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# Micro-Irrigation for Household Food Security in Alebtong District, Mid-North Uganda

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## ABSTRACT

**Purpose:** The study examined contribution of micro irrigation to household food security in Cungaciki ward, Apala town council, Alebtong district.

**Methodology:** A cross-sectional survey was conducted among 63 households, employing structured questionnaires to collect data on perceptions of irrigation and its impacts on food availability, nutrition, and economic benefits. Descriptive statistics, Pearson correlation, and multiple regression analysis were used to analyze the data.

**Findings:** Results indicate that households perceive irrigation as beneficial, particularly in improving food availability, dietary diversity, and household income. Correlation analysis showed a moderate positive relationship between access to irrigation technology and household food security ($r = 0.509$, $p < 0.001$), a modest positive relationship for system effectiveness ($r = 0.351$, $p = 0.005$), and a strong positive relationship for capacity for maintenance ($r = 0.738$, $p < 0.001$). Regression analysis revealed that capacity for maintenance was the only significant predictor of household food security ($B = 0.619$, $p < 0.001$), highlighting that the benefits of irrigation are contingent on proper system upkeep.

**Unique Contribution to Theory, Policy and Practice:** This study contributes to strengthening the view that while irrigation technology and system effectiveness contribute to food security, sustainable outcomes are largely dependent on households' ability to maintain irrigation infrastructure. Consequently, it is recommended that local authorities need to build farmers' technical and management skills, strengthen institutional support, and promote participatory approaches to ensure long-term functionality and food security benefits.

**Keywords:** *Micro Irrigation, Irrigation Technology, Household, Food Security, Alebtong*

## 1.0 INTRODUCTION

Household food security, a fundamental aspect of human well-being, is increasingly threatened by climate change, population growth, and economic instability globally (FAO, 2023; Akello & Mwesigwa, 2023). This challenge is particularly acute in developing countries, where access to sufficient, safe, and nutritious food is essential for well-being and socio-economic development (Ogwal, Obici & Mwesigwa, 2022[a][b][c]; Wen & Elliot, 2018). The global food system has been further stressed by events like the conflict in Ukraine, a major grain exporter, which has disrupted supplies and driven up food and energy prices, impacting even relatively food-secure nations in Europe. For instance, Germany experienced a 40% increase in butter prices over the past year, while Poland saw a 49.2% rise, highlighting the strain on food affordability (AP News, 2025). Similarly, the UK's food and drink exports to the EU have declined by 34% since Brexit, reflecting broader challenges in food trade and security (The Guardian, 2025).

In Sub-Saharan Africa (SSA), the challenges of food insecurity are severe, with nations such as Ghana, Nigeria, and Ethiopia navigating a multifaceted crisis. This crisis arises from the interplay of factors such as vulnerability to climate change, constrained agricultural resources, and economic instability. These issues are further exacerbated by external global disruptions like the Ukraine conflict, which has strained food supply chains and increased commodity prices (IFPRI, 2022; UN, 2022). The region bears an outsized share of global hunger, characterized by persistent malnutrition and chronic food insecurity. Key contributors include low agricultural productivity, a heavy reliance on unpredictable rain-fed farming, and limited access to essential resources like modern farming tools, credit, and infrastructure (Cohen & Meerman, 2022). These challenges underscore the need for sustainable solutions to improve food production, resilience, and access across the region.

In East Africa, countries like Uganda, Kenya, Tanzania, and Rwanda are especially vulnerable due to erratic weather patterns, including droughts and unreliable rainfall, which negatively impact agricultural output (UNDP, 2021). For example, Kenya experiences recurring droughts affecting agriculture (FEWS NET, 2023), Tanzania struggles with unreliable rainfall affecting staple crops (World Bank, 2022), and Rwanda's agricultural sector is susceptible to climate variability (MINAGRI, 2020). In Uganda, where agriculture is central to the economy and household food security (UBOS, 2020), unreliable rainfall, limited land access, and a lack of resources, including irrigation, constrain agricultural production and contribute to food shortages (Okwang & Mwesigwa, 2021). While the Ugandan government and its partners are working to address these issues through agricultural diversification, improved seeds and fertilizers, and irrigation initiatives (MAAIF, 2022; Opok & Mwesigwa, 2021), household food insecurity persists, especially in rural communities.

Household food security, denotes the ability of a family to access enough nutritious food for an active, healthy life, is a crucial component of food security in both urban and rural settings. This issue is tightly interwoven with national food security but requires more localized, direct interventions. In rural communities like Apala Town Council in Alebtong District, Uganda, households depend heavily on rain-fed agriculture, which is vulnerable to the impacts of climate change, such as unpredictable rainfall and prolonged droughts (Alebtong District Local Government, 2021). The ability of these households to maintain food security is further strained by economic challenges, limited access to markets, and inadequate storage facilities, which result in post-harvest losses. Besides, small-scale farming households, which form the backbone of food production in much of SSA, often face barriers such as insufficient access to capital, education, and modern farming techniques (Mwesigwa, 2018). These factors exacerbate food insecurity within households, where food choices may be constrained to low-nutrient staple foods that do not meet the dietary needs of all family members (FAO, 2017). As climate change intensifies, food production at the household level is becoming less predictable (Mwesigwa, 2016), making it increasingly difficult for families to plan and provide for their food needs throughout the year.

In the modern world, micro irrigation offers a potentially transformative solution by mitigating the effects of unpredictable rainfall, boosting crop yields, and diversifying production (Opio & Mwesigwa, 2021; FAO, 2014). Households in rural areas such as Alebtong could benefit significantly from such systems, which would help stabilize food production and, by extension, household food security, which remains acute in Lango sub-region (Ogwal, Amot, & Mwesigwa, 2020) as compared to other regions such as mid-western Uganda (Mwesigwa & Mubangizi, 2019). However, successful implementation requires not only appropriate technology but also sufficient water resources, adequate infrastructure, and capacity-building initiatives to empower farmers to manage and maintain irrigation systems effectively (Anena & Mwesigwa, 2021). At the same time, improving access to diverse food sources at the household level can be supported through initiatives such as kitchen gardening, which promotes the production of nutrient-rich foods like vegetables and legumes. This, in turn, can complement household nutrition and reduce reliance on external food markets, which are often subject to price volatility. Consequently, the intricate relationship between household food security at the national and local levels calls for integrated approaches that consider both broader macroeconomic factors, like trade and food prices, and micro-level solutions focused on empowering households to withstand shocks. By investing in agricultural resilience, supporting small-scale farmers, and improving access to affordable, nutritious food, governments and development partners can help mitigate the impacts of climate change, economic instability, and global shocks, ensuring a more secure food future for all.

### 1.1 Problem Statement

Despite interventions such as the promotion of improved seed varieties, provision of fertilizers, and the introduction of small-scale irrigation schemes, Apala Town Council continues to face significant challenges in achieving household food security. The town's heavy reliance on rain-fed agriculture, combined with increasingly unpredictable weather patterns, has led to frequent crop failures, reduced yields, and income losses, severely impacting food availability, access, and utilization. Notably, in the 2021/22 financial year, only 42% of the allocated funds for the Micro-scale Irrigation Program were utilized across various districts, indicating challenges in program implementation. The Government of Uganda's Micro-scale Irrigation Program supports farmers in purchasing irrigation equipment through a matching grant scheme, co-financing the cost between the government and the farmer. However, despite these efforts, persistent challenges in achieving household food security in Apala Town Council suggest that additional research is needed to fully understand the effect of micro-irrigation systems on food security outcomes. Given these challenges and the mixed outcomes of existing interventions, it is essential to investigate how the adoption and maintenance of micro-irrigation systems impact food availability, access, and utilization at the household level. This study aimed to assess the role of micro-irrigation in improving household food security in Apala Town Council, Alebtong District.

### 1.2 Objective of the study

The study aimed to investigate contribution of micro irrigation to household food security in Alebtong District. Specifically, our study answered three questions, namely: (a) What is the effect of access to irrigation technology on household food security in Apala Town Council? (b) what is the effect of effectiveness of irrigation systems on household food security in Apala Town Council? And (c) what is the capacity for maintenance on household food security in Apala Town Council?

## 2. LITERATURE REVIEW

### 2.1 The effect of access to irrigation technology on household food security

The empirical literature consistently highlights the significant positive impact of access to irrigation technology on household food security, with various scholars providing evidence through rigorous studies. For instance, a study in Ethiopia by Awol and Arebu (2024) using Propensity Score Matching (PSM) found that small-scale irrigation users had significantly higher annual incomes and daily caloric intake compared to non-users. Similarly, Manjur et al. (2023) in northern Ethiopia demonstrated that irrigation positively influenced household income, food availability, food variety score, household diet diversity, and calorie intake. These findings underscore the crucial role of irrigation in enhancing food availability and economic access to food. Furthermore, the literature emphasizes the role of irrigation in facilitating crop diversification and improving nutritional outcomes. IFAD (2005) reported that in Ethiopia, small-scale irrigation schemes led to increased production, income, and diet diversification, with cash generated from vegetable sales helping households meet food demands during deficit months. A study by Mekonnen et al. (2022) in Ethiopia and Tanzania found that small-scale irrigation improved women's dietary diversity and the weight-for-height of children under five, particularly in drought-affected households. This highlights irrigation's contribution to both the quantity and quality of food consumed at the household level.

Beyond the direct impacts on production and nutrition, scholars have also examined the broader economic benefits of irrigation on household food security. Jambo et al. (2021) in the Oromia

Regional State of Ethiopia found that irrigation improved agricultural production, consumption, and revenue generation, all contributing to enhanced food security. Similarly, studies in sub-Saharan Africa indicate that access to reliable irrigation enables farmers to adopt new technologies, intensify cultivation, and achieve greater returns from farming, ultimately improving their food security status (e.g., Nigigi). The application of econometric methods like PSM and regression analysis has strengthened the empirical evidence linking irrigation to food security. For example, a study in the Raya Kobo Woreda, Ethiopia, used PSM to reveal a substantial positive impact of small-scale irrigation on household expenditure, a key indicator of food security (F1000Research, 2024). Likewise, a study in Nigeria by AIMS Press (2024) using linear regression with endogenous treatment effects and PSM showed a significant positive effect of irrigation technology use on crop yield, crop income, and household food security. These studies controlled for confounding factors, providing more robust causal inferences.

**2.2 The effect of effectiveness of irrigation systems on household food security**

The effectiveness of irrigation systems remains a critical determinant of their impact on household food security, with contemporary empirical evidence reinforcing this relationship. For instance, a recent study conducted in Kenya by Onyango et al. (2023) found that households participating in irrigation schemes characterized by reliable water supply and efficient water distribution networks experienced significantly higher levels of food security, measured by dietary diversity and food consumption scores, compared to those in poorly managed schemes or rain-fed areas. Similarly, research in Nepal by Sharma and Bhattarai (2022) highlighted that the dependability of irrigation water delivery was a strong predictor of increased agricultural productivity and reduced vulnerability to food shortages among smallholder farmers. Consequently, the choice and effective implementation of irrigation technology continue to be significant factors influencing outcomes. Studies have consistently shown that more advanced and water-efficient technologies, such as micro-irrigation systems, can yield greater food security benefits, especially in water-stressed regions. For example, a study in Morocco by El Alaoui et al. (2024) demonstrated that the adoption of drip irrigation led to substantial increases in crop yields and water productivity, directly contributing to improved household food availability and income. Furthermore, Khan et al. (2023) in Pakistan emphasized the importance of matching irrigation technology to local agro-ecological conditions and providing adequate training to farmers for optimal utilization and impact on food security.

Obtainable literature increasingly emphasizes that the effectiveness of irrigation systems is not solely a technological issue but is deeply intertwined with management practices and institutional support. Inadequate infrastructure maintenance, weak water user associations, and a lack of access to extension services can significantly limit the positive effects of irrigation on food security (Owusu & Giordano, 2019; Shah et al., 2017). For instance, a study in Tanzania by Mdemu et al. (2022) identified that the lack of proper maintenance of irrigation canals and the limited capacity of water management committees hindered equitable water distribution and ultimately constrained the food security benefits for some households. Therefore, effective irrigation requires a holistic approach that includes technical interventions alongside robust institutional frameworks and capacity development. Recent investigations also continue to explore the strong economic pathways through which effective irrigation enhances household food security. Increased and stable agricultural production resulting from reliable irrigation often leads to higher incomes, improved market access, and greater resilience to economic shocks, all of which contribute to food security (Haggblade et al., 2017; Pingali, 2012). For example, a study in Uganda by Ninsiima et al. (2023) found that farmers with access to well-functioning irrigation schemes experienced significant increases in their household income and were better able to afford diverse and nutritious food. This underscores the importance of ensuring the long-term sustainability and economic viability of irrigation infrastructure and management for sustained food security benefits.

**2.3 The effect of capacity for maintenance on household food security**

The effect of capacity for maintenance on household food security is increasingly recognized as a crucial factor in ensuring sustained benefits from agricultural interventions, particularly irrigation systems. Recent empirical literature highlights that the ability of households and communities to maintain agricultural infrastructure directly influences their long-term food security. For instance, a study in Uganda by Ninsiima et al. (2023) emphasized that irrigation schemes with well-established maintenance mechanisms, often involving community participation (Mwesigwa, 2021; Mwesigwa, Bogere & Ogwal, 2022), were more likely to provide consistent water supply, leading to stable crop yields and enhanced household food security. This underscores that the initial provision of technology is insufficient without the capacity for its upkeep. No wonder, the capacity for maintenance extends beyond just technical skills to encompass financial resources and institutional arrangements. Empirical evidence suggests that households with better access to financial resources are more likely to invest in the maintenance of their agricultural tools and irrigation equipment, thereby ensuring their continued functionality and contribution to food production (Onyango et al., 2023, Kenya). Moreover, studies have shown that the presence of strong local institutions, such as water user associations with clear maintenance responsibilities and resource mobilization strategies, plays a significant role in the sustainability of irrigation systems and the food security of the beneficiary households (Sharma & Bhattarai, 2022, Nepal).

Conversely, the lack of maintenance capacity can lead to the rapid deterioration of agricultural infrastructure, undermining its intended benefits for food security. For example, a study in Tanzania by Mdemu et al. (2022) found that poorly maintained irrigation canals resulted in inefficient water distribution, reduced crop yields, and consequently, negatively impacted household food availability. Similarly, the failure to maintain farm equipment can lead to decreased productivity and increased costs in the long run, affecting the economic dimension of food security (Oluwasanya & Abolude, 2022, Nigeria). These findings highlight the vulnerability of households to food insecurity when maintenance capacity is lacking. Thus, recognizing the importance of maintenance capacity, recent literature emphasizes the role of capacity building and community involvement in ensuring the sustainability of agricultural interventions and their contribution to food security. Programs that empower local communities with the necessary technical skills, management knowledge, and financial resources for maintenance have shown promising results (Al-Adamat et al., 2021, Jordan). Furthermore, participatory approaches that involve households in the planning and implementation of maintenance activities can foster a sense of ownership and responsibility, leading to better upkeep of infrastructure and more sustainable food security outcomes (Abimbola et al., 2023).

### 2.4 Research gaps

The above literature reveals that access to effective irrigation technology and the capacity for its maintenance are critical for enhancing household food security through increased agricultural productivity, crop diversification, improved nutrition, and higher incomes, as evidenced by studies across Africa and Asia; well-managed irrigation systems with reliable water delivery, supported by appropriate technology, strong institutions, and farmer training, lead to significant improvements in food security outcomes, while the ability of households and communities to maintain this infrastructure is essential for sustaining these benefits in the long term.

## 3.0 MATERIAL AND METHODS

### 3.1 Study Design

The study used a cross-sectional survey design in Cungaciki Ward to investigate the relationship between micro-irrigation and household food security at a single point in time. Both quantitative and qualitative data were gathered from households to assess micro-irrigation adoption, system effectiveness, maintenance capacity, and food security levels. This design helped identify associations between these variables. To gain a richer understanding, qualitative data from interviews and focus groups complemented the quantitative data, allowing for a more comprehensive analysis through triangulation. The study was conducted in Cungaciki Ward, Apala Town Council, Alebtong District (Omara & Mwesigwa, 2020). Apala Town Council was characterized by a reliance on rain-fed agriculture and was susceptible to the impacts of climate change, making it a relevant context for studying the role of micro-irrigation in enhancing household food security. Cungaciki Ward was specifically chosen due to the presence of households that had adopted micro-irrigation technologies, as well as those that had not, allowing for comparative analysis. The ward's socio-economic characteristics, primarily agrarian livelihoods, made it a suitable location to examine the interplay between irrigation practices and food security outcomes at the household level.

### 3.2 Study Population

The target population for this study comprised all households residing in Cungaciki Ward, Apala Town Council. This included households that were using micro-irrigation systems, those that had used them in the past, and those that relied solely on rain-fed agriculture. Focusing on all households within the selected ward provided a comprehensive understanding of the food security situation and the varying impacts of irrigation technologies.

### 3.3 Sampling Techniques and Sample Size

Study participants were selected using a multi-stage sampling technique. First, households in Cungaciki Ward were divided into two strata: those using micro-irrigation and those not using it, ensuring representation of both groups. Lists from the local council and agricultural extension workers were used for this stratification. Second, simple random sampling was applied within each stratum to select the required number of households, giving each household an equal chance of selection and minimizing bias. The sample size for the quantitative survey was calculated using Cochran's formula, considering a 95% confidence level, a 5% margin of error, and an estimated proportion of micro-irrigation users. Adjustments were made for the total population size and potential non-response. Therefore, the population size was 75, and the sampling size was 63, determined using Krejcie and Morgan's (1970).

### 3.4 Data collection instruments

A structured questionnaire was the main tool for collecting quantitative data, gathering information on household demographics, access to irrigation technology (type, information source, cost, ease of access), effectiveness of irrigation systems (reliability, water adequacy, impact on yields, efficiency), maintenance capacity (knowledge, resources, frequency, challenges), household food security (using HDDS, FCS, CSI, and perceived status), and socio-economic factors (income, land ownership, credit access, program participation). The questionnaire was pre-tested outside Cungaciki Ward on similar households to ensure clarity, validity, and reliability, and was revised accordingly. Also, an interview guide with open-ended questions was used to collect qualitative data from key informants. The guide covered topics such as their perspectives on the impact of micro-irrigation on food security, challenges faced by farmers in adopting and maintaining irrigation systems, and recommendations for improving irrigation practices and food security in the area.

### 3.5 Data Analysis

The study's quantitative data from household surveys were analyzed using both descriptive and inferential statistics. Descriptive statistics (frequencies, percentages, means, standard deviations, and ranges) summarized the sample's demographics, micro-irrigation adoption, system effectiveness, maintenance capacity, and food security levels. Inferential statistics such as correlation analysis were used to assess relationships between independent (irrigation access, effectiveness, maintenance) and dependent (food security indicators) variables. Multiple linear regression determined the individual and combined effects of micro-irrigation dimensions on household food security while controlling for factors such as household size, income, and education. Statistical significance was considered at a p-value of 0.05. correspondingly, the qualitative data from interviews and focus groups underwent thematic analysis, following Braun

& Clarke's (2006) steps: familiarization (transcribing and reading), coding (identifying themes), searching for themes (grouping codes), reviewing themes (refining accuracy), defining and naming themes, and producing the report (presenting findings with quotes). These qualitative findings enriched the quantitative results by providing context and deeper insights into participants' experiences and perceptions about how micro-irrigation related to their household food security.

### 3.6 Ethical Considerations

The following measures were taken: (a) Informed Consent as participants were fully informed about the purpose of the study, the data collection procedures, their right to refuse participation or withdraw at any time, and the confidentiality and anonymity of their responses. A consent form was administered and signed by each participant before data collection. (b) Confidentiality and anonymity as all data collected were kept confidential and anonymous. Participants were not identified by name in any reports or publications. Data were stored securely and accessed only by the research team. (c) Voluntary Participation as participation in the study was entirely voluntary. No incentives or coercion were used to encourage participation. (d) Respect for privacy as data collection was conducted at a time and place convenient for the participants, respecting their privacy and cultural norms. And (e) Ethical approval as this research proposal was submitted to the Department for review and approval before the commencement of data collection to ensure adherence to ethical research standards.

## 4.0 FINDINGS

### 4.1 Background characteristics

The study involved 63 respondents, of whom the majority were male (65.1%), while females constituted 34.9%. The largest proportion of respondents were aged 25–34 years (31.7%) and 35–44 years (28.6%), followed by those aged 45–54 years (19.0%) and 18–24 years (17.5%), with only 3.2% aged 55–64 years. Regarding marital status, most respondents were married (81.0%), while 14.3% were single, and smaller proportions were widowed (3.2%) or divorced (1.6%). In terms of education, the majority had attained primary education (61.9%), followed by secondary (19.0%), tertiary (9.5%), and university education (4.8%), while 4.8% had no formal education.

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**Table 1 Background Characteristics**

| Variable | Category | Frequency (N) | Percentage (%) |
|---|---|---|---|
| **Sex of respondent** | Male | 41 | 65.1 |
| | Female | 22 | 34.9 |
| **Age (years)** | 18–24 | 11 | 17.5 |
| | 25–34 | 20 | 31.7 |
| | 35–44 | 18 | 28.6 |
| | 45–54 | 12 | 19 |
| | 55–64 | 2 | 3.2 |
| **Marital status** | Single | 9 | 14.3 |
| | Married | 51 | 81 |
| | Divorced | 1 | 1.6 |
| | Widowed | 2 | 3.2 |
| **Highest education** | No formal education | 3 | 4.8 |
| | Primary | 39 | 61.9 |
| | Secondary | 12 | 19 |
| | Tertiary | 6 | 9.5 |
| | University | 3 | 4.8 |
| **Main occupation of household** | Crop farming | 40 | 63.5 |
| | Livestock farming | 16 | 25.4 |
| | Business | 5 | 7.9 |
| | Salary | 2 | 3.2 |
| **Monthly household income (UGX)** | Less than 100,000 | 9 | 14.3 |
| | 200,000–399,000 | 28 | 44.4 |
| | 400,000–990,000 | 21 | 33.3 |
| | Above 1,000,000 | 5 | 7.9 |

With respect to occupation, most households relied on crop farming (63.5%), followed by livestock farming (25.4%), with fewer engaged in business (7.9%) and salaried employment (3.2%). Household income levels were relatively low, with 44.4% earning between UGX 200,000–399,000 per month and 33.3% earning UGX 400,000–990,000. Only 14.3% earned less than UGX 100,000, while 7.9% reported monthly incomes above UGX 1,000,000.

### 4.2 The effect of access to irrigation technology on household food security in Cungaciki Ward

Table 2 presents respondents' perceptions of the contribution of micro irrigation in enhancing household food security. The results indicate that slightly over two-fifths (42.8%) of respondents agreed or strongly agreed that access to irrigation technology significantly improves the amount of food available to households, while about 28.6% were undecided and 28.6% disagreed. The mean score of 3.19 (SD = 1.014) suggests a moderate agreement among respondents. On the role of irrigation in improving household nutrition, more than half of respondents (52.4%) agreed or strongly agreed that irrigation helps households consume a wider variety of foods and improve their nutrition, while 25.4% were undecided and 22.2% disagreed. The mean score of 3.35 (SD = 0.883) indicates a fairly positive perception of irrigation's nutritional benefits.

**Table 2 Descriptive statistics on effect of access to irrigation technology on household food security**

| Statement | Mean | SD |
|---|---|---|
| Access to irrigation technology significantly improves the amount of food available to households | 3.19 | 1.014 |
| Irrigation plays a crucial role in helping households consume a wider variety of foods and improve their nutrition | 3.35 | .883 |
| The economic benefits resulting from irrigation are a key factor in enhancing household food security | 3.52 | .840 |
| Research methods like Propensity Score Matching provide strong evidence for the positive link between irrigation and household food security | 3.40 | .925 |

Regarding economic benefits, the majority of respondents (61.9%) agreed or strongly agreed that irrigation contributes to household food security through economic gains. Only 15.9% disagreed, while 22.2% were undecided. This statement recorded the highest mean of 3.52 (SD = 0.840), showing stronger agreement compared to other aspects. Finally, regarding methodological evidence, more than half of the respondents (55.5%) agreed or strongly agreed that research methods such as Propensity Score Matching provide strong evidence for the positive link between irrigation and household food security. About 23.8% were undecided, while a smaller proportion (20.6%) disagreed or strongly disagreed. The mean score of 3.40 (SD = 0.925) also reflects a generally favorable perception.

> A female farmer aged 39 noted that; *"Since we got access to irrigation technology, my family no longer worries about food during the dry season because we can grow vegetables and maize throughout the year"*. A male 47 stated that; *"Even with the irrigation pumps, it is still difficult for us to produce enough food because sometimes we lack the skills and money to keep the technology running properly."*

### 4.3 The effect of effectiveness of irrigation systems on household food security in Cungaciki Ward

The findings in table 3 show that respondents generally expressed strong agreement regarding the positive role of irrigation in improving household food security. A large majority (84.2%) agreed or strongly agreed that reliable irrigation water delivery strongly predicts better household food security, while only 1.6% disagreed and 14.3% were undecided. This item had the highest mean score of 4.00 (SD = 0.622), reflecting a strong consensus. Similarly, the majority of respondents (82.5%) agreed or strongly agreed that advanced irrigation technologies generally lead to greater improvements in household food security, while 11.1% remained undecided and 6.4% disagreed or strongly disagreed.

**Table 3 Descriptive statistics on the effect of effectiveness of irrigation systems on household food security**

| Statement | Mean | SD |
|---|---|---|
| Reliable irrigation water delivery strongly predicts better household food security in this area | 4 | 0.62 |
| Advanced irrigation technologies generally lead to greater improvements in household food security here | 3.86 | 0.74 |
| Effective irrigation's impact on food security depends heavily on good management and support systems in this place | 3.84 | 0.60 |
| Well-functioning irrigation significantly boosts household income, improving their food security in this place | 3.94 | 0.64 |

Further, the mean score of 3.86 (SD = 0.737) suggests a generally favorable view of technological advancement in irrigation. The results also indicate that respondents recognize the importance of institutional and managerial aspects, with 76.2% agreeing or strongly agreeing that effective irrigation's impact on food security depends heavily on good management and support systems. About 22.2% were undecided, and only 1.6% disagreed. The mean score of 3.84 (SD = 0.601) highlights a strong acknowledgment of management factors. Lastly, most respondents (85.7%) agreed or strongly agreed that well-functioning irrigation significantly boosts household income, thereby improving food security. Only 4.8% disagreed, and 9.5% were undecided. This statement recorded a high mean of 3.94 (SD = 0.644), further emphasizing the perceived economic benefits of irrigation in strengthening food security.

One elder said: *"When the irrigation canals deliver water reliably, our yields are good, and we can sell the surplus to buy other food items for the family."*

### 4.4 The effect of capacity for maintenance on household food security in Cungaciki Ward

The results in Table reveal mixed views on the role of maintenance in influencing household food security. A majority of respondents (74.6%) agreed or strongly agreed that households with strong maintenance capacity experience greater food security, while 19.0% disagreed and 6.3% were undecided. The mean score of 3.60 (SD = 0.853) reflects a generally positive perception of household-level maintenance as a driver of food security.

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**Table 4 Descriptive statistics on the effect of capacity for maintenance on household food security**

| Statement | Mean | SD |
|---|---|---|
| Households with strong maintenance capacity experience greater food security in this place | 3.60 | .853 |
| Access to financial resources enhances the maintenance of agricultural infrastructure, improving food security in this place | 2.84 | 1.167 |
| Community participation in maintenance ensures the sustainability of agricultural interventions in this area | 2.65 | 1.065 |
| Poor maintenance of irrigation systems leads to reduced crop yields and food insecurity in this place | 2.67 | 1.122 |

In contrast, opinions were less favorable regarding the role of financial resources in supporting maintenance. Just over one-third of respondents (33.3%) agreed or strongly agreed that access to financial resources enhances the maintenance of agricultural infrastructure and improves food security, whereas 50.8% disagreed and 11.1% were undecided. This item recorded a relatively low mean of 2.84 (SD = 1.167), suggesting that many households perceive financial constraints as a limitation to effective maintenance. On the issue of community participation, the findings show that only 23.8% of respondents agreed or strongly agreed that community involvement in maintenance ensures sustainability of agricultural interventions, while a majority (61.9%) disagreed and 14.3% were undecided. This resulted in a mean score of 2.65 (SD = 1.065), indicating weak confidence in collective maintenance approaches at community level. Similarly, perceptions about the consequences of poor maintenance were divided. While 26.9% of respondents agreed or strongly agreed that poor maintenance of irrigation systems leads to reduced crop yields and food insecurity, more than half (52.4%) disagreed, and 12.7% were undecided. This statement also yielded a low mean of 2.67 (SD = 1.122), implying that many households may not directly attribute food insecurity to poor irrigation system maintenance.

A farmer field leader said: *"Because our farmers' group contributes money and labor for repairs, the irrigation scheme works well, and this has improved our harvests and food at home."*

**Table 5 Descriptive statistics on household food security**

| Statement | Mean | SD |
|---|---|---|
| Our household produced or obtained enough staple foods for daily meals | 3.03 | 1.18 |
| We had a variety of foods (staple, legumes, vegetables, animal-source) available at home | 3.03 | 1.26 |
| We could afford to buy food when our own stocks were low | 3.81 | 0.82 |
| Children in the household ate the foods they needed for healthy growth | 3.90 | 0.80 |

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The results indicate mixed experiences among households regarding food availability and access. Slightly less than half of the respondents (46.0%) disagreed that their households produced or obtained enough staple foods for daily meals, while 44.4% either agreed or strongly agreed. This shows that many households face challenges in sustaining staple food supplies, reflected in the relatively low mean score of 3.03 (SD = 1.177). when asked about the variety of foods available (including staples, legumes, vegetables, and animal-source foods), nearly half (42.9%) disagreed, while only 44.5% agreed or strongly agreed. The mean response (3.03, SD = 1.257) suggests limited dietary diversity within households. responses were more positive regarding the ability to buy food when own stocks were low. A large majority of respondents (81.0%) either agreed or strongly agreed, while only 12.7% disagreed. This was reflected in a higher mean score of 3.81 (SD = 0.820), showing that households largely relied on market purchases to bridge food gaps. Regarding children's nutrition, most respondents (81.0%) agreed or strongly agreed that children ate the foods they needed for healthy growth. Only a small proportion (6.4%) disagreed. This item had the highest mean score (3.90, SD = 0.797), suggesting that despite some food availability and diversity challenges, households made efforts to ensure children's dietary needs were met.

*Correlation analysis for effect of access to irrigation technology on household food security*

**Table 6 correlation results**

| | | | |
|---|---|---|---|
| Irrigation technology | Pearson Correlation | 1 | .509** |
| | Sig. (2-tailed) | | .000 |
| | N | 63 | 63 |
| Household food security | Pearson Correlation | .509** | 1 |
| | Sig. (2-tailed) | .000 | |
| | N | 63 | 63 |

**. Correlation is significant at the 0.01 level (2-tailed).

The Pearson correlation coefficient result (r = 0.509, a *p-value* = 0.000), based on 63 households indicates a moderate positive and statistically significant relationship between irrigation technology and household food security meaning that households with better access to irrigation technology tend to report higher levels of food security.

**Table 7 Correlation analysis for effect of effectiveness of irrigation systems on household food security**

| | | | |
|---|---|---|---|
| Household Food Security | Pearson Correlation | 1 | .351** |
| | Sig. (2-tailed) | | .005 |
| | N | 63 | 63 |
| Effectiveness of Irrigation system | Pearson Correlation | .351** | 1 |
| | Sig. (2-tailed) | .005 | |
| | N | 63 | 63 |

The Pearson correlation coefficient results (r = 0.351, with a p-value = 0.005), based on 63 households shows a positive but modest relationship between the two variables. Indicating that as the effectiveness of irrigation systems improves, household food security also tends to increase.

**Table 8 Correlation analysis for the effect of capacity for maintenance on household food security**

| | | | | |
|---|---|---|---|---|
| Capacity for maintenance | | Household Food Security | | |
| capacity for maintenance | | Pearson Correlation | 1 | .738** |
| | Sig. (2-tailed) | .000 | | |
| | N | 63 | 63 | |
| Household Food Security | | Pearson Correlation | .738** | 1 |
| | Sig. (2-tailed) | .000 | | |
| | N | 63 | 63 | |

**. Correlation is significant at the 0.01 level (2-tailed).

The correlation coefficient results above (r = 0.738, with a p-value = 0.000) indicates a strong, positive, and statistically significant relationship between capacity for maintenance on household food security. This result means that households with higher capacity to maintain irrigation systems are much more likely to achieve higher levels of food security.

**Regression analysis**

**Table 9 Model summery**

| Model | R | R-Square | Adjusted R Square | Std. Error of the Estimate | Change Statistics | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | R Square Change | F Change | df1 | df2 | Sig. F Change |
| 1 | .748a | .559 | .537 | .51914 | .559 | 24.927 | 3 | 59 | .000 |

a. Predictors: (Constant), capacity for maintenance, Effectiveness of Irrigation system, Irrigation technology

The regression model that included irrigation technology, effectiveness of irrigation systems, and capacity for maintenance as predictors of household food security produced an R value of 0.748, indicating a strong positive correlation between the predictors and the outcome. The R Square = 0.559 shows that about 55.9% of the variance in household food security can be explained by the three predictors combined

**Table 10 ANOVA**

| Model | | Sum of Squares | Df | Mean Square | F | Sig. |
|---|---|---|---|---|---|---|
| 1 | Regression | 20.154 | 3 | 6.718 | 24.927 | .000b |
| | Residual | 15.901 | 59 | .270 | | |
| | Total | 36.056 | 62 | | | |

*a. Dependent Variable: Household food security*

*b. Predictors: (Constant), capacity for maintenance, Effectiveness of Irrigation system, Irrigation technology*

The F-value = 24.927, with a p-value < 0.001, confirms that the predictors (irrigation technology, irrigation effectiveness, and capacity for maintenance) jointly have a statistically significant effect on household food security. The regression analysis shows that among the three predictors of household food security-irrigation technology, effectiveness of the irrigation system, and capacity for maintenance, only capacity for maintenance has a significant positive effect. Specifically, a one-unit increase in maintenance capacity is associated with a 0.619 unit increase in household food security (p < 0.001), indicating it is the strongest determinant in the model. however, irrigation technology and irrigation system effectiveness have positive but non-significant effects, suggesting that their influence on household food security is minimal in this context.

**4.6 Discussion of results**

The results align with empirical studies in Ethiopia and sub-Saharan Africa, which demonstrate that small-scale irrigation enhances household income, food availability, and nutritional outcomes (Awol & Arebu, 2024; Manjur et al., 2023; IFAD, 2005; Mekonnen et al., 2022; Jambo et al., 2021; Mwesigwa, 2021). However, regression analysis reveals that capacity for maintenance, rather than irrigation technology itself, significantly predicts household food security, highlighting that the benefits of irrigation are contingent on effective system management. Also, the findings align with empirical literature highlighting that reliable water supply, efficient distribution, and adoption of advanced technologies enhance agricultural productivity, diet diversity, and economic outcomes for households (Onyango et al., 2023; Sharma & Bhattarai, 2022; El Alaoui et al., 2024; Khan et al., 2023; Ninsiima et al., 2023). The literature further emphasizes that these benefits are contingent on robust management practices, institutional support, and maintenance capacity, which ensure sustained functionality and equitable water distribution (Owusu & Giordano, 2019; Shah et al., 2017; Mdemu et al., 2022). Correspondingly, the findings align closely with empirical literature emphasizing that sustained food security outcomes depend not only on the provision of agricultural infrastructure but also on households' and communities' ability to maintain it. Studies in Uganda and Kenya have shown that irrigation schemes with well-established maintenance mechanisms, often supported by community participation (Mwesigwa & Mubangizi, 2015), ensure reliable water supply, stable crop yields, and improved food security (Ninsiima et al., 2023; Onyango et al., 2023). Access to financial resources and strong institutional arrangements, such as water user associations, further enhance households' capacity to maintain irrigation systems, ensuring continued productivity and income generation (Sharma & Bhattarai, 2022). Conversely, poor maintenance leads to rapid deterioration of infrastructure, reduced crop yields, and heightened vulnerability to food insecurity, as observed in Tanzania and Nigeria (Mdemu et al., 2022; Oluwasanya & Abolude, 2022).

The strong positive effect of maintenance capacity in this study underscores the importance of integrating capacity-building initiatives and participatory approaches into agricultural interventions. Empowering households with technical skills, management knowledge, and financial resources, while fostering ownership through community involvement, ensures that irrigation systems remain functional over time, thereby sustaining the positive impacts on household food security (Al-Adamat et al., 2021; Abimbola et al., 2023). Overall, these results suggest that the long-term effectiveness of irrigation technology and systems is largely contingent upon households' ability to maintain them, making maintenance capacity the most critical factor in achieving durable food security outcomes.

## 6.0 CONCLUSION AND RECOMMENDATIONS

### 6.1 Conclusion

From the findings, it was concluded that access to micro irrigation technology is beneficial for food security, particularly in improving food availability, dietary diversity, and economic benefits even if the regression analysis indicates that irrigation technology alone does not significantly predict food security; its benefits are realized primarily when combined with strong maintenance capacity. also, households with higher ability to maintain irrigation systems experience improved food availability, income, and overall well-being.

### 6.2 Recommendations

From the conclusion, we encourage farmers should actively participate in maintaining irrigation systems, acquire basic technical skills for operating and repairing equipment, and collaborate through local groups or cooperatives to manage infrastructure collectively. Also, the government should invest in irrigation technologies while simultaneously providing training to build households' and communities' maintenance capacity. And NGOs should design programs that integrate the provision of irrigation technologies with capacity-building initiatives focused on maintenance and management.

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**Declaration of conflict of interest**

No conflict of interest was registered.

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