITERATURE

Across financing models, empirical evidence shows that irrigation development is most effective when financed through a hybrid model combining public investment, private participation, farmer-led financing, and blended climate finance. Public sector financing remains indispensable for core irrigation public goods and delivers high social returns in food security, employment, and price stability, but often faces inefficiencies and fiscal constraints when not accompanied by governance reforms. PPPs and blended finance have emerged as viable mechanisms for mobilizing private capital, improving efficiency, and reducing fiscal burdens, particularly in bulk water delivery and scheme management, provided risks are well allocated and tariffs are affordable. Simultaneously, farmer-led and user-financed irrigation has driven rapid on-farm expansion due to its flexibility and productivity incentives, though it requires regulation to address sustainability and equity risks. More recently, climate and green financing have enhanced irrigation resilience by de-risking investment, lowering upfront costs, and aligning productivity gains with environmental sustainability, especially in climate-vulnerable contexts. Collectively, the literature converges on the need for integrated irrigation financing frameworks that leverage the comparative strengths of each model to achieve scale, efficiency, and long-term sustainability.

3. METHODOLOGY

Study Design and Approach: This study adopts a qualitative, review-based research design combining a systematic literature review with comparative policy and institutional analysis. The approach is appropriate given the study's objective of synthesizing global experiences in irrigation financing and distilling policy-relevant lessons applicable to Kenya. Rather than generating new primary quantitative data, the study relies on secondary sources to assess patterns, outcomes, and financing mechanisms across regions and countries. A review-based methodology is widely used in irrigation economics, water policy, and development studies to evaluate long-term investment trends, institutional arrangements, and financing models that are not easily captured through single-country empirical datasets. This approach allows for cross-regional comparison and contextual interpretation of irrigation financing outcomes.

Literature Search Strategy: Academic literature was sourced from major scholarly databases, including Scopus, Web of Science and Google Scholar. Search terms included combinations of: irrigation financing, irrigation investment, agricultural water management, food security, climate adaptation, public–private partnerships, blended finance, farmer-led irrigation, and irrigation development.

To complement peer-reviewed literature, the study also reviewed grey literature from reputable international and regional institutions, including the Food and Agriculture Organization, World Bank, African Development Bank, IFAD, OECD, and IPCC. These sources were included due to their extensive empirical databases, sector diagnostics, and policy evaluations relevant to irrigation financing and food security.

Inclusion and Exclusion Criteria: To ensure relevance and quality, studies were selected based on the following criteria: Inclusion Criteria, Peer-reviewed journal articles, institutional reports, and policy studies. Publications focusing on irrigation financing models, investment outcomes, or food security implications. Studies published primarily between 2000 and 2025, with earlier seminal works included where necessary.

Exclusion Criteria: Studies focusing exclusively on engineering design without financing or policy dimensions, Opinion pieces lacking empirical or analytical grounding, and Project-specific reports without broader applicability or evaluative content.

Analytical Framework: The analysis employed a comparative analytical framework linking irrigation financing models to observed outcomes in irrigation coverage, food security, and agricultural performance. Financing models were categorized into five broad types: Public sector–led financing; Public–Private Partnerships (PPPs); Blended finance and development partner support; Farmer-led and user-financed irrigation; and Climate and green financing instruments. Each model was assessed against key analytical dimensions derived from the literature, including: Scale and sustainability of investment, Institutional and governance requirements, Affordability and farmer participation, Contribution to food security and resilience, and Applicability to low- and middle-income country contexts.

Regional comparisons were undertaken to identify systematic differences between food-secure regions (e.g., Europe and North America), high-irrigation but moderately food-secure regions (e.g., East and South Asia, MENA), and low-irrigation, food-insecure regions (e.g., Sub-Saharan Africa).

Use of Comparative Regional Data: To contextualize empirical findings, the study draws on secondary regional datasets on population, arable land, irrigation coverage, food security indices, and cumulative irrigation investment (1980–2025). These data were synthesized into Table 1, which provides a comparative overview of regional irrigation and food security outcomes. Rather than conducting statistical estimation, the study uses these data descriptively to identify patterns, contrasts, and policy-relevant relationships, consistent with the study's qualitative and comparative design.

Kenya as a Policy Application Case: Kenya is used as a policy application case, rather than as a site for primary empirical estimation. Insights from global and regional experiences are assessed in relation to Kenya's irrigation potential, climate vulnerability, food import dependency, and institutional context as documented in government reports and development partner studies. This approach allows the study to draw context-specific policy implications while maintaining the broader comparative perspective required for generalizability.

Limitations of the Study: As a review-based study, the analysis is subject to several limitations. First, reliance on secondary data means that findings reflect the quality and scope of existing literature. Second, variations in data definitions and reporting across regions limit direct quantitative comparability. Finally, while the study identifies associations between irrigation financing and food security outcomes, it does not estimate causal effects. Despite these limitations, the methodology is appropriate for achieving the study's objectives of synthesizing global evidence and informing policy design in Kenya.

4. RESULTS

4.1. INTRODUCTION

This chapter presents the findings of the systematic and comparative review of empirical studies on irrigation financing, structured around five dominant financing models identified in the literature: public sector–led financing; public–private partnerships (PPPs); blended finance and development partner support; farmer-led and user-financed irrigation; and climate and green financing instruments. The analysis synthesizes global and African evidence, drawing on studies that met the predefined inclusion criteria and were retained following the PRISMA-guided screening process. The focus is on identifying patterns, performance outcomes, institutional requirements, and policy-relevant lessons, with particular relevance to developing and climate-vulnerable contexts such as Kenya. From an initial pool of 598 records identified through database and grey literature searches, 414 records were screened after removal of duplicates. Following title and abstract screening, 102 full-text studies were assessed for eligibility. Sixty-four studies were excluded due to a lack of financing focus, insufficient empirical rigor, or limited policy relevance. A total of 38 studies were retained for qualitative synthesis, of which 24 met the full inclusion criteria.

4.2. PUBLIC SECTOR–LED FINANCING

The empirical studies reviewed show that public sector–led financing for irrigation development has been examined primarily through secondary data analysis, comparative project reviews, and institutional assessments, with limited use of large-scale primary surveys. Most global and regional studies—including those by Bhattarai and Narayanamoorthy [13], Barker and Molle [11], Rosegrant *et al*. [6], FAO [42], and FAO [1] rely on national-level datasets, project databases, policy documents, and cross-country case studies to assess the performance of publicly financed irrigation systems. These studies cover a wide geographic scope, including South and East Asia, Sub-Saharan Africa, the Middle East and North Africa, and Latin America, and focus on large-scale public investments in dams, canals, reservoirs, and command-area development. Project-level evidence from Inocencio *et al*. [16], based on a database of over 300 irrigation projects, provides comparative metrics on costs and performance across regions.

Across the reviewed literature, publicly financed irrigation is consistently associated with increases in irrigated area, cropping intensity, and agricultural output, particularly in Asia, where state-led irrigation expansion supported multiple cropping

seasons and staple food production. Kenya-specific evidence from Otieno *et al*. [17], based on secondary agricultural and irrigation statistics, indicates that publicly financed irrigation infrastructure can substantially increase maize yields relative to rain-fed production. At the farm level, Ammani [18] provides one of the few primary-data studies, using survey data from 94 small-scale irrigated farmers in Nigeria to show that publicly supported irrigation systems generate positive net returns and benefit–cost ratios for irrigated maize and tomato production, despite high input and energy costs.

Methodologically, the evidence also documents recurrent performance characteristics of public irrigation systems. Several studies report high capital costs per hectare, particularly in Sub-Saharan Africa, alongside low financial cost recovery for operation and maintenance, with user fees covering only a fraction of recurrent costs. Utilization rates of public irrigation schemes are frequently reported to be below full design capacity, while institutional and governance assessments highlight variability in management effectiveness across regions. Collectively, the reviewed studies provide a detailed empirical record of the scale, productivity outcomes, cost structures, and operational characteristics of public sector–led irrigation financing, forming a quantitative and methodological baseline for comparison with alternative financing models in subsequent chapters.

Table 2 shows that public sector–led financing of irrigation generates substantial social and economic benefits, even where financial cost recovery remains low. Public irrigation investments consistently produce high social returns, reflected in increased food production, rural employment creation, price stabilization, and import substitution effects. Across multiple studies, economic rates of return (ERRs) frequently exceed 15–20%, largely driven by food security gains and employment effects rather than direct financial revenues. Large-scale public irrigation has been particularly impactful in Asia, where state-led expansion underpinned the Green Revolution and enabled food self-sufficiency through dams, canals, and command-area development, raising cropping intensity from one crop to two or three crops per year and contributing to poverty reduction.

At the same time, the findings document persistent performance and efficiency challenges associated with publicly financed irrigation systems. Many public schemes recover less than 30% of operation and maintenance (O&M) costs from users, requiring continued fiscal support, which in irrigation-dependent economies may amount to 1–2% of agricultural GDP annually. Underperformance of public schemes is widely attributed to weak institutional arrangements, inadequate O&M, limited farmer participation, and politically constrained water pricing, rather than a lack of economic viability. Utilization rates are often below design capacity, and water-use efficiency tends to decline where pricing and regulatory mechanisms are weak, particularly in contexts of groundwater development supported by public investment and energy subsidies.

Regional comparisons further highlight important cost and performance differentials. Public irrigation projects in Sub-Saharan Africa exhibit significantly higher unit capital costs—averaging USD 8,000–12,000 per hectare—compared to USD 2,000–4,000 per hectare in South and East Asia, alongside lower productivity and scheme performance. In Kenya, irrigation development remains heavily dependent on national budget financing for dams, water pans, and irrigation schemes. Empirical evidence indicates that irrigation can increase maize yields by 100–400% relative to rain-fed agriculture; however, expansion has been constrained by high upfront capital costs, weak cost recovery, and reliance on public funding. The findings also show that while purely public, scheme-led irrigation has delivered limited expansion in some regions, farmer-led systems are growing more rapidly but continue to depend on public investment in bulk water infrastructure, regulation, and support services.

The studies reviewed are summarized in Annexure I.

4.3. PUBLIC–PRIVATE PARTNERSHIPS (PPPs)

The empirical literature on PPPs in irrigation presents mixed but context-specific findings. PPPs have been most successful in middle-income countries with relatively strong regulatory frameworks and institutional capacity, particularly in irrigation management, rehabilitation, and bulk water delivery rather than greenfield infrastructure development. Case studies from Morocco and Egypt indicate that PPP arrangements improved operational efficiency, reduced fiscal pressure on governments, and enhanced service delivery where risks were clearly allocated and contracts effectively enforced.

In contrast, evidence from Sub-Saharan Africa highlights significant constraints to PPP implementation in irrigation. Limited farmer ability and willingness to pay, political sensitivity around water tariffs, and weak regulatory oversight have undermined the financial viability of PPPs. As a result, fully commercial PPP models have rarely succeeded in low-income and smallholder-dominated agricultural systems. Studies consistently find that PPPs are more viable when public financing covers initial capital investment, while private partners focus on operations, maintenance, and performance-based service delivery.

The findings suggest that PPPs should be viewed as complementary instruments rather than substitutes for public investment. Their success depends on strong public institutions, appropriate risk-sharing mechanisms, and affordability safeguards for farmers.

The studies reviewed are summarized in Annexure II.

4.4. BLENDED FINANCE AND DEVELOPMENT PARTNER SUPPORT

Blended finance, combining public resources, concessional loans, grants, and limited private capital, has emerged as a dominant financing mechanism for irrigation development in low- and middle-income countries, particularly in Sub-Saharan Africa. Empirical studies show that blended finance has enabled irrigation investments that would otherwise be commercially unviable, including smallholder schemes and climate-resilient infrastructure. Development of partner-supported irrigation projects in countries such as Kenya, Ethiopia, and Ghana has improved water access, crop yields, and household incomes when aligned with national agricultural strategies.

Despite these gains, the findings also highlight significant limitations. Blended finance initiatives often suffer from donor dependence, fragmented project implementation, and weak sustainability once external financing ends. In several cases, irrigation schemes experienced performance declines after donor withdrawal due to inadequate domestic financing and institutional capacity. The literature emphasizes that blended finance is most effective when it serves as a catalytic instrument that mobilizes domestic public and private resources and strengthens national institutions, rather than functioning as a permanent substitute for domestic financing.

Overall, the results indicate that blended finance plays a critical transitional role in irrigation development but must be embedded within coherent national financing frameworks to achieve scale and sustainability.

The studies reviewed are summarized in Annexure III.

4.5. FARMER-LED AND USER-FINANCED IRRIGATION

Farmer-led and user-financed irrigation emerges from the empirical evidence as one of the most dynamic and demand-responsive financing models, particularly for small-scale irrigation. Studies from South Asia document the rapid expansion of irrigation through private farmer investment in wells, pumps, and micro-irrigation technologies, resulting in substantial productivity gains and poverty reduction. These investments were characterized by relatively low public costs and strong alignment with farmer needs.

In Africa, farmer-led irrigation remains underdeveloped but shows significant potential. Empirical studies indicate that the main constraints are limited access to finance, energy, markets, and extension services rather than a lack of farmer demand. Where these constraints were addressed through credit schemes, input support, or market linkages, small-scale irrigation expanded rapidly and improved farm incomes.

However, the findings also identify risks associated with unregulated farmer-led irrigation, including groundwater depletion, inequitable access, and environmental degradation. Consequently, the literature emphasizes the need for supportive public policies that combine access to finance with regulation, water governance, and extension services to ensure sustainability and equity.

The studies reviewed are summarized in Annexure IV.

4.6. CLIMATE AND GREEN FINANCING INSTRUMENTS

The reviewed empirical literature shows that climate and green financing have been increasingly applied to irrigation development across the world, primarily through grants, concessional loans, guarantees, and blended financing instruments. Most studies rely on portfolio-level evaluations, project performance assessments, and cross-country syntheses, drawing on secondary datasets from climate funds, development partners, and multilateral institutions, supplemented by case studies and stakeholder consultations. Evidence from FAO [30], the Green Climate Fund [40], and IFAD [31] indicates that climate-financed irrigation projects are typically integrated with climate-smart technologies and adaptation objectives, with a strong focus on smallholder systems and ASAL regions.

Across the studies, climate and green financing are consistently associated with improvements in water-use efficiency, agricultural productivity, and climate resilience. Reported quantitative outcomes include water savings of 20–50 percent, yield increases of 30–70 percent, and increases in cropping intensity from 1 to 2-3 seasons per year in climate-financed irrigation schemes. Several studies also report that climate finance instruments improved project bankability by lowering perceived climate risks and enabling co-financing from public and private sources. Projects designed as climate finance achieved higher adaptive capacity indicators, improved system reliability, and enhanced operation and maintenance performance compared to non-climate-aligned investments.

The empirical record further indicates that climate and green financing have supported scalability and fiscal efficiency in irrigation development. Studies by the World Bank [3,41], OECD [4,28], and AfDB [4,43] show that climate-aligned irrigation investments mobilized additional financing through leverage ratios ranging from 1:3 to 1:5, reduced implementation timelines by nearly 30 percent, and improved long-term sustainability through environmental safeguards and climate screening requirements.

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At the smallholder level, IFAD (2019) documents that climate-financed irrigation interventions increased household incomes by nearly 40 percent and reduced vulnerability to rainfall variability. Overall, the findings document measurable performance improvements in efficiency, resilience, and financial sustainability associated with climate and green financing for irrigation development.

The studies reviewed are summarized in Annexure V.

4.7. SYNTHESIS OF CHAPTER FINDINGS

Across all financing models, the findings demonstrate that no single approach is universally optimal. Successful irrigation development depends on aligning financing instruments with institutional capacity, farmer affordability, climatic conditions, and governance frameworks. Public sector financing remains foundational, while PPPs, blended finance, farmer-led investment, and climate finance each play complementary roles. For countries such as Kenya, the central policy challenge lies not in selecting one financing model, but in designing a diversified and coherent irrigation financing framework that integrates these approaches within a broader agricultural and food systems transformation agenda.

5. POLICY OPTIONS FOR STRENGTHENING IRRIGATION FINANCING IN KENYA

5.1. INTRODUCTION

The empirical evidence reviewed in Chapter Four demonstrates that irrigation development outcomes are shaped not merely by the volume of investment, but by the structure, sustainability, and institutional alignment of financing mechanisms. For Kenya, where irrigated agriculture accounts for 5% remains predominantly rain-fed and climate vulnerability is increasing, irrigation expansion is central to achieving food security, reducing import dependence, and supporting inclusive rural transformation. However, Kenya's irrigation financing landscape remains fragmented, heavily reliant on public budgets and development partner support, and constrained by weak cost recovery and limited private sector participation. This chapter proposes policy options for strengthening irrigation financing in Kenya, drawing explicitly on global and African experiences and tailoring them to Kenya's institutional, fiscal, and socio-economic context.

5.2. STRENGTHENING PUBLIC SECTOR–LED IRRIGATION FINANCING

Sustain public financing for core irrigation public goods: Public sector financing will remain the foundation of irrigation development in Kenya, particularly for bulk water infrastructure such as dams, weirs & intakes, conveyance canals & pipes, and flood control works. These investments exhibit strong public good characteristics and are unlikely to attract private financing without substantial public support. Public investment should continue to prioritize dams, reservoirs, bulk water conveyance, canals, and command-area development, given the consistently high social and economic returns (ERRs above 15–20%) documented across regions.

Evaluate irrigation investments based on social returns rather than financial cost recovery: Project appraisal frameworks should explicitly incorporate food security, employment creation, price stabilization, and import substitution benefits, recognizing irrigation as a public good rather than a purely commercial investment.

Reorient public spending from expansion alone to rehabilitation and modernization of public irrigation schemes: Empirical evidence supports shifting public funds toward rehabilitating underperforming schemes, improving conveyance efficiency, and upgrading to water-saving technologies to raise utilization and productivity.

Strengthen institutional framework for O&M: Persistent underperformance of public schemes highlights the need for a strong institutional framework for O&M collection, professional scheme management, and clear accountability mechanisms to address utilization rates.

Avoid over-reliance on user charges for cost recovery: Given that many public schemes recover less than 30% of O&M costs, governments should fund recurrent costs through public budgets while introducing efficiency incentives, rather than pursuing full cost recovery through politically constrained water pricing.

Improve project design, appraisal, and cost control mechanisms: High unit capital costs in Sub-Saharan Africa call for better feasibility studies, realistic scheme sizing, standardized design templates, and stronger implementation capacity to enhance capital efficiency.

Integrate irrigation financing with governance and regulatory reforms: Public irrigation expansion should be accompanied by reforms in water allocation, groundwater regulation, and energy pricing to prevent resource over-extraction and declining water-use efficiency.

Promote farmer participation and co-management in publicly financed schemes: Evidence shows that limited farmer involvement undermines performance; participatory management and strengthened Water User Associations (WUAs) should be embedded in public irrigation investments.

Use public financing to crowd in complementary financing models: Public funds should increasingly play an enabling role, especially by lowering entry barriers and de-risking investments, while allowing space for farmer-led irrigation, PPPs, and blended finance to scale irrigation development.

Align public irrigation financing with climate adaptation objectives: Given rising climate vulnerability, irrigation investments should integrate climate risk screening, resilience measures, and environmental safeguards to ensure long-term sustainability.

5.3. STRATEGIC USE OF PUBLIC–PRIVATE PARTNERSHIPS (PPPs)

The findings indicate that PPPs in irrigation are most effective when applied selectively and under strong public oversight. For Kenya, PPPs should not be pursued as a replacement for public financing of core irrigation infrastructure, but rather as a mechanism to improve efficiency in specific segments of the irrigation value chain.

Use public funds to de-risk large-scale irrigation PPPs through the provision of public goods. Public financing should prioritize dams, reservoirs, bulk water conveyance, and climate-resilient infrastructure to de-risk PPPs in large-scale irrigation projects, enabling private participation in food production, scheme management and service delivery.

Apply PPPs to Farmer-Led Irrigation Development (FLID) through targeted subsidies and de-risked financing. Public funds should subsidize irrigation equipment and smart technologies, while commercial banks and DFIs provide de-risked credit supported by guarantees and concessional finance to enable farmers to access irrigation equipment and services.

Adopt concession and management-based PPP models with balanced public risk sharing. Concession and management contracts, supported by public capital contributions and risk-sharing mechanisms, should be prioritized over fully commercial PPPs to improve operational efficiency and financial sustainability. Capacity building within PPP units and irrigation agencies is critical to designing, negotiating, and managing such partnerships effectively.

Introduce differentiated irrigation tariff structures by project scale and user category

Tariffs should be designed to reflect differences between large-scale commercial schemes, community irrigation projects, and smallholder systems, ensuring affordability for smallholders while supporting cost recovery in larger schemes.

Position PPPs as complementary instruments within a hybrid irrigation financing framework. PPPs should be integrated with public financing, blended finance, climate finance, and farmer-led investment models, leveraging public funds to crowd in private capital while preserving efficiency and equity objectives.

Management of stakeholders in the implementation of large infrastructure projects. Where irrigation development involves multiple stakeholders with diverse and overlapping roles, it is necessary for the relevant host ministry or department to adopt an appropriate Government-Owned Enterprises (GOE) framework to formally vest irrigation assets, mobilize and manage financing, collect and retain revenues, and oversee operation and maintenance (O&M). Such an institutional arrangement provides legal clarity on asset ownership, enables ring-fencing of irrigation revenues, improves financial accountability, and facilitates structured engagement with private partners, communities, and development partners—thereby enhancing the sustainability and performance of irrigation investments.

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Strengthen institutional and human capacity for PPP preparation and implementation. Targeted capacity building is required across public agencies, Irrigation Water User Associations, and local institutions to improve project preparation, contract management, financial oversight, and long-term operation and maintenance of irrigation assets.

5.4. SCALING BLENDED FINANCE AND DEVELOPMENT PARTNER SUPPORT

Blended finance will continue to play a critical role in bridging Kenya's irrigation financing gap, particularly for smallholder-oriented and climate-resilient investments. However, evidence suggests that blended finance must be deployed strategically to avoid long-term donor dependence.

A key policy option is to use concessional finance and grants as catalytic instruments to crowd in domestic public and private investment. This can be achieved by prioritizing blended finance for project preparation, risk mitigation, and initial capital costs, while gradually transitioning to domestic financing sources for recurrent expenditures.

Kenya should also strengthen coordination among development partners to reduce fragmentation and align external financing with national priorities. Establishing a centralized irrigation financing coordination mechanism—anchored within the State Department for Irrigation—would enhance coherence, transparency, and impact.

5.5. PROMOTING FARMER-LED AND USER-FINANCED IRRIGATION

Farmer-led irrigation offers significant potential for rapid and cost-effective expansion of irrigated agriculture in Kenya, particularly through small-scale and micro-irrigation technologies. However, access to finance remains a binding constraint for many farmers.

Policy options include expanding access to affordable credit for irrigation investments through targeted credit lines, guarantee schemes, and partnerships with financing institutions. Integrating irrigation finance with extension services and market linkages would further enhance returns to farmer investment.

At the same time, Kenya should strengthen water governance and environmental regulation to mitigate risks associated with the unregulated expansion of farmer-led irrigation, particularly groundwater depletion or over extraction. This requires improved data systems, licensing frameworks, and enforcement mechanisms, balanced with incentives for efficient water use.

5.6. LEVERAGING CLIMATE AND GREEN FINANCING INSTRUMENTS

Climate and green finance represent an underutilized opportunity for strengthening irrigation financing in Kenya. Given the role of irrigation as a climate adaptation strategy, Kenya is well-positioned to access international climate funds for water-efficient and climate-resilient irrigation investments.

A critical policy option is to enhance national capacity for climate-responsive project preparation, including feasibility studies, climate risk assessments, and monitoring frameworks that meet fund accreditation requirements. Integrating irrigation investments into Kenya's Nationally Determined Contribution (NDC) and climate adaptation plans would further strengthen access to climate finance.

Additionally, Kenya should explore innovative green financing instruments, such as green bonds and results-based financing, to support scalable irrigation investments while promoting environmental sustainability.

5.7. INTEGRATED IRRIGATION FINANCING FRAMEWORK FOR KENYA

The overarching policy implication is that Kenya should adopt an integrated and diversified irrigation financing framework, rather than relying on any single model. Public financing should anchor the system, PPPs should enhance efficiency, blended finance should catalyze investment, farmer-led irrigation should drive grassroots expansion, and climate finance should strengthen resilience and sustainability.

Institutional coordination, policy coherence, and capacity building are essential to operationalizing this framework. Strengthening data systems, monitoring and evaluation, and stakeholder engagement will further improve accountability and learning.

6. CONCLUSION AND POLICY IMPLICATIONS

6.1. CONCLUSION

This study set out to examine global experiences in irrigation financing and to distill policy-relevant lessons applicable to Kenya's efforts to accelerate climate-resilient agricultural transformation through irrigation. Using a qualitative, review-based methodology grounded in a PRISMA-guided selection of empirical studies, the analysis synthesized evidence across multiple regions and financing models, including public sector–led financing, PPPs, blended finance, farmer-led irrigation, and climate and green financing instruments.

The findings demonstrate that irrigation development is a critical enabler of food security, agricultural productivity, and climate resilience, particularly in regions characterized by high rainfall variability and structural vulnerability. However, the evidence also shows that irrigation outcomes are not determined solely by investment levels. Rather, outcomes depend on the alignment of financing models with institutional capacity, governance quality, farmer affordability, and broader agricultural and market systems.

Globally, regions that have achieved sustained irrigation expansion and improved food security—such as East and South Asia—have done so through long-term, predictable public investment complemented by gradual institutional reform and strong linkages to agricultural support services. In contrast, Sub-Saharan Africa continues to exhibit low irrigation coverage and persistent food insecurity, largely due to fragmented financing, weak institutions, underfunded operation and maintenance systems, and heavy reliance on government funding and short-term donor funding.

The study further finds that no single irrigation financing model is universally optimal. Public sector financing remains indispensable for bulk water infrastructure, while PPPs can improve efficiency when applied selectively to operations and service delivery under strong regulatory oversight. Blended finance plays a critical catalytic role but risks donor dependence if not embedded in domestic financing frameworks. Farmer-led irrigation offers a highly responsive and cost-effective pathway for small-scale expansion but requires access to finance, markets, and effective water governance. Climate and green finance provide emerging opportunities to enhance resilience and sustainability, though access remains constrained by limited project preparation capacity.

Applied to Kenya, these findings highlight that the country's irrigation challenge is fundamentally institutional and financial rather than technical. Kenya possesses significant irrigation potential, yet expansion has been constrained by episodic public investment, weak cost recovery, limited private participation, and fragmented development partner support. Addressing these constraints requires a deliberate shift toward a diversified and coherent irrigation financing framework anchored in strong public leadership.

6.2. POLICY IMPLICATIONS FOR KENYA

The central policy implication of this study is that strengthening irrigation financing in Kenya requires moving beyond isolated project interventions toward an integrated, long-term financing strategy. Public sector financing must provide the backbone for irrigation development, supported by predictable budg*et al*locations and adequate provision for operation and maintenance. PPPs should be deployed strategically to enhance efficiency rather than to replace public investment. Blended finance should be used to crowd in domestic resources and strengthen institutions, not to perpetuate donor dependence. Farmer-led irrigation should be actively promoted through access to finance, extension services, and market linkages, while climate and green financing should be mainstreamed into national irrigation and agricultural strategies.

Importantly, irrigation financing reform must be embedded within broader agricultural transformation and food system policies. Without complementary investments in markets, research, extension, and rural infrastructure, irrigation alone will not deliver sustained food security gains. Strengthening institutional coordination, data systems, and monitoring and evaluation mechanisms is therefore essential to maximize the returns to irrigation investment.

6.3. CONTRIBUTION OF THE STUDY

This study contributes to the literature by providing a structured, comparative synthesis of irrigation financing models and their outcomes, with explicit attention to institutional and policy dimensions often overlooked in technical analyses. By applying a PRISMA-guided review approach to irrigation financing, a field where such systematic synthesis is limited, the study enhances transparency and rigor in evidence selection. The Kenya-focused policy application further bridges the gap between global evidence and national decision-making.

6.4. LIMITATIONS AND AREAS FOR FURTHER RESEARCH

While the study offers valuable insights, it is subject to several limitations. As a review-based analysis, it relies on the quality and availability of existing literature, which is uneven across regions and financing models, particularly in Africa. The study also does not estimate causal impacts of specific financing instruments on food security outcomes. Future research could address these gaps through country-level empirical studies, impact evaluations of irrigation financing reforms, and quantitative analysis of the cost-effectiveness of different financing models in Kenya and comparable contexts.

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CONFLICT OF INTEREST

None.

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REFERENCES

1. Food and Agriculture Organization of the United Nations, 2022. The state of food and agriculture 2022: Leveraging automation in agriculture for transforming agrifood systems. FAO. https://www.fao.org
2. Intergovernmental Panel on Climate Change, 2023. AR6 synthesis report: Climate change 2023. IPCC. https://www.ipcc.ch
3. World Bank, 2021. Water in agriculture: Global challenges and solutions. https://www.worldbank.org
4. African Development Bank, 2020. African Economic Outlook 2020: Developing Africa's workforce for the future. African Development Bank Group. https://www.afdb.org
5. Food and Agriculture Organization of the United Nations (FAO), 2023. FAOSTAT statistical database. FAO. https://www.fao.org/faostat
6. Rosegrant MW, *et al*., 2009. Water for agriculture: Maintaining food security under growing scarcity. Annual Review of Environmental Resources; 34, 205–22. https://doi.org/10.1146/annurev.environ.030308.090351
7. You L, *et al*., 2011. What is the irrigation potential for Africa? A combined biophysical and socioeconomic approach. Food Policy; 36(6), 770–82. https://doi.org/10.1016/j.foodpol
8. Shah T, 2009. Taming the anarchy: Groundwater governance in South Asia. Routledge. https://doi.org/10.4324/9781849770864
9. Organisation for Economic Co-operation and Development, 2025. Rebuilding agricultural policy frameworks. OECD Publishing. https://www.oecd.org
10. Food and Agriculture Organization of the United Nations (FAO), 2008. An introduction to the basic concepts of food security. https://www.fao.org
11. Barker R, Molle F, 2004. Evolution of irrigation in South and Southeast Asia. In: International Water Management Institute (IWMI) Research Report No. 5. IWMI. https://www.iwmi.cgiar.org
12. FAO & International Water Management Institute, 2011. Smallholder irrigation in Africa: Lessons from farmers. FAO/IWMI. https://www.iwmi.cgiar.org
13. Bhattarai M, Narayanamoorthy A, 2003. Impact of irrigation on agricultural growth and poverty alleviation: Macro-level analyses in India. Water Policy; 6(5), 449–64. https://doi.org/10.2166/wp.2004.0028
14. Molle F, Berkoff J, 2007. Water pricing in irrigation: Mapping the debate in the light of experience. Irrigation and Drainage; 56(3), 121–38. https://doi.org/10.1002/ird.309
15. Shah T, *et al*., 2012. Political economy of groundwater governance in South Asia. Hydrogeology Journal; 20(3), 471–86. https://doi.org/10.1007/s10040-011-0834-9
16. Inocencio A, *et al*., 2007. Costs and performance of irrigation projects: A comparison of sub-Saharan Africa and other developing regions. IWMI Resources Report 109. https://www.iwmi.cgiar.org
17. Otieno D, *et al*., 2015. Irrigation in Kenya: A solution to food security challenges? Nairobi: Tegemeo Institute of Agricultural Policy and Development.
18. Ammani AA, 2015. An analysis of the economics of irrigated crop production in Kaduna State, Nigeria. Journal of Development and Agricultural Economics; 7(6), 202–209. https://doi.org/10.5897/JDAE2015.0640
19. World Bank, 2017. Public–private partnerships for irrigation: Lessons learned. https://www.worldbank.org
20. Marin P, 2009. Public–private partnerships for urban water utilities: A review of experiences in developing countries. https://doi.org/10.1596/978-0-8213-7956-1
21. Rey D, *et al*., 2018. Optimizing water trading opportunities: Economic analysis of irrigation modernization and water markets. Agricultural Water Management; 196, 24–36. https://doi.org/10.1016/j.agwat.2017.10.012

OPEN ACCESS

22. Hall D, Lobina E, 2012. Water companies, profits, and corruption. In: Public Services International Research Unit. https://www.psiru.org

23. Dayu Irrigation Group, 2016. Yuanmou high-efficiency water-saving irrigation project: Public–private partnership case study. Beijing: Dayu Irrigation Group.

24. Food and Agriculture Organization of the United Nations & World Bank, 2016. Public–private partnerships in irrigation: Lessons from Morocco and Egypt. Washington, DC.

25. Food and Agriculture Organization of the United Nations & World Bank, United Nations Industrial Development Organization, & Partners. 2025. Jowhar Offstream Storage Programme (JOSP): Pre-feasibility study. Rome.

26. World Bank, 2019. Revitalizing irrigation in Sub-Saharan Africa: Policy, investment, and institutional reforms. Washington, DC: World Bank.

27. Njagi P, *et al*., 2025. Public–private partnerships and large-scale irrigation projects in Kenya: Lessons from Galana-Kulalu. African Journal of Agricultural Resource Economics; 20(1), 45–60.

28. Organisation for Economic Co-operation and Development, 2018. Making blended finance work for the Sustainable Development Goals. https://doi.org/10.1787/9789264288768-en

29. International Fund for Agricultural Development, 2018. Innovative financing for smallholder irrigation: Lessons from Africa. Rome: IFAD.

30. Food and Agriculture Organization of the United Nations, 2021. Climate-smart agriculture case studies 2021: Projects from around the world. https://doi.org/10.4060/cb5359en?

31. International Fund for Agricultural Development, 2019. Scaling climate-resilient irrigation for smallholders. https://www.ifad.org/en/initiatives/adaptation-smallholder-agriculture-programme

32. Mukherji A, *et al*., 2012. Irrigation reform in Asia: A review of 108 cases. International Journal of Water Resource Development; 28(4), 553–75. https://doi.org/10.1080/07900627.2012.703132

33. Woodhouse P, *et al*., 2017. African farmer-led irrigation development: Reframing agricultural policy and investment? Journal of Peasant Studies; 44(1), 213–33. https://doi.org/10.1080/03066150.2016.1219719

34. Xie H, *et al*., 2014. Estimating the potential for expanding smallholder irrigation in Sub-Saharan Africa. Agricultural Water Management; 131, 183–93. https://doi.org/10.1016/j.agwat.2013.08.011

35. Merrey DJ, Lefore N. 2018. Improving irrigation in sub-Saharan Africa: Farmer-led approaches. Irrigation and Drainage; 67(4), 527–40. https://doi.org/10.1002/ird.2263

36. Lefore N, *et al*., 2019. Sustainable and equitable growth in farmer-led irrigation in Sub-Saharan Africa: What will it take? Water Alternatives; 12(1), 156–68.

37. International Water Management Institute, 2020. Farmer-led irrigation development in Africa: Synthesis of empirical evidence. http://www.iwmi.cgiar.org/Publications/index.aspx

38. Lefore N, *et al*., 2022. Scaling farmer-led irrigation: Policy and investment priorities. Water Alternatives; 12(1), 156-168.

40. Green Climate Fund, 2021. Climate-resilient irrigation financing: Portfolio performance review. Songdo.

41. World Bank, 2020. Climate finance for water and irrigation: Opportunities and challenges. Washington, DC.

42. Food and Agriculture Organization of the United Nations, 2011. The state of the world's land and water resources for food and agriculture (SOLAW). Managing systems at risk. https://www.fao.org

43. World Bank & African Development Bank, 2018. Financing climate-resilient irrigation in Africa. World Bank/AfDB. https://www.worldbank.org

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Annexures

Annexure I: Studies on Public Sector–Led Financing

Author(s)	Countries / Regions Covered	Methodology (Data, Sample & Respondents)	Key Findings on Public Sector–Led Financing	Key policy findings
Bhattarai, M. & Narayanamoorthy, A. (2003)	South Asia (India); comparative global evidence	Secondary data analysis and econometric evaluation using national irrigation investment, output, and price data; macro- and sector-level indicators.	- Public irrigation investment generates high social returns through increased food production, rural employment, price stabilization, and import substitution, despite low financial cost recovery. Irrigation functions as a public good. - ERRs frequently exceeded 15–20%, driven by food security gains, employment, and price stabilization.	Justify continued public financing of irrigation infrastructure; evaluate projects based on social returns, not only financial recovery; complement investments with productivity-enhancing inputs.
Barker, R. & Molle, F. (2004)	Global (Asia, Africa, MENA)	Comparative institutional analysis and review of multiple country case studies; no primary survey	- Publicly financed irrigation schemes often underperform due to weak institutions, poor O&M, and limited farmer participation, rather than a lack of economic viability. - Many public schemes recover <30% of O&M costs from users	Pair public investment with institutional reform, participatory management, and incentives for efficient water use.
Rosegrant, M., Ringler, C. & Zhu, T. (2009)	Global (Asia, Sub-Saharan Africa, LAC)	Secondary data modeling (IFPRI global water and food models); national-level datasets	- Large-scale public irrigation significantly increased cropping intensity, staple food output, and poverty reduction, especially in Asia; impacts in Africa remain lower due to scale and governance constraints. - Cropping intensity from 1 crop to 2–3 crops per year.	Sustain public investment but reorient spending toward modernization, efficiency, and climate resilience, particularly in Africa.
FAO (2011)	East & South Asia	Sectoral review and synthesis of national irrigation statistics, policy documents, and project reports	- State-led irrigation expansion was central to the Green Revolution, driving productivity gains and food self-sufficiency through dams, canals, and command-area development. - Cropping intensity from 1 crop to 2–3 crops per year.	Public financing remains essential for bulk infrastructure; future investments should focus on rehabilitation, modernization, and water-saving technologies.
Inocencio, A. *et al*. (2007)	Sub-Saharan Africa; Asia; MENA	Comparative project-level analysis of over 300 irrigation projects using	- Public irrigation projects in SSA exhibit higher unit costs and lower performance than in Asia, largely due to design, scale, and weak	Improve project appraisal, design standards, and institutional capacity; avoid

		secondary project databases	implementation capacity rather than financing levels alone. - Average capital costs: Sub-Saharan Africa: USD 8,000–12,000/ha & South & East Asia: USD 2,000–4,000/ha	over-scaled projects; prioritize cost-effective investments.
Otieno, D., Kirimi, L. & Odhiambo, W. (2015)	Kenya (Sub-Saharan Africa)	Secondary data analysis and policy review using national agricultural and irrigation statistics	- Kenya's irrigation development relies heavily on national budget financing for dams, water pans, and schemes; irrigation can increase maize yields by 100–400%, but expansion is constrained by high capital costs and poor cost recovery. - Irrigated maize yields can increase by 100–400% compared to rain-fed production.	Maintain public funding for core infrastructure while introducing innovative financing, private participation, and farmer cost-sharing mechanisms.
World Bank (2021)	Sub-Saharan Africa	Multi-country review and synthesis of project data, national statistics, and case studies	- Purely public, scheme-led irrigation has delivered limited expansion; farmer-led systems are expanding faster, but still depend on public investment in bulk water, regulation, and services. - Public irrigation often requires continued budgetary support for O&M, sometimes 1–2% of agricultural GDP annually in irrigation-dependent economies.	Shift public role from direct scheme ownership to enabling functions: regulation, bulk infrastructure, extension, and finance facilitation.
Molle, F. & Berkoff, J. (2007)	Asia; Africa; MENA	Comparative policy and institutional review; secondary datasets and case studies	- Public irrigation financing faces persistent challenges of low cost recovery and politically constrained water pricing, yet irrigation remains socially beneficial. - Many public schemes recover <30% of O&M costs from users	Avoid over-reliance on water charges; fund O&M through public budgets combined with efficiency incentives rather than full cost recovery.
Shah, T., Burke, J. & Villholth, K. (2012)	South Asia	Mixed-methods: secondary groundwater data, policy analysis, and country case studies	- Heavy public investment in irrigation and energy subsidies enabled massive groundwater expansion, boosting agricultural growth but causing resource over-extraction. - Public irrigation expansion increased output but often reduced water-use efficiency where pricing and regulation were weak.	Public financing must be aligned with strong water governance, regulation, and sustainability safeguards.
FAO (2022)	Global	Global synthesis report drawing on secondary datasets, country reports, and climate assessments	- Public sector–led irrigation remains critical under climate stress, but poorly governed investments risk environmental degradation and fiscal strain.	Integrate irrigation financing with climate adaptation, water governance, and environmental safeguards.

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			- Many public schemes operate at 50–70% of the designed command area due to maintenance and governance challenges.	
Ammani, A. A. (2015)	Nigeria (Sub-Saharan Africa)	Primary survey data from 94 smallholder farmers (maize and tomato); farm-level cost–benefit analysis	- Publicly supported irrigation enables economically viable smallholder production, with positive benefit–cost ratios despite high energy and input costs. However, reliance on public funding alone limits scalability. - Benefit–Cost Ratios: Maize: 1.49 & Tomato: 1.40	Use public funds to lower entry barriers, but complement with private finance, energy solutions, and cost-sharing models to scale irrigation.

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Annexure II: Studies on Public–Private Partnerships (PPPs)

Author(s)	Countries / Regions Covered	Methodology (Data, Sample & Respondents)	Key Findings on Use of PPPs in Irrigation Financing	Policy Recommendations
Marin, P. (2009)	Global (applications from LAC, Asia, SSA)	Comparative review of PPP contracts and case studies in water utilities; secondary data and project documentation	- PPPs improve efficiency, cost control, and service delivery where risks are clearly allocated; irrigation PPPs face challenges due to revenue uncertainty and farmer affordability. - Capital cost overruns reduced by 10–30%; improved O&M efficiency relative to public delivery	Apply PPPs selectively in irrigation, focusing on bulk water delivery and O&M, supported by public risk-sharing mechanisms.
World Bank (2017)	Morocco; Brazil; Peru; India	Comparative case study analysis of multiple irrigation PPPs using project reports and performance indicators	- PPPs enhanced service reliability, O&M efficiency, and cost recovery, particularly in water conveyance and scheme management. - ERR: 12–18%; O&M cost recovery: 80–100%; utilization 85–95%.	Use PPPs where regulatory frameworks are strong, and tariffs are partially cost-reflective; avoid full privatization of irrigation assets.
FAO & World Bank (2016)	Morocco (Guerdane); Egypt (selected schemes)	Case study review using secondary data, stakeholder interviews, and project evaluations	- Private participation improved water delivery efficiency and reduced system losses; fiscal pressure on governments declined. - Water delivery reliability >95%; system losses reduced by 20–30%	Structure PPPs with capital cost sharing, affordability safeguards, and credible public oversight.
World Bank (2019)	Morocco (MENA)	Project-level evaluation using operational data, financial records, and farmer outcomes	- Concession-based PPP improved service reliability, cropping intensity, and farmer incomes while reducing public fiscal burden. - FIRR: 8–12%; O&M recovery: ~100%; cropping intensity 1 → 2–3 crops/year	Adopt concession models for bulk water delivery with government support for upfront capital costs.
Dayu Irrigation Group (2016)	China (East Asia)	Project performance analysis using farm-level productivity data and system monitoring	- PPP irrigated 7,600 ha, increased cropping intensity (1 to 3–4 crops/year), improved water-use efficiency, and ensured sustainable O&M. - Cropping intensity 1 to 3–4 crops/year; water savings 30–50%; income increases 30–50%	Integrate PPPs with technology, farmer co-financing, and smart water management.
FAO, UNIDO *et al*. (2025)	Somalia (Horn of Africa)	Pre-feasibility study using technical assessments, institutional analysis, and stakeholder consultations	- PPPs offer viable solutions for rehabilitating irrigation in fragile contexts by improving O&M and cost recovery. - Scheme functionality increased from 25–65% to >80% (projected)	Use PPPs for rehabilitation and management, supported by donor guarantees and phased implementation.

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Author(s)	Countries / Regions Covered	Methodology (Data, Sample & Respondents)	Key Findings on Use of PPPs in Irrigation Financing	Policy Recommendations
Njagi, P., Ajwang, P. & Kabubo, C. (2025)	Kenya (SSA)	Mixed-methods case study: document review, interviews with public officials and private actors	- PPP design flaws, weak feasibility analysis, and political interference undermined performance. - Low utilization (<60%); delays and cost escalation	Anchor PPPs in robust feasibility studies, phased investment, and enforceable contracts.
Rey, D., Garrido, A. & Calatrava, J. (2018)	Europe; MENA	Econometric and institutional analysis using irrigation performance data	- PPPs improved efficiency where water rights and pricing were clearly defined; outcomes weakened under regulatory ambiguity. - Water use efficiency increased 20–40% under volumetric pricing	Strengthen water allocation systems and pricing frameworks before introducing PPPs.
OECD (2020)	Global	Cross-country policy and project review of PPP and blended finance models	- PPPs reduce fiscal exposure when risks are properly shared; irrigation PPPs require public support to manage demand risk. - Recurrent public O&M costs 40–70%	Use blended PPP models combining public finance with private efficiency.
Hall, D. & Lobina, E. (2012)	Global	Critical review of PPP performance using secondary datasets	- PPPs often face affordability and accountability challenges; efficiency gains are context-specific. - No consistent financial gains without public support	Retain strong public control and transparency in irrigation PPPs.
FAO (2022)	Global	Global synthesis of irrigation governance and climate assessments	- PPPs can enhance resilience but may exacerbate inequity if affordability and sustainability are not addressed. - Water efficiency increases **20–30%** where pricing is enforced	Integrate PPPs within climate adaptation and water governance frameworks.
World Bank (2021)	Sub-Saharan Africa; Asia	Portfolio review of irrigation PPP projects	- Many irrigation PPPs struggle to reach financial close due to weak institutions and farmer payment capacity. - Financial close rates <50% in SSA	Strengthen institutional capacity, guarantees, and off-take arrangements.
AfDB (2020)	Africa (Kenya, Morocco, Burkina Faso)	Project evaluation using blended finance and PPP case studies	- PPPs improved project bankability and accelerated implementation when supported by concessional finance. - Implementation timelines shortened by 15–25%	Combine PPPs with blended finance and development partner support.
Ammani, A. A. (2015)	Nigeria (SSA)	Primary survey of 94 smallholder farmers; farm-level cost–benefit analysis	- Irrigated farming is profitable but constrained by high upfront costs, supporting PPP-type risk-sharing arrangements. - BCR: 1.49 (maize); 1.40 (tomato)	Use PPPs to lower entry barriers and improve service delivery efficiency.

Author(s)	Countries / Regions Covered	Methodology (Data, Sample & Respondents)	Key Findings on Use of PPPs in Irrigation Financing	Policy Recommendations
FAO, UNIDO & Partners (2025)	Somalia (Horn of Africa)	Technical, financial, and institutional feasibility analysis	- PPPs are critical for sustaining rehabilitated irrigation assets in fragile and post-conflict contexts. - O&M cost recovery projected at 70–90%	Adopt donor-backed PPPs with phased risk transfer.

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Annexure III: Blended Finance and Development Partner Support

Author(s)	Countries / Regions Covered	Methodology (Data, Sample & Respondents)	Key Findings on Use of Blended Finance & Development Partner Support	Key Quantitative Statistics (ROI / Efficiency / Performance / O&M)	Policy Recommendations on Blended Finance & Donor Support
World Bank (2019)	India; Morocco; Brazil	Portfolio-level project review; secondary financial and operational data	Blended finance reduced fiscal exposure and improved the bankability of irrigation projects by crowding in private capital	ERR 12–20%; public share of capital costs reduced by 30–50%	Use public funds for de-risking and guarantees, not full financing
World Bank & IFAD (2017)	Kenya; Ethiopia; Tanzania (SSA)	Case studies; project M&E data; farmer surveys	Blended finance lowered entry barriers for smallholders and accelerated the adoption of irrigation technologies	Irrigation adoption increased from 20–40%; yields increased 30–60%	Blend grants with concessional credit and farmer contributions
IFAD (2018)	Rwanda; Senegal; Mali	Multi-country case studies; institutional analysis	Donor-supported blended finance improved irrigation access and strengthened farmer organizations	Scheme utilization increased to 70–90%; BCRs >1.2	Combine finance with institutional strengthening and extension
AfDB (2020)	Kenya; Morocco; Burkina Faso	Project evaluation reports; financial analysis	Blended finance improved project bankability and accelerated implementation	Implementation time reduced by 15–25%; private capital leveraged increased from 1:2 to 1:4	Use concessional finance to crowd-in private investors
IFAD & FAO (2019)	East & West Africa	Comparative programme review	Blended finance improved the productivity and sustainability of small-scale irrigation	Productivity increased by 20–50%; O&M recovery up to 60–80%	Align blended finance with WUA strengthening
World Bank (2017)	India; Peru	Comparative fiscal analysis	Blended finance reduced long-term public O&M obligations	Recurrent public O&M costs reduced by 30–60%	Shift public spending from O&M to capital support
OECD (2018)	Global	Cross-country blended finance portfolio analysis	Blended finance mobilizes private capital where risks are high	Average leverage ratio 1:3	Improve project preparation to increase leverage
FAO (2022)	Global	Global synthesis of land and water datasets	Blended finance is essential for climate-resilient irrigation, but requires strong governance	Water efficiency increased by 20–30%	Integrate blended finance into climate and water governance
AfDB (2020)	Africa	Blended finance programme evaluation	Donor guarantees improved private sector confidence	Financial close success increases by >70%	Use guarantees and concessional tranches

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World Bank (2021)	SSA & Asia	Portfolio review of irrigation investments	MFD approach improved the sustainability of irrigation finance	Fiscal burden reduces by 20–40%	Prioritize blended finance over pure public funding
Inocencio *et al*. (2007)	SSA; Asia; MENA	Database of 300+ irrigation projects	Projects with blended support performed better than fully public ones	Capital cost efficiency increases by 15–25%	Improve design and financing mix
You *et al*. (2011)	Africa	Spatial-economic modeling using secondary data	Large irrigation potential exists, but needs blended financing	Potential expansion >20 million ha	Use blended finance to unlock scalable investment
OECD (2020)	Global	Policy and project review	Blended finance is effective in the water sector, where PPPs alone fail	Cost recovery increases by 20–40%	Combine public finance, donor funds, and PPPs
FAO (2021)	East Africa	Case studies; project performance data	Climate-smart irrigation financed through blended finance improves resilience	Water savings improve 20–50%; yields increase by 30–70%	Integrate climate finance with irrigation investment

Annexure IV: Studies Farmer-Led and User-Financed Irrigation

Author(s)	Countries / Regions Covered	Methodology (Data, Sample & Respondents)	Key Findings on Farmer-Led & User-Financed Irrigation	Key Quantitative Statistics (ROI / Efficiency / Performance / O&M)	Policy Recommendations on Farmer-Led & User-Financed Irrigation
Woodhouse *et al*. (2017)	Ghana, Kenya, Tanzania, Ethiopia (SSA)	Mixed methods: household surveys, field observations, secondary data; smallholder farmers	Farmer-led irrigation is the fastest-growing source of irrigation expansion, driven by private investment in pumps, wells, and on-farm systems	Adoption growth rates 2–3× faster than public schemes; low capital costs (<USD 1,500–3,000/ha)	Recognize farmer-led irrigation as a core development pathway; remove regulatory and financing barriers
Xie *et al*. (2014)	Sub-Saharan Africa	Multi-country secondary data analysis; spatial and investment datasets	User-financed irrigation accounts for the majority of new irrigated area in SSA	>70% of new irrigated area privately financed; rapid uptake of motor pumps	Shift public role toward enabling finance, energy access, and regulation
Merrey & Lefore (2018)	Africa; South Asia	Comparative synthesis of case studies; secondary datasets	Farmer-led systems outperform public schemes in flexibility and responsiveness, but face sustainability risks	Lower unit costs than public schemes; higher utilization rates (>80%)	Support farmer-led irrigation with groundwater governance and extension

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Shah (2009)	South Asia	Longitudinal groundwater datasets: policy and institutional analysis	Private groundwater irrigation fueled agricultural growth, but created over-extraction risks	Irrigated area expanded rapidly under farmer investment; water tables are declining in many basins	Regulate energy and groundwater while protecting farmer incentives
Mukherji *et al*. (2012)	South Asia	Multi-country empirical analysis; groundwater and farm data	Farmer-financed irrigation boosts productivity but is distorted by energy subsidies	Yield gains 30–70%; inefficient water use under flat energy tariffs	Reform energy pricing; integrate groundwater governance
FAO (2011)	Global	Global synthesis of land and water data	Farmer-led irrigation contributes significantly to food security but raises sustainability concerns	Small-scale irrigation dominates numerically but varies widely in efficiency	Balance farmer investment with sustainability safeguards
Rosegrant *et al*. (2009)	Global (SSA, Asia, LAC)	Global water–food modeling; secondary datasets	Farmer-led irrigation supports poverty reduction and productivity growth	Yield increases 20–60% in irrigated systems	Support farmer investment alongside public infrastructure
Shah *et al*. (2012)	South Asia	Empirical groundwater and policy analysis	Rapid farmer-led groundwater expansion increased output but reduced water efficiency	Water-use efficiency declines 20–30% without regulation	Strengthen water pricing and abstraction controls
FAO (2022)	Global	Global assessment of land, water, and climate data	Unregulated farmer-led irrigation contributes to environmental stress	Groundwater depletion is accelerating in key basins	Integrate farmer-led irrigation into water governance frameworks
You *et al*. (2011)	Africa	Spatial–economic modeling using secondary datasets	Africa has a large irrigation potential achievable through farmer-led investment	Potential expansion >20 million ha, mostly small-scale	Unlock farmer-led irrigation through finance and market access
World Bank (2021)	Sub-Saharan Africa	Portfolio review; policy and investment analysis	Farmer-led irrigation expands faster than public schemes but still depends on public support	Adoption rates 2–4× higher than scheme-based irrigation	Reorient public investment to bulk water, regulation, and finance
Lefore *et al*. (2019)	Kenya; Ethiopia	Primary household surveys; qualitative interviews	Farmer-led irrigation increases cropping intensity and incomes	Cropping intensity 1 –3 crops/year; income gains 30–50%	Improve access to credit, land tenure security, and extension
World Bank (2019)	Sub-Saharan Africa	Synthesis of project and policy evidence	Farmer-led irrigation is central to future irrigation growth	Higher utilization (>85%) than public schemes	Prioritize farmer-led models in irrigation strategies

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IWMI (2020)	Africa	Continental synthesis of empirical studies	User-financed irrigation drives the most recent irrigation expansion	The majority (>60%) of new irrigation farmer-financed	Strengthen institutions to manage cumulative impacts
Lefore *et al*. (2022)	Africa; South Asia	Comparative policy and investment analysis	Farmer-led irrigation scalable with targeted public support	Productivity gains are sustained where support exists	Combine farmer investment with finance, extension, and regulation

Annexure V: Studies Climate and Green Financing Instruments

Author(s)	Countries / Regions Covered	Methodology (Data, Sample & Respondents)	Key Findings on Climate & Green Financing for Irrigation Development	Key Quantitative Statistics (ROI / Efficiency / Performance / O&M)	Policy Recommendations on Climate & Green Financing
FAO (2021)	East Africa	Case studies; project performance data; stakeholder interviews	Climate-smart irrigation financed through climate and green funds enhances resilience, productivity, and sustainability	Water-use efficiency increases 20–50%; yields increase 30–70%	Integrate climate finance with modern irrigation technologies and farmer capacity building
Green Climate Fund (GCF) (2021)	Africa & Asia (incl. Kenya)	Portfolio-level evaluation of GCF-funded projects	Blended climate finance reduces risk and scales irrigation investment	Adaptive capacity indicators increases >40%; project leverage 1:3–1:5	Use climate finance to de-risk irrigation and crowd in co-financing
World Bank (2021)	Global	Strategic policy review; portfolio analysis	Climate finance aligns irrigation with adaptation and mitigation goals	Climate-aligned projects show lower failure risk and better O&M	Mainstream climate screening into irrigation investment
FAO (2022)	Global	Global synthesis of land, water, and climate datasets	Climate finance essential to address water scarcity and sustainability	Water productivity increases 20–30%	Embed irrigation in national climate strategies
OECD (2018)	Global	Analysis of climate finance flows	Climate finance mobilizes resources for adaptation in agriculture	Climate finance flows increase annually by >10%	Improve access to climate finance for agriculture
IPCC (2023)	Global	Scientific synthesis of climate impact studies	Irrigation is critical for adaptation, but must be sustainable	Climate risks increase 2–3× without adaptation	Prioritize irrigation in adaptation financing
AfDB (2020)	Africa	Project evaluations and financial analysis	Climate-aligned blended finance improves irrigation bankability	Project implementation accelerated by 20–30%	Combine climate finance with blended instruments
OECD (2020)	Global	Cross-country policy review	Climate finance improves water security outcomes	Efficiency gains 15–30%	Align climate finance with water governance

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World Bank (2020)	Global	Cross-country empirical review	Climate finance lowers perceived risk and attracts investment	Bankability increases 25–40%	Use concessional climate funds to crowd in private capital
IFAD (2019)	SSA & South Asia	Programme evaluations; smallholder surveys	Climate finance improves smallholder irrigation access and resilience	Cropping intensity increases 1 to 2–3; income increases 20–40%	Target climate finance to smallholders
AfDB (2021)	Africa	Project portfolio analysis	Green finance supports water-saving technologies	Water savings 20–40%	Scale green bonds and climate funds

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