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Review article

# Smallholder irrigation and poverty reduction in developing countries: a review

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ABSTRACT

Several studies have been conducted on the impacts of smallholder irrigation on food security, agricultural productivity, livelihoods, and poverty. However, little attention has been placed on the nexus between smallholder irrigation and poverty reduction. This study intends to close this gap by identifying and reviewing contemporary published evidence to examine the nexus between smallholder irrigation and poverty reduction in developing countries in general and Zimbabwe in particular. A systematic review of literature was conducted. The AGRICOLA, PubAG and Google Scholar databases were used to search for relevant literature. A multi-stage screening process was used to select relevant literature. The literature reviewed included research publications in peer-reviewed journals, dissertations and reports from world institutions published between 1994 and 2021. The findings show that there are inconsistencies in terms of the contribution of smallholder irrigation to household food security, livelihoods, and poverty reduction. This could be attributed to the methodological and contextual differences. Despite the inconsistencies, it was noted that investments in smallholder irrigation remain a key strategy to enhance agricultural productivity, food security, and livelihoods and reduce poverty in rural communities. Therefore, the study recommends that policies supporting investments in smallholder irrigation development and rehabilitation should be encouraged in developing countries to reduce poverty.

## 1. Introduction

In most developing countries, irrigated agriculture is regarded as an essential strategy to achieve the United Nations Sustainable Development Goals (SDGs) 1 and 2 through guaranteeing food security and poverty reduction by the year 2030 [1,2]. SDG Goal 1 emphasizes on reduction of poverty, while Goal 2 calls for ending hunger, and improving nutrition and food security [1]. The challenges of food insecurity, malnutrition, hunger and poverty have increased research traction in light of increasing climate variability and change, loss of biological diversity, soil nutrient mining, and land degradation, thus threatening the attainment of SDG 1 and 2. It is argued that investments in irrigation infrastructure are instrumental in poverty reduction, agricultural expansion, and improvement in food and nutrition security in many developing countries [2–4]. The World Bank [5] reports that investments in irrigation contribute to agricultural growth and poverty reduction through (1) permitting crop intensification and diversification and hence, increasing farm

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outputs and incomes; (2) increasing agricultural wage employment; and (3) reducing local food prices and hence, improving real net incomes. Irrigated agriculture is therefore, acknowledged as a key strategy to attain agricultural growth. However, further understanding of the nexus between smallholder irrigation and poverty alleviation is required to improve the ability to exploit it in reducing poverty.

Almost 70% of the global land area equipped for irrigation is located in Asia, with China and India accounting for 42% of this area [6]. In addition, about 41% of the cultivated land area in Asia is irrigated compared to 13% in the Americas, 9% in Europe, 7% in Oceania, and 6% in Africa [7,8]. Most of the irrigation investments in Asia are large-scale. For instance, in India and Pakistan, it is common to find irrigation schemes of up to 10 000 ha (ha) [9]. However, there is some literature that argues that large-scale irrigation investments are not always economically viable [5,10]. This is mainly attributed to the high operation and maintenance costs associated with large-scale irrigation schemes and the lack of capacity of the farmers to manage huge projects [10].

In Africa, the low irrigation development is often attributed to the high cost of irrigation projects [11,12]. For example Inocencio et al [11], conducted a study to assess the costs of irrigation projects in Sub-Saharan Africa (SSA) and determine factors influencing the projects' costs and overall performance. The study used secondary data obtained from the World Bank, African Development Bank, and International Fund for Agriculture Development. The study analysed 314 irrigation projects implemented from 1967 to 2003 in 50 countries in Africa, Asia, and Latin America. The results show that the average total cost for new construction projects was US$14, 455/ha in SSA and US$6590/ha in non-SSA. For rehabilitation projects, the average unit total cost was US$8200/ha in SSA and US $2300/ha in non-SSA. The cost differences were statistically significant at 5%. The factors influencing performance (measured by internal rate of returns (IRR)) of irrigation projects were project size and average size of systems, complexity of projects, water availability, country's level of development, farmers' contribution to investment cost, and design and technology factors [11]. concluded that small-scale irrigation projects performed better than large-scale projects. The study also concluded that small-scale irrigation schemes also offer significant performance advantages over large-scale systems within irrigation investment projects.

A study conducted by Fujiie et al. [12] examined the scale economy and diseconomy of irrigation projects in SSA. The study used secondary data obtained from the International Water Management Institute (IWMI) irrigation project database. A sample of 243 large-scale irrigation projects (more than 100ha), four small-scale projects (5–100 ha) and five micro-scale projects (less than 5ha) were purposively selected. Scale economies were obtained using unit total cost and unit overhead cost. Performance of irrigation projects was measured using IRR. The study found that small and micro scale irrigation projects have far lower unit overhead as well as construction costs, yield better returns and perform better than large scale schemes. Hence, investing in small irrigation projects was found to be more viable compared to large-scale irrigation projects. Large scale irrigation schemes have generally been developed by public agencies in several SSA countries, particularly Sudan, Madagascar and Nigeria [10]. However, the performance (measured by the economic internal rate of return) of these large-scale irrigation schemes has been poor [5,11].

Nearly 6% of the arable land in Africa, is irrigated, with two thirds of this area concentrated in Egypt, Algeria, Morocco, South Africa and Sudan [8]. Countries in the northern part of Africa have developed their land and water resources to the maximum [13]. However, in SSA, with the exception of South Africa, irrigation development has been slow with only 3.5% of the area cultivated equipped for irrigation [13]. Considering both land and water resources, SSA has high potential to increase the area under irrigation, from the current 7.7 million ha to 38 million ha [8]. As mentioned earlier, the slow pace of irrigation development in SSA can be attributed to the relatively high costs of irrigation development in the region compared to other regions [11,12]. For example, in 2000 prices, the average irrigation development cost for SSA was reported to be US$14,455/ha while that for non-SSA was US$6590/ha compared with US$3393 per ha for South Asia, US$8221/ha for East Asia and US$4903/ha for Latin America and the Caribbean [11].

Smallholder agricultural growth is critical for poverty alleviation in SSA more than elsewhere in the world [14,15]. In SSA, smallholder agricultural growth is estimated to be 11 times more effective in reducing poverty when compared with non-farm growth [16]. Several researchers argue that investments in smallholder irrigation contribute to poverty reduction [2,17–20]. Hence, in SSA, sustainable agriculture and smallholder irrigation development have been prioritized as strategies to meet the SDGs number 1 and 2 [2].

In Zimbabwe, about 70% of smallholder farmers live in agro ecological regions[1] IV and V. The regions are characterized by low rainfall (usually less than 650mm/annum) and generally shallow and infertile soils derived from granite [21]. The country's rainfall is erratic, unreliable, and insufficient as only 35% of the country receives adequate rainfall for sustainable rain-fed crop production (see Table 1) [22]. Since 1980, trends show that the majority of wet seasons are often punctuated by mid-season dry spells which affect crops and result in poor harvests [23]. Under such conditions, irrigated agriculture is significant to foster agricultural expansion and improve food security and livelihoods of smallholder farmers. This explains why, both the colonial and post-colonial governments of Zimbabwe invested in dam building and irrigation infrastructure development to make best use of the erratic rainfall the country receives [24]. Thus, in Africa, Zimbabwe has the second highest number of dams (213 dams) after South Africa with 539 dams [25].

Based on land suitable for irrigation, Zimbabwe has an irrigation potential of 1.5 million ha, with about 180 000ha (12%) equipped for irrigation [25,26]. Approximately 70% of the land area equipped for irrigation is operational while, the rest needs rehabilitation [25]. Irrigation infrastructure on almost 50 000ha was vandalised during the era of the Fast Track Land Reform Program (FTLRP) [26]. Currently, almost 45% of irrigation developments in the country fall under smallholder irrigation [26]. The government of Zimbabwe continues to invest in smallholder irrigation development to attain four main development goals, namely; (1) to counteract the effects of prevalent drought in smallholder farming areas, (2) to increase and sustain food production per unit area of land and improve food

[1] Agro ecological regions are land areas representing unique combinations of homogenous agro-climate, ecology, soil units and agricultural activities.

**Table 1**
Classification of natural regions and farming systems in Zimbabwe.

| Region | Area ($km^2$) | % | Climatic conditions | Farming systems |
|---|---|---|---|---|
| I | 6008.8 | 1.5 | Annual rainfall more than 1000 mm, Probability of exceeding 500 mm at least 95%, length of rainfall season >130days and maximum temperature between 21 and 25 °C. | Specialised and diversified farming region. Suitable for forestry plantations, banana apples, macadamia nuts, coffee, and tea in addition to intensive livestock production. |
| IIa | 22085.4 | 5.7 | 750 - 1000 mm rainfall per year confined to summer. Probability of exceeding 500 mm at least 90%, length of rainfall season between 120 and 130days and maximum temperature between 23 and 27 °C | Suitable for maize varieties requiring 120–130 days to maturity, flue-cured tobacco, groundnuts, Irish potato, cotton and soybean. Barley and wheat are grown under irrigation in the winter and drier months, Intensive livestock production (beef, dairy and poultry) (based on pastures and pen fattening) is also recommended. |
| IIb | 36304.7 | 9.3 | Annual rainfall between 750 and 1000 mm. Probability of exceeding 500 mm at least 80%, length of rainfall season between 115 and 120 days and maximum temperature between 25 and 28 °C | Suitable for maize varieties requiring 115–120 days to maturity, Cotton, Irish potato, barley, flue-cured tobacco, groundnuts, sorghum, sugar beans, coffee and horticultural crops can be successfully grown. Winter wheat is also grown under irrigation. Intensive livestock production is recommended in this region. |
| III | 63215.2 | 16.2 | 650–800 mm rainfall per year. Probability of exceeding 500 mm between 75 and 80%, length of rainfall season between 110 and 120days and maximum temperature between 25 and 28 °C | Suitable for maize varieties requiring 110–120 days to maturity. Soybean, groundnuts, cotton and sunflower are also suitable crops in this region. Supplementary irrigation is critical for successful crop production. The region is also suitable for semi-intensive livestock production (beef, dairy and small stock (e.g. goats and poultry). |
| IV | 113594.9 | 29.1 | 450–650 mm rainfall per year. Probability of exceeding 500 mm between 60 and 80%, length of rainfall season between 105 and 120 days and maximum temperature between 27 and 29 °C | Suitable for maize varieties requiring 105–120 days to maturity. However, in the absence of irrigation farmers are advised to grow drought tolerant crops such as sorghum (finger millet, pearl millet, water melons and cowpeas. Extensive cattle ranching, rearing of small stock (e.g. goats and poultry) and wildlife are ideal farming systems for this region. |
| Va | 115041.2 | 29.4 | Less than 650 mm annual rainfall. Probability of exceeding 500 mm between 60 and 80%, length of rainfall season between 100 and 120days and maximum temperature between 28 and 30 °C | Suitable for extensive cattle ranching and goat production. The region is marginal for drought tolerant crops such as sorghum, finger millet, pearl millet and cowpeas. Sugarcane is an ideal crop under irrigation, particularly in the vertisol and siallitic soils. Tree plantations, mainly oranges, lemons and lime are recommended where irrigation is available. This region is also suitable for extensive game-ranching and tourism |
| Vb | 34499.8 | 8.8 | Annual rainfall below 600 mm, Probability of exceeding 500 mm less than 60%, length of rainfall season less than 110days and maximum temperature between 28 and 32 °C | Tree plantations, mainly oranges, lemons and lime are recommended where irrigation is available. This region is also suitable for extensive cattle ranching, goats and wildlife tourism |
| Total | 390 750 | 100 | | |

Source: [Manatsa et al., 2020]

and nutrition security in rural areas, (3) to create employment opportunities in rural areas and improve the living standards of smallholder farming societies and (4) to increase agricultural exports and foreign currency earnings [17,20].

As part of the National Development Strategy (NDS) 1, the government of Zimbabwe targets to expand the land area equipped for irrigation from 180 000 ha to at least 350 000 ha during the period 2021 to 2025 [27]. To attain this goal, the country's government intends to revive the Irrigation Development Fund (IDF) and invest in building dams, drilling boreholes along with irrigation development and infrastructure rehabilitation [27]. Despite the significance of investments in smallholder irrigation in Zimbabwe, few contemporary studies have evaluated the impact of these investments on poverty reduction [26,28,29]. Little attention has been placed on the nexus between smallholder irrigation and poverty reduction. This study intends to close this gap by identifying and reviewing contemporary published evidence to examine the nexus between smallholder irrigation and poverty reduction in developing countries in general and Zimbabwe in particular.

## 2. Research objectives

The objective of the study was to bring together a broad set of literature and serve as a resource for those interested in understanding the connection between small-scale irrigation projects and poverty reduction. Moher et al. [30] suggest that when specifying a research objective, one has to address it with reference to participants, interventions, comparisons, study designs, and outcomes. In this study, we adopted the method with regard to the following: participants (smallholder irrigators), interventions (small-scale irrigation), comparisons (rain fed crop production), study design (quantitative, qualitative and mixed methods) and outcomes (contributions of small-scale irrigation to poverty reduction). The methodology suggested by Moher et al. [30] is commonly used in literature reviews. Other studies use the setting, perspective, intervention, comparison, evaluation (SPICE) and the sample, phenomenon of interest, design, evaluation, research type (SPIDER) methodologies.

## 3. Review methodology

A systematic review of literature was conducted. The methodology allows for transparency and replication. It offers a flexible, iterative, and reflexive search criterion to allow for a comprehensive review process. The researchers performed an initial search of relevant literature using electronic databases namely; AGRICOLA, PubAG and Google Scholar. Boolean operators, keywords, and synonyms were used to perform the literature search. This was conducted in an iterative manner to ensure that all the articles on the subject matter were extracted from the bibliometric databases. The snowballing technique was used to hand-search relevant articles in Google Scholar. Snowballing was used to ensure that the keywords identified by the researchers from the retrieved articles were used to enrich and make the search strategy more comprehensive. This is the iterative and important part of the search where the search syntax will continue to be modified, considering the Boolean operators. The literature reviewed included research publications in peer-reviewed journals, dissertations and reports from world institutions published between 1994 and 2021 and written in English. The restriction on the time of publication enabled the review to focus on all studies conducted on small-scale irrigation and poverty reduction in the past three decades. Methodological and quality assessment of the research evidence were addressed by focusing on literature that went through stringent peer-review publication processes.

The study used a multi-stage screening process based on the title, abstract, and full text of selected articles. Initial screening was

**Table 2**
Characteristics of the articles included; smallholder irrigation and food security.

| Author (Year) | Title | Type of data | Sampling technique | Sample size | Analytical tools | Findings |
|---|---|---|---|---|---|---|
| Jambo et al. [33] | Impact of small-scale irrigation on household food security: Evidence from Ethiopia. | Primary and secondary | Simple random sampling | 194 respondents (94 irrigators and 100 non-irrigators) | Descriptive statistics, Propensity score matching (PSM) and Econometric models | - Variables such as age, education, land size, access to extension service, and participation in off or non-farm activities have a positive influence on participation in irrigation.<br>- Irrigation has a positive impact on crop production, consumption and revenue generation |
| Wondimagegnhu and Bogale [32] | Small-scale irrigation and its effect on food security of rural households in North-West Ethiopia: A comparative analysis | Primary | Simple random sampling | 185 respondents (84 irrigators and 101 non-irrigators) | Descriptive analysis, Household food balance sheet model and Binary logit regression | -Out of all sampled households, 74% were food secure and 26% were not. The gap in food calorie availability ranged from 753 to 6659 kcal/adult equivalent/day.<br>- About 85% of the irrigators were food secure, while, only 65% of the non-irrigators were food secure. |
| Adeninyi and Dinbabo [34] | Efficiency, food security and differentiation in small-scale irrigation agriculture: Evidence from North West Nigeria | Primary | Simple random sampling | 306 irrigators | Food consumption score, Stochastic production frontier model, Pearson correlation analysis, Segmentation approach using cluster analysis and Multinomial regression model | -The mean efficiency level of smallholder farms was 85.9% and that the majority of the households were food insecure.<br>-Positive and significant relationship between efficiency, income and food security status, and some degree of class stratification among the households.<br>-Farm size, farming experience and diversification were major factors influencing households' livelihoods. |
| Peter [31] | The impact of small-scale irrigation schemes on household food security in Swaziland. | Primary | Purposive sampling | 4 communities (actual sample size not mentioned) | Descriptive statistics | -Irrigation schemes focused at household level and fields around the home contribute positively to income generation and food security. |

based on the relevance of the titles of the articles. The second screening assessed the abstracts to further select the relevant articles. Third, the selected articles were then screened based on the full article review, where articles were further screened based on the following inclusion criteria:

➢ The article investigated and reported the contribution of small-scale irrigation projects to either poverty reduction, livelihoods, food security and/or productivity,
➢ The article contains sufficient information to assess the validity of empirical methodology,
➢ The article contains original results and
➢ The article was published in English.

Articles that did not meet any one or more of the criteria were excluded. The search of literature covered three 10-year periods (1992–2001; 2002–2011 and 2012–2022) and 62 research publications were used. The proportions of publications reviewed for each period were 6%, 34% and 60% respectively. The studies that passed the inclusion criteria and full-text screening were considered for data extraction. The data extracted include the name of the author, publication year, location, study participants, study design, analytical framework, sample size and results. Systematic reviews assess the strength of research evidence. Thus, the study assessed the validity and reliability of the survey instrument, sample size calculation, the econometric model estimated, the goodness of fit tests and findings for the articles reviewed. The findings of the review were then summarized and discussed under specific themes.

## 4. Results and discussion

There is evidence which suggests that irrigation contributes to household food security [31–34], livelihoods of the rural poor [35–38], agricultural intensification and productivity [39–44], and poverty reduction [9,26,45–51]. Among other factors like type of system, availability of water resources, soil fertility, access to credit and markets, the socio-economic impact of smallholder irrigation largely determines the success and sustainability of the project [16].

### *4.1. Contribution of smallholder irrigation to household food security*

Food security means a situation where all people, at all times, have physical, social and economic access to sufficient, safe and nutritious food to meet their dietary needs and food preferences for an active and healthy life [33,52–57]. This definition brings out the four dimensions of food security, namely; food availability, food access, food utilization and stability [33,56,57]. Food availability means that sufficient quantities and quality of food must be available either through own production or imports [33]. Food access means that individuals must have access to entitlements for acquiring appropriate foods for a nutritious diet [52,55,57]. Food utilization implies consumption of adequate diet, clean water, sanitation and health care to reach a state of nutritional well-being where all physiological needs are met [57]. Food stability means a population, household or individual must have access to adequate food at all times and must be able to withstand sudden shocks [55–57]. Smallholder irrigation has been shown to positively impact food security [31–34]. Table 2 shows the characteristics of the published studies on smallholder irrigation and food security that were reviewed.

Out of the reviewed studies, two were conducted in Ethiopia, one in Nigeria and one in Swaziland. One study was conducted in the year 2021, two in 2020 and one in 2011. All the studies were cross sectional surveys. The participants in all the studies were smallholder farmers. The extracted data also shows that three studies used primary data and one used both primary and secondary data. The sample sizes ranged from 194 to 306 respondents. Three studies used the simple random sampling technique to select respondents [32,33,34] while, one study used purposive sampling [31]. None of the included studies gave information on the sample size determination in terms of the population heterogeneity and the power tests. The studies used several data analysis methods. The study by Jambo et al. [33] used a combination of descriptive statistics and econometric models and Propensity score matching (PSM) was used to analyze the impact of smallholder irrigation on food security [32]. used a combination of descriptive analysis, household food balance sheet model and binary logit regression model. The study by Adeninyi and Dinbabo [34] analysed data using the stochastic production frontier model, Pearson correlation analysis, segmentation approach using cluster analysis and multinomial regression model. The Food consumption score (FCS) was used to measure household food security. The study by Peter [31] used descriptive statistics to analyze the data.

The reviewed studies show that household food security was measured using the calorie intake, crop harvest and consumption levels [31–34]. The results show that variables such as age, education, land size, access to extension service, and participation in off or non-farm activities had a positive influence on participation in irrigation [33]. Furthermore, participation in smallholder irrigation was found to increase the daily calorie intake of irrigators by 643.76 kcal over non-irrigating households [33]. Irrigation was found to have a positive impact on crop production, consumption and revenue generation. The results from a study conducted by Wondimagegnhu and Bogale [32] revealed that out of all sampled households, 74% were food secure and 26% were not. The gap in food calorie availability ranged from 753 to 6659 kcal/adult equivalent/day in the study area. About 85% of the irrigators were food secure, while, only 65% of the non-irrigators were food secure. The studies by Jambo et al. and Wondimagegnhu and Bogale [32,33] concur that smallholder irrigation improves the daily calorie intakes of the irrigators.

The results of a study conducted by Adeninyi and Dinbabo [34] show that the mean efficiency level of smallholder farms was 85.9% and that the majority of the households were food insecure as measured by the FCS (calculated based on dietary diversity, nutrient intake and frequency of consumption). Furthermore, the findings established a significant positive relationship between efficiency, income and food security status, and some degree of class stratification among the households. Differences in household characteristics were found to determine the variation in the efficiency, food security and income of households. Farm size, farming experience and diversification were major factors influencing households' livelihoods. The results from a study by Peter [31] reveal that when irrigation schemes are focused at household level and to the fields around the home, they contribute positively to income generation and food security. All the studies that were included in the review concur that smallholder irrigation has a positive and significant impact on household food security.

### 4.2. *Contribution of smallholder irrigation to agricultural productivity*

The contribution of smallholder irrigation to agricultural productivity was assessed. There is evidence that smallholder irrigation contributes to agricultural productivity [39–44]. A total of six studies were included in the review [39,40,41,42,43,44]. Table 3 shows a summary of the studies reviewed. Three of the reviewed studies were conducted in the year 2017, followed by one study conducted in 2012, 2001 and 1998 respectively. Three of the studies were conducted in Ethiopia, two in Zimbabwe and one in Tanzania. Four of the studies used primary data, while, one study used both primary and secondary data and one study used secondary data. Both probability and non-probability sampling techniques were utilized to select the respondents for the studies. A study conducted by Fikire and

**Table 3**
Characteristics of the articles included; smallholder irrigation and agricultural productivity.

| Author (Year) | Title | Type of data | Sampling technique | Sample size | Analytical tools | Findings |
|---|---|---|---|---|---|---|
| Fikirie and Mulualem [42] | Review on the role of small-scale irrigation agriculture on poverty alleviation in Ethiopia. | Secondary (literature review) | Snowball | Not mentioned | Thematic analysis | -Smallholder irrigation increases productivity, household incomes and employment.<br><br>-The average crop yields per hectare from irrigated land were 2.3 times more than those under rainfed agriculture |
| Makombe et al. [43] | An analysis of the productivity and technical efficiency of smallholder irrigation in Ethiopia. | Primary data | Simple random sampling | 434 farmers | Descriptive statistics and stochastic frontier production function | -The marginal productivity of land was highest for communal modern irrigation system at 2137 ETB (Ethiopian currency) followed by rainfed without access to irrigation at 1056 ETB, traditional irrigated system at 660 ETB and rainfed system with access to irrigation at 625 ETB for the traditional irrigated sample<br>- Average technical efficiency for the communal modern irrigation schemes was 71%, for the rainfed systems with no access to irrigation was at 78% and the irrigated perennial system was at 13% |
| Mkanthama et al. [44] | The technical efficiency of lowland rainfed and irrigated rice production in Tanzania | Primary data | Simple random sampling | 142 farmers (68 irrigators and 74 non-irrigators) | Descriptive statistics and stochastic frontier production function | -The average technical efficiency of the irrigators was 96% compared to an average of 39% for the rainfed lowland system |
| Gebregziabher et al. [41] | Technical efficiency of irrigated and rain-fed smallholder agriculture in Tigray, Ethiopia | Primary data | Stratified random sampling | 613 farm households (331 irrigators and 282 non-irrigators) | Propensity score matching (PSM)<br><br>Descriptive statistics and Stochastic frontier production function | -The average technical efficiencies of irrigated and rain-fed plots were 45% and 82%, respectively<br>- Productivity of irrigated plots was higher than that of rain-fed crops |
| Makombe et al. [40] | An evaluation of Bani (dambo) systems as a smallholder irrigation development strategy in Zimbabwe | Primary data | Simple random sampling | 149 farmers | Stochastic frontier production function | -The inefficiency of the formal systems was estimated to be 11%, while, for the bani system was estimated to be 13% |
| Makombe et al. [39] | An analysis of the water management performance of smallholder irrigation schemes in Zimbabwe | Primary and secondary data | Purposive | 12 irrigation schemes | Theil measure of accuracy of forecasts, | -The community schemes committed less error, 0.03% than Agritex schemes, 0.05%, expressed as a percentage of the total possible committable error. |

**Table 4**
Characteristics of the articles included; smallholder irrigation and livelihoods.

| Author (Year) | Title | Type of data | Sampling technique | Sample size | Analytical tools | Findings |
|---|---|---|---|---|---|---|
| Akudugu et al. [36] | The Livelihoods Impacts of Irrigation in Western Africa: The Ghana Experience | Primary data | Multistage sampling | 32 focus group discussions, 60 key informants and 864 households | Regression adjustment (RA) technique, Thematic, Content and Discourse analyses | -The average farm income level per year was higher (US$713.29) in communities with irrigation facilities than in communities without irrigation (US$493.91) ($P < 0.01$)<br>-Average duration of effective employment was 13 weeks (3 months) for communities without irrigation facilities and about 20 weeks (5 months) for communities with irrigation facilities ($P < 0.01$)<br>-Irrigation has a significant and positive impact on farm household consumption<br>-Food security and average consumption expenditure was US $326.63 for communities without irrigation facilities and US $513.18 for communities with irrigation facilities |
| Maepa et al. [38] | Is the Revitalization of Smallholder Irrigation Schemes (RESIS) programme in South Africa a viable option for smallholder irrigation development? | Primary data | Simple random sampling | 50 irrigators | Descriptive statistics and gross margin analysis | -Gross margin for the scheme per year was ZAR2,652,067.29 (South Africa currency) and after accounting for the 50% paid to the strategic partner, each beneficiary received ZAR17,680.<br><br>−76% of the respondents reported that the RESIS program had a positive impact on household income, 75% reported a positive impact on household asset ownership and 76% reported a high impact on access to food |
| Chazovachii [35] | The impact of small-scale irrigation schemes on rural livelihoods: The case of Panganai irrigation scheme Bikita district Zimbabwe | Primary data | Simple random sampling | 50 farmers | Descriptive statistics | -The irrigation scheme had managed to create employment, generate income, and enhance acquisition of assets such as scotch carts and livestock by farmers.<br>-The yields produced were found to be still low |
| Hagos et al. [37] | Importance of irrigated agriculture to the Ethiopian economy: Capturing the direct net benefits of irrigation | Primary and secondary data | Not mentioned | Not mentioned | Gross margin analysis | -Irrigation generates an average income of US$323/ha compared to US$147/ha for rainfed farming.<br><br>-In 2005/06 cropping season, smallholder irrigation contributed about 4.46% (US $262.3 million) of national agricultural GDP and 1.97% of the total overall gross domestic product (GDP)<br>-The total income earned from large-scale irrigation schemes was estimated to be about US$74 million (accounting for about 1.26% of the agricultural and 0.5% of the total GDP respectively).<br>-The overall contribution of irrigation to agricultural and total national GDP was 5.7% and 2.5% during the 2005/06 cropping season |

**Table 5**
Characteristics of the articles included; smallholder irrigation and poverty reduction.

| Author (Year) | Title | Type of data | Sampling technique | Sample size | Analytical tools | Findings |
|---|---|---|---|---|---|---|
| Hussain and Hanjra [45] | Irrigation and Poverty Alleviation: Review of the Empirical Evidence | Secondary (literature review) | Snowballing | Not mentioned | Thematic analysis | -There are strong direct and indirect linkages between irrigation and poverty.<br>-Irrigation technology increase crop production, increase yields, lower risk of crop failure, and create farm and nonfarm employment.<br>-Irrigation enables smallholders to adopt more diversified cropping patterns, and switch from low-value subsistence production to high-value market-oriented production |
| Huang et al. [9] | Irrigation, agricultural performance and poverty reduction in China | Primary data | Simple random sampling | 1199 households | Descriptive statistics, Multiple linear regression analysis and Cost benefit analysis | -Irrigation significantly increase crop yields. Wheat yields of irrigated plots were 70.9% higher than those of non-irrigated ones, irrigated cotton yields were 177% higher and irrigated maize yields were 16.4% higher.<br>-The revenues from irrigated plots were found to be 93% higher than those from non-irrigated plots.<br>-The cost benefit analysis results show that irrigation investments have positive returns. |
| Haji et al. [49] | Impact analysis of Mede Telila small-scale irrigation scheme on house poverty alleviation: Case of Gorogutu District in Eastern Haratghe Oromia National Regional State Ethiopia | Primary data | Stratified random sampling | 200 households (100 irrigators and 100 non-irrigators) | Descriptive statistics, the Foster, Greer and Thobeck (FGT) poverty indices and Propensity Score Matching (PSM) | -Per capita consumption expenditure of irrigators was 25% more than that of non-irrigators.<br>-The incidence of poverty was found to be significantly lower among irrigators (27%) than non- irrigators (55%) |
| Bacha et al. [47] | Impact of small-scale irrigation on household poverty: empirical evidence from the Ambo district in Ethiopia | Primary data | Simple random sampling | 222 households (107 irrigators and 115 non-irrigators) | Descriptive statistics, FGT poverty indices and Heckman's selectivity model | -There were statistically significant differences between irrigators and non-irrigators in terms of mean food expenditure, mean non-food expenditure and total off-farm income ($P < 0.01$).<br>-The share of food expenditure in total household consumption expenditure was more than 55% for both irrigators and non-irrigators.<br>-Variables such as farm size, livestock holding, land productivity and family size were found to significantly infiuence the level of household consumption expenditure.<br>-The incidence, depth and severity of poverty were significantly lower among irrigators.<br>-Around 63% of non-irrigators were below the poverty line, whereas 34.6% of irrigators were below the poverty line.<br>-The poverty gap index (a measure of depth of poverty) was 10% for irrigators and 21% for non-irrigators. |
| Namara et al. [48] | Rural Poverty and Inequality in Ethiopia: Does Access to Small-Scale Irrigation Make a Difference? | Primary data | Simple random sampling | 1024 farmers (627 irrigators and 397 non-irrigators) | Foster, Greer and Thorbecke poverty measures, Logistic regression model | -The incidence of and severity of poverty was higher in rural (52%) than urban areas (36%).<br>-The depth of poverty for irrigators was 0.322 compared to 0.425 for non-irrigators. |

(*continued on next page*)

**Table 5** (*continued*)

| Author (Year) | Title | Type of data | Sampling technique | Sample size | Analytical tools | Findings |
|---|---|---|---|---|---|---|
| Sinyolo [50] | The impact of smallholder irrigation and water security on household welfare: The case of Tugela Ferry irrigation scheme in KwaZulu-Natal, South Africa | Primary data | Stratified random sampling | 256 farmers (186 irrigators and 70 non-irrigators) | Treatment effect, Propensity score matching (PSM), Descriptive statistics and FGT indices | -Increases in farm size, irrigated area and years of schooling significantly reduce the probability of being poor, while increases in family size and area share of food grains in the total cultivated area significantly increases the probability of being poor<br>-Irrigators had higher consumption expenditures, more livestock, higher incomes and better education than the non-irrigators.<br><br>-The consumption expenditure per adult equivalent per year of an irrigator was R2,216.14 more than that of a non-irrigator.<br>-The poverty gap index, a measure of depth of poverty, was 31% for non-irrigators and 16% for irrigators |
| Desulie and Abebe [51] | A critical review of small-scale irrigation in Ethiopia: Prospects and challenges | Secondary data (Literature review) | Snowballing | 12 studies | Thematic analysis | -Investments in smallholder irrigation are a key poverty reduction strategy<br><br>-Smallholder irrigation was found to be underdeveloped which limited its contribution to agricultural production and food security.<br>-The major constraints to smallholder irrigation highlighted by the study include; institutional, technical, financial, socio-economic and market related aspects |
| Chivizhe [26] | Agricultural productivity and poverty in smallholder irrigation schemes: The case of Midlands Province in Zimbabwe | Primary data | Simple random sampling | 127 irrigators | Descriptive statistics, Stochastic Frontier analysis, Gini coefficient and Lorenz curves and the FGT class of poverty measures | -The mean technical efficiency was 69% for Ngondoma irrigation scheme and 65% for Hamamavhaire irrigation scheme.<br><br>-The Gini coefficients of 0.516 for Ngondoma irrigation scheme and 0.624 for Hamamavhaire irrigation scheme.<br>-The poverty prevalence was 97% for Ngondoma irrigation scheme and 94% for Hamamavhaire irrigation scheme.<br>-The poverty gap index was 0.645 for farmers at Ngondoma irrigation scheme and 0.639 for those at Hamamavhaire irrigation scheme |

Mulualem [42] used the snowballing technique to select articles that were included in the literature review. Similarly, a study conducted by Makombe et al. [39] utilized non-probability sampling as the respondents were purposively selected. Four of the included studies used the simple random sampling technique to select respondents [40,41,43,44].

The results extracted from the included studies found that in most cases irrigated farms had higher technical efficiencies compared to rainfed farms. For example, the desktop study conducted by Fikirie and Mulualem [42] found that smallholder irrigation increases productivity, household incomes and employment. The average crop yields per hectare from irrigated land were found to be 2.3 times more than those under rainfed agriculture. The increase in productivity by small-scale irrigators enabled them to switch from subsistence production to market oriented production as the farmers produced surplus from the irrigated plots. Hence, the adoption of smallholder irrigation is a viable strategy to increase crop production to meet the growing food demands, achieve food security and improve the livelihood of rural households. A similar study conducted by Makombe et al. [43] found that the marginal productivity of land was highest for the communal modern irrigation system at 2137 ETB (Ethiopian currency) followed by rainfed without access to irrigation at 1056 ETB, traditional irrigated system at 660 ETB and rainfed system with access to irrigation at 625 ETB for the traditional irrigated sample. The average technical efficiency for the communal modern irrigation schemes was 71%, for the rainfed systems with no access to irrigation was at 78% and the irrigated perennial system was at 13%. Thus, there were potential gains to be realized by the farmers if technical efficiency of the communal modern irrigation system and rainfed system with no access to irrigation were to be improved.

The technical efficiency of rainfed and irrigated rice production in Tanzania was found to be 96% for the irrigators compared to an average of 39% for the rainfed lowland system [44]. This implied that for the irrigators, potential gains could be achieved by changing the existing technology as the farmers were found to be efficient. For the rainfed lowland rice production, there are gains that can be made by increasing the technical efficiency at current input levels. The study recommended the need to strengthen the extension system to improve the technical efficiency of the rainfed system.

However, a study conducted by Gebregziabher et al. [41] found that irrigated agriculture had a lower technical efficiency compared to rainfed agriculture in Ethiopia. The results show that the average technical efficiencies of irrigated and rain-fed plots were 45% and 82%, respectively. These figures indicate that rain-fed agriculture operated close to its production frontier, while irrigated agriculture produced at less than 50% of its potential. The production frontier of irrigated plots was on a higher level than that for rain-fed plots, meaning that the productivity of irrigated plots was higher than that of rain-fed crops.

The management of an irrigation system also has an implication on its productivity and technical efficiency [40]. evaluated Bani (Dambo) systems as a smallholder irrigation development strategy in Zimbabwe. The study compared and evaluated socio-economic characteristics and technical efficiency of the Bani system to the formal irrigation systems. The smallholder irrigation sector in Zimbabwe consists of the formal Agritex systems (government-managed), community systems (farmer-managed), and the informal farmer-managed bani (dambo) systems. These three systems were compared for their technical efficiency. The inefficiency of the formal systems was estimated to be 11%, while, for the bani system was estimated to be 13%. The study concluded that the bani system is at least as efficient as the formal systems, even given all the government support given to formal systems.

The efficiency of water management in an irrigation project influences the productivity of the irrigated farms. Makombe et al. [39] analysed the water management performance of smallholder irrigation schemes in Zimbabwe. The performance of irrigation systems was measured using the system's capability to meet the crop water requirements. The Theil measure of accuracy of forecasts was used to calculate the error committed by each system in trying to match water supply and demand. The results show that the community schemes committed less error, 0.03% than Agritex schemes, 0.05%, expressed as a percentage of the total possible committable error. The study concluded that community irrigation schemes were better than the Agritex schemes in terms of matching the supply and demand of water.

### 4.3. Contribution of smallholder irrigation to livelihoods

The contribution of smallholder irrigation to farmers' livelihoods has also been an area of interest to researchers. It is often argued that smallholder irrigation can be a basis for rural development and improved livelihoods in rural poor communities [35,36,38]. Four studies were included in the review to assess the contribution of smallholder irrigation to livelihoods (see Table 4). The studies were conducted in Ghana, South Africa, Zimbabwe and Ethiopia. Three of the studies used primary data while one study used both primary and secondary data. Two of the studies included used the simple random sampling technique to select respondents, one study used the multi-stage sampling technique and one of study did not mention the sampling procedure. The analytical tools that were utilized by the studies to measure the contribution of irrigation to livelihoods include the Regression adjustment (RA) technique, Thematic, Content and Discourse analyses, descriptive statistics, and gross margin analysis.

The livelihoods were measured using various indicators such as farm income, household income, duration of effective employment, farm household consumption, gross margin, and asset and livestock ownership. All the studies reviewed reported that smallholder irrigation had a positive contribution to livelihoods. For instance, a study conducted by Akudugu et al. [36] in Ghana examined the impacts of irrigation on farmers' livelihoods. The study found that the average farm income level per year was higher (US$713.29) in communities with irrigation facilities than in communities without irrigation (US$493.91) ($P < 0.01$). The average duration of effective employment was 13 weeks (3 months) for communities without irrigation facilities and about 20 weeks (5 months) for communities with irrigation facilities ($P < 0.01$). The regression results revealed that irrigation has a significant and positive impact on farm household consumption and food security and average consumption expenditure was US$326.63 for communities without irrigation facilities and US$513.18 for communities with irrigation facilities. Hence, governments should accelerate investments in irrigation infrastructure to transform smallholder agriculture to improve livelihoods.

In the same vein, a study conducted by Maepa et al. [38] to evaluate the viability of the Revitalization of Smallholder Irrigation Schemes (RESIS) program in South Africa reported similar findings. The results show that gross margin for the scheme per year was ZAR2,652,067.29 (South Africa currency) and after accounting for the 50% paid to the strategic partner, each beneficiary received ZAR17,680. Furthermore, 76% of the respondents reported that the RESIS program had a positive impact on household income, 75% reported a positive impact on household asset ownership and 76% reported a high impact on access to food. Thus, smallholder irrigation is vital towards transforming farmers from food self-sufficiency and subsistence to commercial production, thus, improving livelihoods. In addition, the study conducted by Chazovachii [35] assessed the impact of smallholder irrigation on rural livelihoods at Panganai irrigation scheme in Bikita district, Zimbabwe. The study found that the irrigation scheme had managed to create employment, generate income, and enhance acquisition of assets such as scotch carts and livestock by farmers.

A study conducted by Hagos et al. [37] measured the contribution of irrigation to livelihoods at a country level. The study's aim was to quantify the actual and expected contribution of irrigation to the Ethiopian national economy. The results show that irrigation generates an average income of US$323/ha compared to US$147/ha for rainfed farming. In 2005/06 cropping season, smallholder irrigation contributed about 4.46% (US$262.3 million) of national agricultural GDP and 1.97% of the total overall gross domestic product (GDP). The total income earned from large-scale irrigation schemes was estimated to be about US$74 million (accounting for about 1.26% of the agricultural and 0.5% of the total GDP respectively). The overall contribution of irrigation to agricultural and total national GDP was 5.7% and 2.5% during the 2005/06 cropping season. In 2009/2010 the expected contribution of smallholder managed irrigation to national economy was expected to be US$414.2 million (accounting for 5.5% of the agricultural GDP and 2.3% of the overall GDP). The large-scale irrigation schemes were estimated to contribute US$253.3 million (3.3% and 1.4% of the agricultural and overall GDP respectively). The study concluded that irrigation contributes significantly to the Ethiopian economy. To enhance irrigation's contribution to the economy, there is need to improve provision of agricultural inputs, promote high value crops through the extension system, create good market conditions, and increase the efficiency of small and large schemes.

The studies included in the review concur that smallholder irrigation contributes positively to the improvement of livelihoods at both household and national levels. The improvement in livelihoods are measured by increases in farm income, household income, duration of effective employment, farm household consumption, gross margin, and asset and livestock ownership.

### *4.4. Contribution of smallholder irrigation to poverty reduction*

Studies on the impact of smallholder irrigation on poverty reduction are not conclusive. Some studies argue that smallholder irrigation reduces poverty while others argue otherwise. A total of eight studies were included in the review of the contribution of smallholder irrigation to poverty reduction (see Table 5). Six of the included studies were empirical researches which used primary data [9,26,47–50] while, two of the included studies were reviews of literature [45,51]. Four of the reviewed studies used the simple random sampling technique to select the respondents, two studies used stratified random sampling to select respondents and two studies used the snowballing technique to select relevant literature. For the empirical studies that were reviewed, the sample sizes ranged from 127 to 1199 respondents. The studies explained how they arrived at the sample sizes. The data were analysed using various methods, which include; descriptive statistics, multiple linear regression analysis and Cost benefit analysis, thematic analysis, Foster, Greer and Thobeck (FGT) poverty indices, and Gini coefficient.

The findings of the included studies are mixed. For example Hussain and Hanjra [45], conducted a desktop study to understand the linkages between irrigation and poverty. The study documented evidence on studies from countries in South and South-East Asia. The study found that there are strong direct and indirect linkages between irrigation and poverty. Irrigation technology was found to increase crop production, increase yields, lower risk of crop failure, and create farm and nonfarm employment. Furthermore, irrigation enables smallholders to adopt more diversified cropping patterns, and switch from low-value subsistence production to high-value market-oriented production. Irrigation investments were found to have a strong positive effect on growth, benefiting the poor in the long run. The study concluded that investments in irrigation development are significant in reducing rural poverty. The findings by Hussain and Hanjra [45] concur with those of Shah and Singh [46] who undertook a study on the impact of irrigation development on rural poverty in Gujarat, India. The aim of the study was to determine if investing in irrigation projects helps to reduce poverty. The study used secondary data. The results show that primary education infrastructure and improved land productivity through irrigation were key variables in the design of poverty reduction programs.

Furthermore Huang et al. [9], conducted a study on the impact of irrigation on agricultural performance and poverty reduction in China. The results showed that irrigation significantly increase crop yields. For example, wheat yields of irrigated plots were 70.9% higher than those of non-irrigated ones, irrigated cotton yields were 177% higher and irrigated maize yields were 16.4% higher. In addition, the results show that irrigation increases incomes for poor farmers. The revenues from irrigated plots were found to be 93% higher than those from non-irrigated plots. The cost benefit analysis results show that irrigation investments have positive returns. The study concluded that irrigation was important in the reduction of poverty in China.

In Africa, studies conducted on irrigation and poverty reduction tend to be inconclusive. For example Haji et al. [49], conducted a study on the impact of Mede Telila smallholder irrigation scheme on household poverty alleviation in Gorogutu district in Ethiopia. The Average Treatment effect of Treated (ATT) indicated that, the per capita consumption expenditure of irrigators was 25% more than that of non-irrigators. The incidence of poverty was found to be significantly lower among irrigators (27%) than non-irrigators (55%). Based on the findings, the study concluded that smallholder irrigation has a positive impact on poverty reduction. Bacha et al. [47] conducted a similar study to that of Haji et al. [49] and assessed impacts of smallholder irrigation development on poverty reduction in Ethiopia, using a case study of Indris irrigation scheme. The results of the study show that there are statistically significant differences between irrigators and non-irrigators in terms of mean food expenditure, mean non-food expenditure and total off-farm income ($P < 0.01$). The share of food expenditure in total household consumption expenditure was more than 55% for both irrigators and non-irrigators. In addition, other variables such as farm size, livestock holding, land productivity and family size were found to significantly infiuence the level of household consumption expenditure. The incidence, depth and severity of poverty were significantly lower among irrigators. Around 63% of non-irrigators were below the poverty line, whereas, 34.6% of irrigators were below the poverty line. The poverty gap index (a measure of depth of poverty) was 10% for irrigators and 21% for non-irrigators. The study concluded that stallholder irrigation reduced poverty.

A study by Namara et al. [48] assessed the efficacy of irrigation investments in reducing poverty in rural Ethiopia. The results show that the incidence of and severity of poverty was higher in rural (52%) than urban areas (36%). Poverty incidence for households belonging to the first quartile of irrigated area was 65.8%, which decreased to 40.3% for those in the fourth quartile. The depth of poverty for irrigators was 0.322 compared to 0.425 for non-irrigators. The regression results show that increases in farm size, irrigated area and years of schooling significantly reduce the probability of being poor, while increases in family size and area share of food grains in the total cultivated area significantly increases the probability of being poor. The study concluded that the incidence, depth and severity of poverty is affected more by the intensity of irrigation use (as measured by the size of irrigated area) than mere access to irrigation.

While irrigation access is important, water security is critical to enhance the effectiveness of smallholder irrigation to poverty reduction in rural communities. Thus, the argument that participation of rural farmers in irrigation initiatives is necessary though not sufficient for enhancing household welfare. A study conducted by Sinyolo [50] empirically tested this assertion. The study assessed the contribution of smallholder irrigation to household welfare in rural South Africa. The results showed that irrigators and non-irrigators were homogenous in terms of socioeconomic characteristics. Irrigators had higher consumption expenditures, more livestock, higher incomes and better education than the non-irrigators. The consumption expenditure per adult equivalent per year of an irrigator was R2,216.14 more than that of a non-irrigator. FGT indices showed that poverty was more pronounced among the non-irrigators. The poverty gap index, a measure of depth of poverty, was 31% for non-irrigators and 16% for irrigators. Water security was found to be crucial for smallholder irrigation as a tool to reduce poverty.

A desktop study conducted by Desulie and Abebe [51] critically reviewed 12 contemporary studies on smallholder irrigation in Ethiopia. The study argues that investments in smallholder irrigation are a key poverty reduction strategy for the country. However, smallholder irrigation was found to be underdeveloped which limited its contribution to agricultural production and food security. The major constraints to smallholder irrigation are institutional, technical, financial, socio-economic and market related aspects. Based on the findings, the study recommended the government to work on improving the technical knowhow of farmers on irrigation technologies, extending credit facilities, expanding markets and road infrastructure and setting clear organizational structures for irrigation departments at various levels. The study's findings confirm those of [47,49] who also conducted similar studies in Ethiopia.

In Zimbabwe, Chivizhe [26] conducted a study on agricultural productivity and poverty alleviation in smallholder irrigation. The study addressed poverty prevalence, inequality and technical efficiency issues at Hamamavhaire and Ngondoma irrigation schemes. The study found that the mean technical efficiency was 69% for Ngondoma irrigation scheme and 65% for Hamamavhaire irrigation scheme. Gini coefficients of 0.516 for Ngondoma irrigation scheme and 0.624 for Hamamavhaire irrigation scheme were found. The poverty prevalence was 97% for Ngondoma irrigation scheme and 94% for Hamamavhaire irrigation scheme. This means that the majority of the respondents were poor. The poverty gap index was 0.645 for farmers at Ngondoma irrigation scheme and 0.639 for those at Hamamavhaire irrigation scheme. The study's findings showed that the prevalence of poverty among the irrigators was significantly high while technical efficiency was high. The researcher however, suggests that smallholder irrigation schemes should not be totally condemned as a development model as they avail opportunities for poverty alleviation. The weakness of the study was that there was no control in the sample used as the selected sample did not have non-irrigators for comparison purposes.

## 5. Conclusion

The literature reviewed, provided a basis for understanding smallholder irrigation and poverty reduction nexus. Studies reviewed argue that smallholder irrigation enhances household welfare in most developing countries. Smallholder irrigation was found to contribute to improvement in household food security, increase in household income, create employment, enhance livelihoods through asset accumulation, increase agricultural productivity all of which are factors that contribute to poverty reduction among rural households [17–20,26,29,58–60]. The studies reviewed also show that despite its potential, smallholder irrigation has, in some instances, failed to meet expectations. The failure of smallholder irrigation to meet expectations has been attributed to poor management resulting in conflicts among water users, exploitation of water resources, poor living standards and poverty [29]. Hence, there is a need to address these challenges to enhance the performance of smallholder irrigation and its positive impact on rural poverty.

The literature reviewed show that qualitative and quantitative methods are commonly used in studies on contribution of smallholder irrigation to food security, productivity, livelihoods and poverty reduction [9,33,41,45,46,51,61]. For instance Jambo et al. and Gebregziabher et al. [33,41], used quantitative methods in their studies to measure the impact of smallholder irrigation on household food security and technical efficiency in Ethiopia. The quantitative studies mainly used descriptive statistics, econometric models, PSM, Stochastic frontier analysis, FGT poverty indices to analyze the data. Qualitative studies were mainly in the form of desktop studies. Content, discourse, and thematic analyses were mainly used to determine the findings. Despite the multifaceted nature of food security, livelihoods and poverty, only a few studies have employed the mixed methods approach [35,36]. The mixed methods approach allows researchers to triangulate and cross-validate their findings. The reviewed studies employed both primary and secondary data sources for triangulation purposes. Furthermore, most studies compared irrigators and non-irrigators in their analyses. The non-irrigators were used as a control group. The respondents were mainly randomly selected to avoid bias and enhance generalization of the findings.

The literature review showed that most studies have focused on smallholder irrigation and its contribution to food security, livelihoods, productivity, incomes and poverty. However, not much research has been done on the nexus and dynamics between smallholder irrigation and poverty. Many studies also use variables that are proxies, or are correlated with poverty not the direct impacts on poverty. Thus, there is need to conduct contemporary studies on this subject matter in developing countries. Furthermore, the inconsistency of the methods used to measure poverty in the reviewed studies makes comparison of the findings difficult. Hence, there is a need to come up with a framework to measure poverty and baselines for comparison of findings. This will help policy makers and development practitioners to appreciate the contribution of smallholder irrigation investments to poverty reduction in developing countries [34,62].

## Declarations

### *Author contribution statement*

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No data was used for the research described in the article.

### *Declaration of interest's statement*

The authors declare no competing interests.

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