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Farmers' Perceptions and Barriers to Adoption of Solar-Powered Irrigation Systems: Evidence from Ewaso Ng'iro Basin in Kenya

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Abstract

Solar-powered irrigation systems offer a promising pathway to climate-resilient agriculture in Kenya's arid and semi-arid lands, where rain-fed farming is increasingly unreliable due to climate variability. Despite abundant solar resources and supportive policy frameworks, adoption rates among smallholder farmers remain persistently low. This study examines smallholder farmers' perceptions of solar-powered irrigation, barriers to adoption, and the current adoption gap in Kenya's Upper Ewaso Ng'iro Basin, focusing on three counties—Isiolo, Laikipia, and Meru. The study draws from household survey data and qualitative insights from 180 smallholder farming households. The findings reveal overwhelmingly positive perceptions of solar irrigation technology: 93.9% of farmers agree that solar irrigation saves money, and 96.1% recognise sufficient sunlight for effective operation. However, a significant perception-adoption gap exists, as actual adoption stands at only 16.7% overall, with the highest adoption in Isiolo (26.7%) and lowest in Meru (6.7%). Perceived affordability presents a major constraint, with 70.6 % of respondents agreeing that solar pumps are very expensive. Barrier analysis identifies four primary constraint categories: financial barriers including high upfront costs and limited credit access, technical barriers related to inadequate knowledge and limited maintenance services, institutional barriers including weak extension support and land tenure insecurity, and awareness barriers stemming from limited exposure to demonstrations. The barrier severity index shows financial barriers as most severe across all counties (0.74), followed by technical (0.47), institutional (0.42), and awareness barriers (0.41). County-level analysis reveals distinct profiles, with Isiolo farmers facing the most severe multi-dimensional barriers, Laikipia showing moderate barriers, and Meru exhibiting the lowest perceived barriers, though with the lowest SPIS adoption rate, suggesting possible unobserved constraints or satisfaction with existing diesel-based systems. The study concludes that addressing the perception-adoption gap, equivalent to 72% overall, requires integrated and county-specific interventions, including innovative financing models such as pay-as-you-grow and irrigation-as-a-service, strengthened technical support ecosystems, expanded demonstration and peer-learning opportunities, and integration of solar irrigation into agricultural extension services.

Keywords: farmer perceptions, adoption barriers, perception-adoption gap, solar-powered irrigation systems, Kenya

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Introduction

Globally, energy and water management challenges are becoming increasingly interconnected under climate change, fossil-fuel dependence and rising energy costs (Getnet et al., 2026; Lamichhane et al., 2021). Irrigation is widely recognized as a critical pathway to climate resilience and agricultural intensification. Achieving the Sustainable Development Goals (SDGs) of No Poverty, Zero Hunger, and Climate Action depends on adopting renewable energy in irrigation, designed to promote sustainable production, increase agricultural productivity, improve food security and mitigate climate change (Khanna & Miao, 2022). Despite the clear potential and supportive policy frameworks in Kenya, adoption of solar-powered irrigation among smallholders remains surprisingly low (Durga et al., 2024). This adoption gap persists even as awareness grows and technology costs decline. Besides economic and technical characteristics, adoption of agricultural technologies is also influenced by farmers' perceptions of their usefulness, affordability, complexity, reliability and compatibility with existing production systems. Perceptions, including attitudes, norms and behaviours, shape how farmers evaluate the expected benefits and risks associated with an innovation (Getnet et al., 2026; (Karbo et al., 2025). Despite increasing research on SPIS adoption, empirical evidence on farmer perceptions as determinants of SPIS adoption in Kenya remains limited. This is particularly the case in the Upper Ewaso Ng'iro Basin, where irrigation is important for agricultural production but farmers operate under markedly different ecological, socioeconomic and infrastructural conditions. The basin extends from relatively high-altitude agricultural areas towards semi-arid and arid environments, creating substantial variation in agricultural production and water access. This study examines smallholder farmers' perceptions of solar-powered irrigation, barriers to adoption, and the current adoption gap in Kenya's Upper Ewaso Ng'iro Basin, focusing on three counties—Isiolo, Laikipia, and Meru.

Material and Methods

The study was conducted in Isiolo, Laikipia, and Meru counties in the Upper Ewaso Ng'iro Basin in Kenya. Data were derived from a household survey of 180 households (60 per county) randomly sampled across the three counties. The survey captured farmer knowledge and perceptions of solar irrigation across five dimensions: cost savings, durability/maintenance, sunlight adequacy, affordability, and scalability. Quantitative analysis employed descriptive statistics, cross-tabulations, and chi-square tests to examine county-level variation in perceptions and adoption patterns. Qualitative thematic analysis of enumerator comments and farmer responses provided deeper insights into perceived barriers. A barrier severity index was constructed to compare the relative importance of different constraints across counties.

Results and Discussion

Solar-powered irrigation adoption rate

Irrigated farming was widespread in the study population. A total of 152 households, equivalent to 84.4% of the sample, reported practising irrigated farming. This confirms that irrigation is an important component of agricultural production in the surveyed areas. However, the use of solar energy for irrigation was considerably less widespread. Thirty households reported using solar energy for irrigation, equivalent to 16.7% of total households sampled. In terms of adoption distribution, out of the 30 SPIS

adopters, the highest adoption proportion was in Isiolo (54%), which is in the arid agroecological zone, while the lowest was in Meru (13%), attributed to a relatively higher agroecological zone, which is suitable for gravity water flow and therefore has a limited need for water pumping.

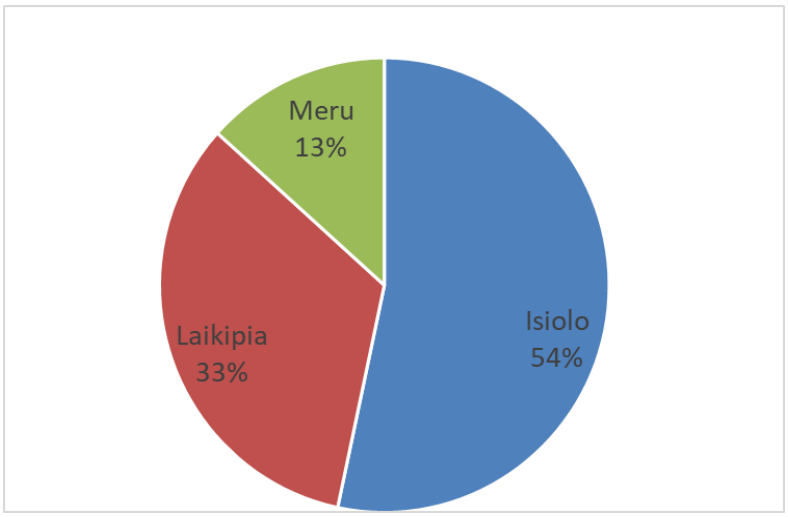


Figure 1: SPIS adoption rate distribution across the counties

Farmer perceptions on solar-powered irrigation

Farmers generally expressed favourable perceptions regarding the economic and technical characteristics of SPIS. The strongest perception concerned solar-resource availability. Approximately 96.1% of irrigating farmers agreed or strongly agreed that there is enough sunlight for solar irrigation pumps, with a mean score of 4.81 out of 5. Similarly, 93.9% agreed or strongly agreed that SPIS save a lot of money (mean= 4.69). The scalability statement also received a strongly favourable response, with 92.1% agreeing that solar pumps can be used at any scale of farming (mean= 4.60). For durability and ease of maintenance, 90% agreed or strongly agreed with the statement (mean= 4.50). The affordability dimension produced a more mixed response. Approximately 70.6% agreed or strongly agreed that solar-powered irrigation pumps are very expensive. This indicates that farmers can simultaneously recognize the economic benefits of solar irrigation while considering the initial cost of the equipment to be high.

Barriers to adoption of solar-powered irrigation systems

Barrier analysis identifies four primary constraint categories: (1) financial barriers (high upfront costs, limited credit access, competing household priorities); (2) technical barriers (inadequate knowledge, limited installation and maintenance services, water source compatibility); (3) awareness and information barriers (limited exposure to demonstration, insufficient understanding of benefits and operation); and (4) institutional barriers (weak extension support on solar technologies, land tenure insecurity affecting investment, policy and subsidy gaps). The barrier severity index shows financial constraints as most severe across all counties (mean= 0.74), followed by technical (0.47), institutional (0.42), and awareness barriers (0.41). County-level analysis reveals distinct profiles: Isiolo farmers face the most severe multi-dimensional barriers, particularly financial and technical; Laikipia shows moderate barriers with relatively better information access; Meru exhibits the lowest perceived barriers but also the lowest adoption, suggesting unobserved constraints or satisfaction with existing diesel-based irrigation systems.

Perception-adoption gap

The analysis of farmer perception of SPIS shows positivity across the three counties, indicating that, overall, smallholder farmers see benefits of the use of SPIS. However, the results reveal a significant gap between positive perceptions and the adoption rate of 72%. The perception-adoption gap is highest in Meru (81%) due to a relatively lower adoption rate, followed by Laikipia (73%) and lowest in Isiolo (62%).

Conclusions and Outlook

The study reveals a high perception-adoption gap. While farmers recognize the benefits of solar irrigation, multiple interacting barriers prevent widespread uptake. Financial constraints are paramount, but technical, informational, and institutional barriers compound the challenge. Significant county heterogeneity underscores the need for context-specific interventions. Findings highlight the urgency of developing inclusive financing models (e.g., pay-as-you-go, revolving fund model), strengthening technical support ecosystems, expanding demonstration and peer-learning opportunities, and integrating solar irrigation into agricultural extension services. By moving beyond binary adoption analysis to examine the multi-dimensional barrier landscape, this research provides actionable insights for policymakers, development partners, and private sector actors seeking to accelerate solar irrigation adoption in Kenya's ASALs.

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