



Farmer-Led Irrigation Development in Sub-Saharan Africa: Implications for Household Income, Asset Creation and Food Availability

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ABSTRACT

This systematic review examines the potential impact of farmer-led irrigation development on the socioeconomic welfare of farming households in Sub-Saharan Africa. The study reviewed literature on the implications of farmer-led irrigation development on household income, asset creation and food availability. A systematic search across six electronic databases (SCOPUS, AGRIS, AJOL, PROQUEST, INGENITA and Science Direct) and snowballing identified 502 records after removing duplicates. Twenty-two peer-reviewed publications published after 2011 were selected for thematic analysis after being screened and subjected to predetermined inclusion and exclusion criteria. Farmer-led irrigation development significantly increases annual household income. These income gains drive asset creation (motorised pumps, livestock and modern housing) and improve food availability. This review, however, revealed that benefits associated with farmer-led irrigation development are uneven across sociodemographic levels. Adult men tend to realise higher returns compared to women and the youth. In addition, women-led households face persistent barriers (education, income) to converting revenue into improved food availability and dietary diversity. The findings of this review suggest that policymakers in Sub-Saharan Africa should develop policies and interventions that address systemic exclusion in farmer-led irrigation. Interventions require gender-inclusive training and support to ensure women and youth can capitalise on productivity gains.

Key words: Farmer-led irrigation, Food availability, Household income, Irrigation participation, Sub-Saharan Africa.

Food demand is expected to increase by 60% by the year 2050 owing to global population growth and this could be aggravated by the effects of climate change (Harmon *et al.*, 2023; Osewe *et al.*, 2020; FAO, 2022) estimated that about 670 million people in the world will not have access to sufficient food by the year 2030. This is attributed to a widening gap between potential and actual crop yields. Harmon *et al.* (2023) observed that this difference is more pronounced in Sub-Saharan Africa, where actual yields are only 24% of the potential yield for cereal and horticultural crops. This problem is more pronounced for small-scale farmers. The observed low yields in small-scale farming are associated with seasonal production systems. These farmers (small-scale) practice seasonal production because of reliance on seasonal rainfall and limited access to water for irrigation (which could be due to poor infrastructural development, among other factors) (Passarelli *et al.*, 2018; Scoones *et al.*, 2019; Shah *et al.*, 2020; FAO, 2020) reported that low yields in developing economies are caused by limited soil moisture, which correlates to an overreliance on rainfed agriculture. This system of farming is vulnerable to climate change and small-scale farmers are often faced with multi-scale poverty traps at individual, household and community levels (Burney and Naylor, 2012). Numerous small-scale farmers and their families survive on less than US\$1.25 per day, exposing them to nutrition deficiency (Burney and Naylor, 2012). Moreover, most households spend their income on food and immediate household needs. As a result, households remain asset-poor over

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time, lacking buffers against bad future harvests (Burney and Naylor, 2012; FAO, 2020; Shah *et al.*, 2020). Nevertheless, only 8 million hectares of cropland in the world are irrigated (FAO, 2020, 2022) and this is about 5% of the potential irrigation land.

State-led large irrigation scheme developments in sub-Saharan Africa have failed to increase the potential of irrigation to improve the lives of small-scale farming communities, evoking the need to rethink irrigation development. Various authors reported that farmer-led initiatives have the potential to facilitate sustainable production in agriculture and improve food security in developing countries (Duker *et al.*, 2023; Harmon *et al.*, 2023; Hall *et al.*, 2017). Lefore *et al.* (2019); (Merrey *et al.*, 2017) noted that Sub-Saharan Africa cannot adequately feed its people without irrigation. Despite significant growth in agricultural productivity in a few countries such as Ethiopia, South Africa and Rwanda (Merrey *et al.*, 2017; FAO, 2017), such developments still fell short of sustaining agriculture through major shocks such as droughts. In Zimbabwe, various smallholder irrigation schemes spearheaded by the government have largely failed to improve the livelihoods of small-scale farmers (Mutiro and Lautze, 2015). The situation is likely to remain so even with continued financial support due to limited access to farming inputs, weak agricultural policies and unstable markets, among other factors (Mutiro and Lautze, 2015). It was, therefore, assumed that farmer-led irrigation development has the potential to identify the factors that caused previously developed state-led irrigation projects not to significantly impact the lives of small-scale farmers.

Farmer-led irrigation development (FLID) is an approach in which farmers themselves assume the leading role in the establishment, initiation, operation, maintenance and acceleration of improvements in irrigation and water use for agriculture (Woodhouse *et al.*, 2017). In this approach, small-to-medium-scale farmers drive changes in production knowledge, promote the use of innovative irrigation technology, adopt effective investment patterns and establish linkages with key stakeholders, including the private sector and government (Izzi *et al.*, 2021; Woodhouse *et al.*, 2016, 2017). According to Veldwisch *et al.* (2019), FLID is not defined by the level of mechanisation, the size of irrigable land, or predominant cropping enterprises, but by the locus of decision-making power. FLID is adopted by entrepreneurial farmers who take risks, making significant investments in irrigation development and farming for both profit and subsistence (Izzi *et al.*, 2021). In Sub-Saharan Africa, such farmers normally work independently (private irrigation) or in small groups (community-based irrigation schemes) on areas ranging from 2 to 10 hectares (Izzi *et al.*, 2021; El Ouaamari *et al.*, 2019; Scoones *et al.*, 2019; Lefore *et al.*, 2019). Despite the relatively small irrigated areas, FLID may amount to large tracts of land with a significant impact on the economy and the surrounding communities (Xie *et al.*, 2014; Otoo *et al.*, 2018; Izzi *et al.*, 2021).

There is a high potential to increase investments in FLID in Sub-Saharan Africa with the potential to increase crop yields (Lefore *et al.*, 2019), generating additional revenues (Beekman *et al.*, 2014; Lefore *et al.*, 2019) and

improving land and water governance systems (Abric *et al.*, 2017; Cassman and Grassini, 2013; Passarelli *et al.*, 2018; Shah *et al.*, 2020). Nevertheless, it is argued that the invisibility of FLID and its inherently autonomous character limit its expansion (Muturi *et al.*, 2019). Namara *et al.* (2014); Colenbrander and van Koppen (2013) observed that FLID only benefits young and resourced male farmers. Vulnerable members of society, such as women, the aged and child-headed families, do not have financial resources and access to information services to fully utilise this approach (Theis *et al.*, 2018). In addition, several women in Sub-Saharan Africa do not have land, affecting their potential to initiate and manage irrigation development independently (Lefore *et al.*, 2019). Wiggins and Lankford, 2019; Shah *et al.*, 2020) reported that there was a slow growth in advancing FLID in Sub-Saharan Africa in the last decade. Lack of adequate financial resources and an enabling environment are some of the hindering factors to FLID (Woodhouse *et al.*, 2017; Shah *et al.*, 2020). It is generally agreed that FLID is associated with an increase in yields and high income. Nonetheless, it is yet to be established if this is consistent in Sub-Saharan Africa and if there is reported evidence for these positive elements at the household level. The purpose of this study was, therefore, to carry out a comprehensive analysis of the impacts of FLID on food availability and access, household income and asset development for small-to-medium scale farmers in Sub-Saharan Africa.

A systematic literature review was carried out following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) protocol (Moher *et al.*, 2015). To avoid bias, six electronic databases, SCOPUS, AGRIS, AJOL, PROQUEST, INGENTA and ScienceDirect, were searched to locate relevant publications (Fig 1). These databases were selected because they are multidisciplinary and contain several research articles and papers focusing on agriculture and irrigation development (Prancutė, 2021; Kraus *et al.*, 2022). The search string included a combination of the following keywords: household income, farmer-led irrigation, food availability, irrigation participation and Sub-Saharan Africa. A general syntax was applied to all databases as follows: ("Farmer-led irrigation" OR "Community-based irrigation" OR "Smallholder irrigation challenges") AND ("Irrigation development benefits" OR "Irrigation system drawbacks") AND ("Household Income" OR "Asset Creation" OR "Food Availability").

The search results were extracted and duplicates were subsequently removed (Fig 1). The titles and abstracts of the remaining research articles and papers were then screened using clearly defined inclusion and exclusion criteria. The inclusion criteria were publications on farmer-led irrigation, articles written in English, published research materials, journal papers published in 2011 or later and peer-reviewed publications. This was followed by reading full texts assessing conformity to the inclusion criteria.

This criterion was applied to ensure that current and relevant knowledge on farmer-led irrigation is reviewed. Moreover, the inclusion of peer-reviewed papers was meant to make conclusions based on results that have gone through the quality control system, *i.e.*, the peer review process. Literature studies were not included; however, reference lists of reviews and eligible articles were screened to identify relevant publications. Studies that were not peer-reviewed journal articles (such as books, conference proceedings, or theses), published in a language other than English, or published before 2011 were not included. Research that focused only on state-led programs, or other small-scale irrigation systems in which farmers were not the key agents of development, was not included.

The data extraction process was preceded by a quality assessment of all the research papers that met the inclusion and exclusion criteria. The articles were evaluated using the checklists of the Critical Appraisal Skills Programme (CASP). For each evaluation, the criteria were three-stepped (yes/can't tell/no). Research papers with a score of four or less were excluded at this stage. The selected articles had a score ranging from five to eight. A thematic analysis based on Braun and Clarke (2006) was then used to analyse the selected articles. This was achieved through familiarisation with data, coding, thematic generation and linking of themes to give a comprehensive meaning to several clusters of ideas. The thematic approach enhanced the data synthesis process and ensured the rigour and validity of the results. The literature search in digital databases and snowballing obtained 502 papers after

removing duplicates. Screening (*i.e.*, filtering titles and abstracts) identified 64 publications, which were further assessed for eligibility. After the full-text eligibility assessment, 22 research papers were included in the review.

Characterisation of articles included in this review

All the studies included in this review were conducted in Sub-Saharan Africa (Fig 2). Most of the studies ($n = 7$) included in this review were conducted in Ethiopia, followed by Zimbabwe ($n = 5$).

The reviewed studies employed various research methods and sampling procedures to select participants. Stratified and multistage random sampling was the most common sampling approach used in quantitative studies (Hirko *et al.*, 2018; Mango *et al.*, 2018; Passarelli *et al.*, 2018; Kafle *et al.*, 2022; Kiratu *et al.*, 2025). Other studies (Zeweld *et al.*, 2015; Legesse, 2018; Faye and von Braun, 2025) used simple random sampling. A mixed approach combining purposive and random sampling was observed in (Osewe *et al.*, 2020; Adetoro *et al.*, 2022) and Bojago and Abraham (2023). Purposive sampling was predominant ($n = 6$) in studies that used qualitative and mixed research designs. In this review, studies that employed purposive sampling include (Chauruka *et al.*, 2023; De Fraiture *et al.*, 2014; Kamwamba-Mtethiwa *et al.*, 2021; Theis *et al.*, 2018; Mhembwe *et al.*, 2019; Scoones *et al.*, 2019; Duker *et al.*, 2023). Other sampling procedures included multi-stage sampling (Abarike *et al.*, 2024), non-randomised sampling (Dillon, 2011) and quota sampling (Dube, 2016).

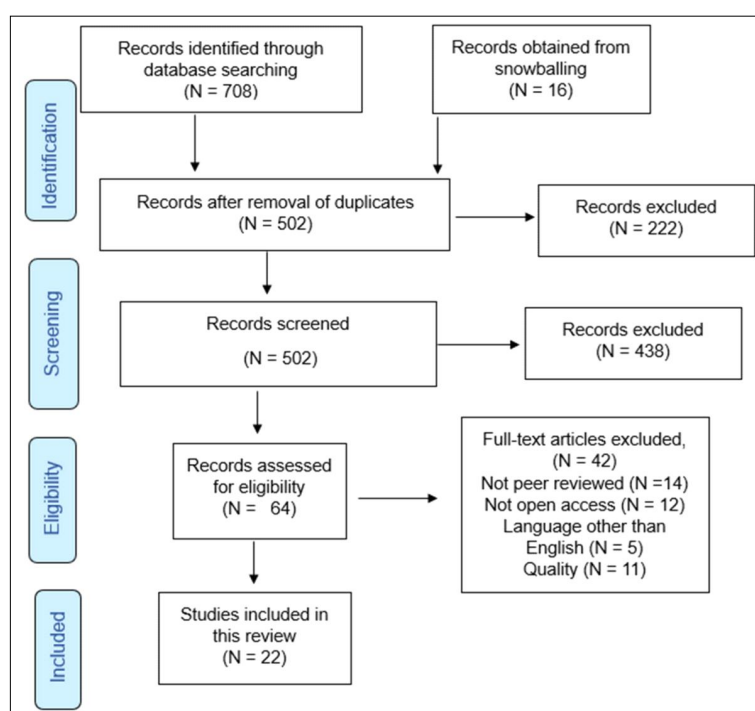


Fig 1: Systematic review according to the PRISMA Model.

Fig 3 presents a comparison of the number of participants across the reviewed studies (2011-2025). Although a wide span in research scale is illustrated, the majority of the reviewed studies (73%) had sample sizes between 30 and 500. In contrast, 3 papers (Dillon, 2011; Kafle *et al.*, 2022; Faye and von Braun, 2025) had sample sizes above the 1000-participant threshold. The observed sample sizes highlight the dominance of research centred on localised case studies and limited large-scale quantitative assessments.

In this systematic review, studies that utilised a quantitative research design and probability sampling consistently produced large samples (Kafle *et al.*, 2022; Faye and von Braun, 2025). The use of probability sampling in these studies reduces selection bias and enables the statistical generalization of findings to the broader population beyond the study area (Acharya *et al.*, 2013).

In contrast, studies that used a qualitative research design relied on purposive and quota sampling. These sampling procedures yielded significantly low sample sizes (Mhembwe *et al.*, 2019; Scoones *et al.*, 2019; Chauruka *et al.*, 2023; Duker *et al.*, 2023). Although findings from these studies may not be statistically generalised to a broad region, they provide extensive insights that are often neglected by surveys with huge sample sizes. Moreover, participants in the study are selected based on information the sample holds (Malterud *et al.*, 2016). Polit and Beck (2010) argued that the majority of qualitative studies aim to provide a comprehensive understanding of some aspect of the human experience through the in-depth analysis of specific examples rather than to make generalizations.

The temporal distribution of the reviewed research papers is shown in Fig 4. Approximately 68% of the reviewed papers were published between 2018 and 2025.

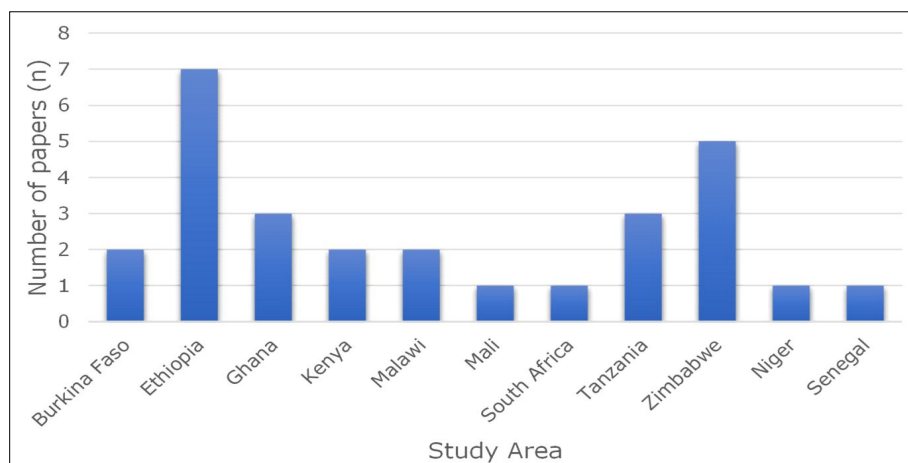


Fig 2: Geographic distribution of study areas represented in the reviewed literature.

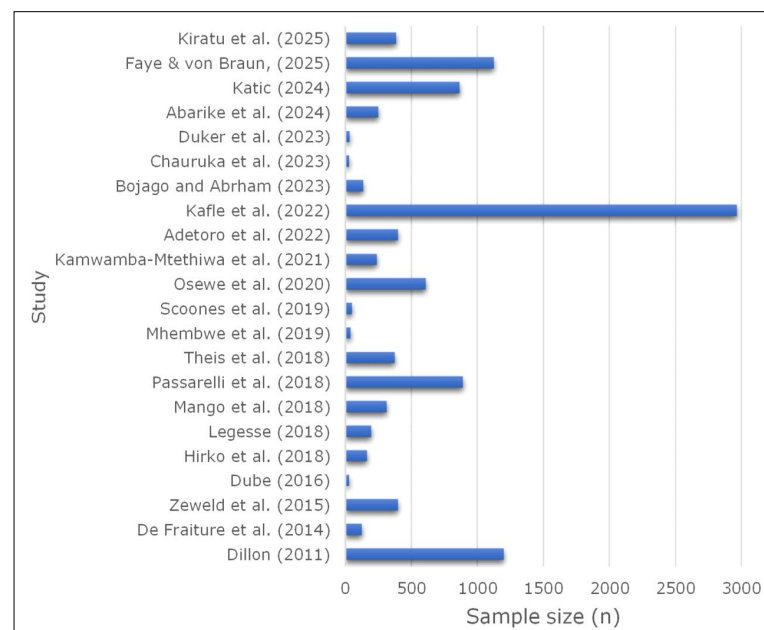


Fig 3: Sample sizes of reviewed studies.

Moreover, 36% of the reviewed literature was published in the most recent period (2022-2025). The currency of the included research papers enhances the relevance of findings and conclusions drawn from this review.

Thematic analysis of findings

The thematic analysis identified three (3) interlinked themes: household income, asset creation and wealth accumulation and food availability. These are discussed below:

Household income

In Sub-Saharan Africa, farm incomes are generally low, especially for small to medium-scale farmers. However, in 20 of the 22 studies included in this review, farmer-led irrigation development was reported to substantially increase annual farm income. Faye and von Braun (2025) provided compelling evidence from a study across four countries (Niger, Senegal, Mali and Burkina Faso) (Table 1) showing that FLID yields significantly higher net returns per hectare in comparison to rainfed farming. Notably, the authors applied inverse probability weighting to reduce selection bias, providing a comprehensive assessment of profitability, often lacking in earlier descriptive studies.

Evidence from Ethiopia further corroborates these findings, showing consistent income gains across various methodologies. Legesse (2018) found that farmer-led irrigation schemes increased the annual household farm income of participant households by US\$200. In a related study, Hirko *et al.* (2018) noted that the mean income of irrigating households was significantly higher than that of non-irrigating households. The observed average treatment effect on the irrigating households in this study was approximately US\$100 higher than that of non-irrigating farmers. Zeweld *et al.* (2015) found that these differences in household income translate into poverty reduction, 80% of the irrigating group was found to be non-poor, compared to only 70% of the non-irrigating group. Using propensity score matching, Osewe *et al.* (2020) confirmed that the

adoption of farmer-led irrigation practices significantly increased the per capita net crop income by a range of US\$28 to US\$36. More recently, Bojago and Abraham (2023) in Ethiopia reported even wider disparities, with small-scale farmer-led irrigators earning an average annual gross income of US\$3400 compared to US\$750 for non-irrigating farmers. These revenue gains are attributed to the ability of irrigating farmers to grow a range of high-value crops as well as the timely application of inorganic fertilisers, which enhances production (De Fraiture *et al.*, 2014; Passarelli *et al.*, 2018; Theis *et al.*, 2018; Bojago and Abraham, 2023; Duker *et al.*, 2023).

In Zimbabwe, similar trends are observed whereby capital and labour combinations drive productivity. Scoones *et al.* (2019) reported that gross annual household income ranged from US\$4700 to US\$30000, depending on the level of mechanisation and size of irrigable land. The study identified a strong correlation between investment in technology (pumps, greenhouses) and income. Furthermore, the household income of irrigating small-scale farmers increased by 25 to 30% compared to non-irrigators (Chauruka *et al.*, 2023; Dube, 2016; Mhembwe *et al.*, 2019; Chauruka *et al.*, 2023) noted that women who employ bucket irrigation to grow vegetables for subsistence on small areas along sand rivers produce excess for resale. Interestingly, their economic independence is furthered by this revenue. Mhembwe *et al.* (2019) reported that farmers involved in irrigation enterprises produce a variety of crops all year round and hence raise constant income from selling and marketing these products. In a study by Dube (2016), receipts from the sale of crops from

Table 1: Net returns of land under FLID and rainfed farming.

Country	FLID mean (USD/ha)	Rainfed mean (USD/ha)
Niger	1 898.26	59.98
Senegal	2 095.40	148.52
Mali	900.95	170.16
Burkina faso	828.32	200.25

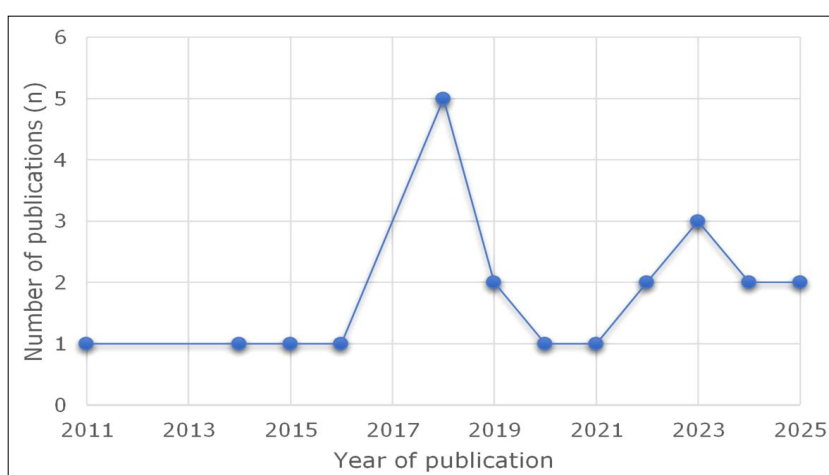


Fig 4: Currency of reviewed papers.

the Lower Gweru irrigation scheme were reported to contribute significantly to household income, enabling investments in home improvements, the education of children and agricultural equipment. These improvements inadvertently enhanced stability in household income (Dube, 2016). The profit margin for each farming season varied from US\$3500 to US\$5000 for the irrigating households earning far more than the poverty threshold in their respective provinces (Dube, 2016). The average disposable income of irrigators in this irrigation scheme was US\$458, compared to a national datum line of US\$161. While FLID is generally profitable, a recent study by Kiratu *et al.* (2025) found that both FLID and public irrigation systems in Kenya increase gross farm income. In contrast to earlier studies, Kiratu *et al.* (2025) noted that public irrigation systems (US\$1386) generate a stronger positive effect on farm income in comparison to FLID (US\$961).

This review found that income benefits are not uniformly distributed. Two studies highlighted the complexity of income implications across gender and age (Bojago and Abraham, 2023; Katic, 2024). Katic (2024) revealed that adult men had the highest farm income, followed by young men. Young women had the lowest realised farm income regardless of the comparable scale of irrigation, suggesting systemic barriers (Katic, 2024). Hirko *et al.* (2018) identified key determinants of these disparities, including access to credit, education level, household size and information services. Access to financial credit enables investment in irrigation equipment, enabling them to boost farm productivity and generate higher incomes (Hirko *et al.*, 2018; Katic, 2024). On the other hand, higher education levels are associated with better decision-making regarding resource management and adoption of innovative farming methods. Farmers with higher levels of education were more likely to use innovative farming methods, which enhanced their crop yield and outcome (Hirko *et al.*, 2018). According to Katic (2024), farmers who had improved access to information had high revenue levels. It was essential to have access to education and training on contemporary farming methods. Participating in training programs gave households the tools they needed to practice irrigation more efficiently, increasing yields and income (Hirko *et al.*, 2018). AlShamary *et al.* (2025) demonstrated that drip irrigation achieves markedly higher water use efficiency (0.607 kg m^{-3}) suggesting that the adoption of water-efficient technologies within farmer-led systems could further amplify the income benefits documented in this review.

Asset creation and wealth accumulation

Investing in irrigation is associated with the accumulation of physical assets at the household level. These assets include motorised pumps, solar pumps, livestock, boreholes and modern houses (Theis *et al.*, 2018; Kamwamba-Mtethiwa *et al.*, 2021; Kifle *et al.*, 2022; Abarike

et al., 2024). Beyond direct ownership, Dillon (2011) found that in Northern Mali, farmer-led irrigation systems have secondary effects, including household asset accumulation that assist households in mitigating covariate and idiosyncratic risks. Quantifying this advantage in Ethiopia, Legesse (2018) revealed that small-scale irrigation increased physical asset holding with a corresponding value of US\$300. Irrigators had a mean physical asset value of US\$450 compared to a mean value of US\$150 for non-irrigators (Legesse, 2018). Similarly, investigating the impact of small-scale irrigation on households' livelihood in Northern Ethiopia, Zeweld *et al.* (2015) observed that the average adult equivalent asset ownership for irrigators was slightly higher than that of the non-irrigating group. In Ghana, Katic (2024) noted that a farmer-led river pumping irrigation system increased the value of farm assets by US\$100.

Irrigation driven by farmers increases the value of current assets and encourages diversification. Adetoro *et al.* (2022) and Katic (2024) found that small-scale irrigators leveraged these assets to participate in various agricultural operations, resulting in higher disposable incomes and less susceptibility to market volatility. For instance, Scoones *et al.* (2019) reported that irrigating farmers in Zimbabwe purchased cattle and drilled boreholes with the income obtained from farming activities. However, the scale of accumulation depends on the level of technology. Bucket irrigators, however, have the least capacity for wealth accumulation. They often lack the necessary financial resources to invest in irrigation systems effectively. As a result, their agricultural output remains limited and they struggle to escape poverty. Moreover, access to a reliable water resource is a major challenge. Small-scale farms rarely have a dependable water source and drilling a borehole is often beyond the reach of many farmers (Scoones *et al.*, 2019). In a study of the implications of rural irrigation schemes on the household economy, Dube (2016) observed substantial wealth accumulation by irrigating farmers in Zimbabwe. The average number of animals per family has increased as a result of the Insukamini irrigation program in Lower Gweru. When farmers joined the initiative, the average number of livestock among irrigators increased for all livestock categories. Irrigators have a better cattle herd than dryland farmers due to higher purchasing potential (Dube, 2016). In Zimbabwe, cattle are highly priced and regarded as a sign of affluence. Again, irrigators had a significant number of goats and poultry compared to dryland farmers. The average livestock population per household of 3.3, 2.3 and 11.4 for cattle, goats and poultry was recorded, respectively. In contrast, the average livestock populations for the same livestock types for dryland farmers were 1.13, 1.11 and 5.4 per household. Furthermore, the majority of irrigating households owned agricultural tools and equipment, including ox-drawn ploughs, irrigation pumping units and solar systems.

Food availability and dietary diversity

Rural households in Sub-Saharan Africa are often extremely poor due to overreliance on rain-fed small-scale farming for food production. Nevertheless, this review indicates that small-scale farmer-led irrigation systems significantly enhance food availability and dietary diversity (Zeweld *et al.*, 2015; Dube, 2016; Adetoro *et al.*, 2022; Abarike *et al.*, 2024; Kiratu *et al.*, 2025). Adetoro *et al.* (2022) noted an increase in food consumption per capita among irrigated households, stemming from improved crop yields and the cultivation of marketable crops, which enhanced farm incomes. Households that do not participate in farmer-led irrigation systems have compressed food consumption per capita (Adetoro *et al.*, 2022); Mhembwe *et al.* (2019) noted that irrigating small-scale farmers had the capacity to improve food availability and accessibility through crop diversification. These farmers produced several crops, including maize, beans, tomatoes and potatoes. Moreover, Mhembwe *et al.* (2019); Kiratu *et al.* (2025) observed that irrigation farming allows for year-round cropping, leading to higher annual yields and improved food availability for irrigating households. A study by Passarelli *et al.* (2018) in Ethiopia noted that farmer-led irrigation increases dietary diversity through the income pathway. An increase in household income allows farmers to purchase a variety of foods with their additional revenue. However, Katic (2024) noted that for women irrigators, food availability and dietary diversity are affected negatively. Male dietary diversity is nonetheless enhanced. The paper, however, did not discuss the causative factors of this scenario. Begum *et al.* (2025) highlight that organic nutrient management can enhance the nutritional quality of agricultural produce, including increased protein content (8-19% in maize) suggesting that integrating organic practices with farmer-led irrigation could improve food availability and dietary diversity. Similarly, Fayçal *et al.* (2026) found that drip-irrigated olive trees exhibited superior physiological performance compared to rain-fed conditions, findings that align with this review's observation that irrigating farmers achieve year-round production and crop diversification.

The present review assessed the impacts of FLID on food availability and access, household income, asset creation and wealth accumulation of small-to-medium scale farmers in Sub-Saharan Africa. The reviewed literature revealed positive effects of FLID across these dimensions. While FLID is not a new concept, its potential has historically been under-recognised by engineers and development stakeholders (Mati, 2023). Consequently, analysing its role in enhancing rural livelihoods is crucial for stakeholders to fully appreciate the scalability of this approach.

This review confirms that FLID significantly improves household income for participating farmers, validating the importance of farmer-led irrigation systems in small-scale farming. Irrigating households consistently reported higher annual incomes than non-irrigating farmers across

numerous studies conducted in various nations. In Ethiopia, annual household farm income increased by approximately US\$100-200 for irrigating households (Legesse, 2018; Hirko *et al.*, 2018). These findings align with broader research from Asia, where small-scale irrigation has been shown to raise farm earnings by 25-80% (Hussain and Hanjra, 2004). Moreover, research in South Asia indicated a positive relationship between the growth of small-scale, privately owned irrigation systems and higher agricultural productivity (Giordano and de Fraiture, 2014; Burney and Naylor, 2012; Hossain, 2009). Notably, Giordano and de Fraiture (2014) utilised several case studies from Burkina Faso, Ethiopia, Ghana, Tanzania, Zambia and India, concluding that farmer-led small-scale private irrigation directly increases farmer cash income and reduces poverty in rural households. The research was conducted under the Agricultural Water Management Solutions program, during which interviews were conducted with 20,000 farmers, government officials, community leaders and other key stakeholders (Giordano and de Fraiture, 2014). This income growth is driven by several factors, including year-round crop production, crop diversification, increased use of synthetic fertilizers and improved seeds (de Fraiture and Giordano, 2014; Hirko *et al.*, 2018; Legesse, 2018; Scoones *et al.*, 2019). Globally, diversification and intensification of agriculture remain a key driver of income growth (Xie *et al.*, 2014). Nonetheless, benefits obtained from investments in irrigation are not uniformly distributed.

The economic benefits of FLID, however, are not uniformly distributed. The review noted significant differences in household income influenced by socio-demographic variables. Gender and age disparities were particularly pronounced (Bojago and Abrham, 2023; Katic, 2024), with adult men generally benefiting more than women and resource-constrained youth. Irrigating households headed by men attained higher farm incomes than women-headed households (Bojago and Abrham, 2023; Katic, 2024). Resource-endowed young men with access to substantial funds tend to invest substantially in irrigation equipment and improved seeds leading to higher productivity and farm earnings (Bojago and Abrham, 2023). This disparity suggests that FLID does not inherently guarantee on poverty reduction or equitable family welfare. These findings amplify broader research on agrarian disparities by Quisumbing *et al.* (2014) who demonstrated persistent variations in access to resources within farmer-led interventions. There is, therefore, a need for a collective effort to accelerate efforts to ensure equitable benefits from FLID. Minh *et al.* (2020) recommended increasing access to markets and gender inclusion to widen the societal impacts of FLID. Similarly, de Bont (2019) emphasised the need to develop relevant infrastructure that links small-scale farmers to service providers, thereby improving access to inputs, irrigation equipment and spares and information services. Furthermore, regulatory frameworks are often absent. Oke *et al.* (2023) reported a lack of a

policy framework controlling water abstraction and infrastructure protection in South western Nigeria, a challenge common across Sub-Saharan Africa. Therefore, irrigation planners and policymakers should recognise the largely unreported role and function of private irrigators in irrigation development. Woodhouse *et al.* (2017) suggest a need to formalise positive informal approaches promoted by private small-scale irrigators.

Regarding household asset holding and wealth creation, FLID demonstrated a clear positive impact. Livestock ownership, a key indicator of wealth and stability in many Sub-Saharan African contexts, was high among irrigating farmers (Dube, 2016). Moreover, farmers invested in productive assets such as farm tools, irrigation equipment and solar-powered homesteads (Scoones *et al.*, 2019; Dube, 2016). This aligns with Dillon (2011), who noted that asset accumulation increases household wealth and provides a buffer against unforeseen risks. However, the capacity for wealth accumulation varies with irrigation type. The simplest forms of irrigation, such as bucket irrigation, showed the least potential for significant asset growth (Woodhouse *et al.*, 2017). Thus, access to improved irrigation technology is, therefore, key to accelerating asset accumulation and wealth creation in farmer-led irrigation systems.

Finally, concerning food security, FLID positively influences food availability and dietary diversity. Year-round cropping, made possible by irrigation, allowed farmers to increase annual production, directly enhancing access to food (Mhembwe *et al.*, 2019). Crop diversification enabled farmers to broaden their nutritional intake (Adetoro *et al.*, 2022; Dube, 2016; Zeweld *et al.*, 2015). Domènech *et al.* (2015) also reported the positive effects of irrigation on food availability and nutrition. Despite these general gains, gendered differences in food availability outcomes persist. Thus, given the apparent positive effects of FLID, gender-sensitive interventions ought to be put in place to enhance and ease its uptake amongst smallholders across the gender spectrum. Such interventions could include credit programmes and training and extension services targeting women and vulnerable households (de Fraiture and Giordano, 2014; Njuki *et al.*, 2016). Furthermore, increased adoption of efficient irrigation technologies and innovative farming systems can maximize the benefits of FLID (Burney and Naylor, 2012). Moreover, to maximize the food security effects of FLID and reduce gender disparities, efforts should be made to increase market access and value chain integration for small-scale irrigating farmers. This is consistent with findings from other research that stressed the importance of market linkages in realizing the full potential of farmer-led small-scale irrigation (Maestre *et al.*, 2017).

CONCLUSION

This review confirms that farmer-led irrigation initiatives have the potential to transform small-scale farming and significantly improve the livelihoods of rural communities.

Specifically, the analysis reveals compelling evidence that FLID has a positive effect on household farm income and asset creation. In addition, private small-scale irrigation enhances food availability and dietary diversity. These benefits are driven by increased crop productivity, improved produce quality, commercialisation and all-year-round production. Nonetheless, substantial disparities in the distribution of income, assets and food availability benefits were observed. Women and other vulnerable members of the community do not derive benefits commensurate with those of men and non-vulnerable groups. Moreover, asset accumulation through private small-scale irrigation remains limited in scale in comparison to the broader national economy. While irrigating households acquired cattle using farm proceeds, the number of livestock units per capita remains modest. To amplify the societal impacts of FLID, critical interventions are required. This includes targeted training and extension support for farmers, enhanced access to credit by small-scale farmers and improved information services within farming communities. Furthermore, small-scale farmers need access to affordable irrigation technology to improve water use efficiency and enhance energy savings. Ultimately, policymakers and irrigation planners must acknowledge the increasing importance of FLID in driving smallholder transformation in Sub-Saharan Africa. They must provide relevant policy support while preserving the autonomy that defines farmer-led development.

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Disclaimers

The views and conclusions expressed in this article are solely those of the authors and do not necessarily represent the views of their affiliated institutions. The authors are responsible for the accuracy and completeness of the information provided, but do not accept any liability for any direct or indirect losses resulting from the use of this content.

Informed consent

This study did not involve human or animal participants.

Conflict of interest

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