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Original Research Article

Economic Viability of Micro-Irrigation Technologies in Smallholder Horticultural Farming: A Comparative Study with Traditional Furrow Irrigation in Northern Tanzania

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Abstract: This study investigated the economic viability of Micro Irrigation Technologies (MITs) compared with traditional furrow irrigation in smallholder horticultural farming in northern Tanzania. Using a quasi-experimental cross-sectional design, data were collected from 540 farmers, divided into adopters and nonadopters of MITs. Economic metrics, including net present value (NPV), the benefit–cost ratio (BCR), and the internal rate of return (IRR), were analysed over a five-year investment horizon through statistical methods in SPSS and Microsoft Excel. The results indicate that MITs, particularly drip and sprinkler systems, increase the productivity and profitability of high-value crops such as onions and tomatoes, yielding significantly higher NPVs than furrow irrigation does. Despite their high initial costs, these technologies demonstrated long-term economic benefits, including improved water efficiency and labour cost savings. Regression analysis further revealed that both crop type and irrigation technology significantly influence economic outcomes. Onions and tomatoes under MIT presented the highest financial returns, whereas peppers under furrow irrigation achieved better cost efficiency. This study underscores the transformative potential of MITs in enhancing horticultural productivity and sustainability in water-scarce regions. The study recommends targeted interventions, including subsidies, financial incentives, training programs, and policy support, to scale up the adoption of MITs.

Keywords: Cost benefit analysis, Micro irrigation technologies, Furrow irrigation, Horticulture, Drip and sprinkler irrigation.

1.0 INTRODUCTION

Horticulture is a cornerstone of global agricultural production, significantly bolstering economic development and fortifying food security (Ng'atigwa *et al*., 2020). The sector's rapid expansion, fuelled by technological advancements, has made it a leading foreign exchange earner, surpassing other agricultural commodities in trade and production growth (Lutz & Tadesse, 2017; Wang *et al*., 2022). However, the sector faces significant challenges, including water scarcity, inefficient irrigation methods, low productivity and limited adoption of modern agricultural technologies (Saxena *et al*., 2022; Xiuling *et al*., 2023). Traditional irrigation methods, such as furrow systems, are widely used but often result in significant water loss and reduced productivity (Rouzaneh *et al*., 2021). In contrast, modern micro irrigation technologies, such as drip

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and sprinkler systems, are known to increase water use efficiency, reduce labour costs and potentially improve crop yields and profitability (Mattoussi *et al*., 2023). Micro irrigation technologies (MITs), encompassing methods such as drip and sprinkler irrigation, represent a transformative approach to water management (Absanto *et al*., 2025c). These technologies are designed to deliver water efficiently and precisely to crops, minimizing losses and maximizing resource use. In the context of water-scarce regions, MITs have emerged as pivotal interventions to address the dual challenges of water scarcity and declining agricultural productivity (World Bank., 2019).

For Tanzania, a nation where agriculture constitutes approximately one-third of the gross domestic product (GDP) and employs more than 70% of the workforce, the adoption of innovative irrigation methods has profound implications for sustainable development and poverty reduction (URT, 2021).

Despite their potential, the uptake of MITs in Tanzania remains suboptimal, with traditional methods such as furrow irrigation continuing to dominate (Bhatti *et al*., 2022). Furrow irrigation, though familiar and less capital intensive, often leads to significant inefficiencies, including water waste, soil erosion, and suboptimal yields (Lugamara *et al*., 2022). Conversely, MITs, while offering substantial long-term benefits, face barriers to adoption, including high initial investment costs, limited technical expertise among farmers, and inadequate access to financial resources (Absanto *et al*., 2025a; Mattoussi *et al*., 2023). These challenges underscore the critical need to evaluate the economic and practical viability of the MIT in comparison with traditional irrigation systems, particularly in the production of high-value crops such as onions, tomatoes, and peppers, which are key contributors to Tanzania's agricultural output and export earnings (FAO, 2020).

While extensive studies highlight the benefits of modern irrigation technologies in improving water use efficiency and crop productivity, there is limited empirical evidence on their comparative economic viability in the context of smallholder horticultural farming (Hussain *et al*., 2022; Zou *et al*., 2013). Research often focuses on technical efficiency, neglecting a detailed cost–benefit analysis that accounts for investment costs, maintenance costs, operational expenses and profitability (Absanto *et al*., 2025b; Sissoko *et al*., 2022). Furthermore, the economic barriers and specific financial implications of adopting modern irrigation systems in resource-constrained farming communities remain underexplored (Yazdanpanah *et al*., 2022). Moreover, there is a paucity of longitudinal studies examining the economic impacts of the MIT over a five-year investment horizon, and the interplay between crop type, irrigation technology, and economic performance has not been adequately explored, necessitating further empirical investigation.

This study seeks to bridge this knowledge gap by conducting a rigorous benefit–cost analysis of micro irrigation technologies versus traditional furrow irrigation systems across a five-year investment horizon. By employing economic metrics such as the net present value (NPV), benefit–cost ratio (BCR), and internal rate of return (IRR), this research aims to provide evidence-based insights into the profitability and economic sustainability of these technologies. Moreover, by examining the differential effects of crop type and irrigation technology on economic performance, this study offers an understanding of the factors influencing agricultural returns under varying technological contexts.

This study aimed primarily to compare the investment costs and economic benefits of modern micro irrigation technologies and traditional furrow irrigation methods in horticultural farming in northern Tanzania. This study assessed the capital and operational costs of both systems and evaluated their profitability and economic efficiency while providing recommendations to improve their uptake among smallholder farmers.

The significance of this research lies in its potential to inform policy, drive investment, and guide stakeholders in promoting sustainable agricultural practices. The findings are expected to contribute to the formulation of strategies aimed at scaling up the adoption of micro irrigation technologies, thereby enhancing agricultural resilience, improving livelihoods, and advancing Tanzania's broader development goals, as articulated in the Tanzania Development Vision 2025 and Agricultural Sector Development Program (ASDP II) (URT, 2021).

2.0 LITERATURE REVIEW

The adoption of micro irrigation technologies (MITs) has garnered global attention as a sustainable approach for addressing water scarcity and enhancing agricultural productivity. The literature on agricultural innovations, particularly in irrigation systems, underscores their importance in achieving the Sustainable Development Goals (SDGs), particularly Goals 2 (Zero Hunger) and 6 (Clean Water and Sanitation) (UN, 2015). This review synthesizes theoretical, empirical, and contextual perspectives to provide a foundation for understanding the profitability and economic implications of micro irrigation technologies.

2.1 Theoretical Framework

The theory of cost–benefit analysis (CBA) (Drèze & Stern, 1987) was employed to assess the economic efficiency of MITs and furrow irrigation in smallholder horticulture farming. The CBA provides a systematic framework for quantifying the costs and benefits associated with the MIT, encompassing initial investments and operating and maintenance expenses against benefits such as crop yields, income, water savings, and reduced labor (Mangisoni, 2006). A crucial aspect of CBA is the incorporation of the time value of money, which is achieved through discounting techniques, allowing for the comparison of costs and benefits that occur at different times (Ali *et al*., 2020).

2.2 Empirical Evidence from Micro Irrigation Technologies

Empirical studies highlight the economic viability of MITs in diverse agricultural contexts. For example, research by (Martínez-Arteaga *et al*., 2023) demonstrated that MITs significantly reduce water consumption by up to 50% while increasing crop yields by 30–40%. Similarly, (Kiruthika & Suresh Kumar, 2020) underscore the positive impacts of MIT on farmer incomes, noting a marked improvement in the net present value (NPV) and benefit–cost ratio (BCR) for high-value crops such as tomatoes, onions and peppers.

However, regional disparities in adoption persist, with factors such as access to credit, training, and extension services playing critical roles. In Tanzania, studies by (Adebayo *et al*., 2018; Agbenyo *et al*., 2022; Gwambene *et al*., 2023) revealed that while MITs have the potential to transform agriculture, their adoption remains limited due to infrastructural and institutional challenges. These findings highlight the need for targeted interventions to address the barriers to technology uptake.

The financial feasibility of irrigation technologies is a focal point of analysis in agricultural economics (Gorain *et al*., 2020; Namara *et al*., 2007). Cost–benefit analysis (CBA) serves as a critical tool in assessing the long-term economic impacts of irrigation methods (Hussain *et al*., 2022; Zou *et al*., 2013). According to (Parthasarathi *et al*., 2015), the MIT method results in a higher benefit cost ratio (BCR) and internal rate of return (IRR) than traditional methods do, particularly for high-value crops. However, furrow irrigation, despite its inefficiencies, remains popular because of lower initial capital requirements and greater familiarity among farmers (Dewedar *et al*., 2021; Vanghele C., 2019). The Tanzanian horticulture sector is characterized by a predominance of smallholder farmers who face systemic challenges, including limited access to credit, insufficient technical knowledge, and weak market linkages (URT, 2021). These barriers are compounded by the high costs of MITs, which deter adoption despite their long-term benefits. (Limpamont *et al*., 2024) noted that governance and policy frameworks also influence the uptake of agricultural innovations, emphasizing the need for supportive policies and incentive structures.

3.0 METHODOLOGY

This study employed a quantitative research approach to assess the cost–benefit analysis of irrigation methods among smallholder horticultural farmers in northern Tanzania. Data were collected via structured questionnaires administered to a sample of 540 households, which were divided into adopters and nonadopters of micro irrigation technologies. The study adopted a quasi-experimental cross-sectional design to facilitate the comparison of economic indicators such as net present value (NPV), the benefit–cost ratio (BCR), and the internal rate of return (IRR) across the two groups. Statistical analysis, including descriptive and inferential methods, was conducted via SPSS and Microsoft Excel to evaluate the profitability, economic viability, and efficiency of the micro irrigation technologies in the study area.

The cost–benefit analysis (CBA) method was used to assess the economic performance of various irrigation technologies. The CBA evaluates project worthiness via three metrics: the net present value (NPV), internal rate of return (IRR), and benefit cost ratio (BCR) (Wise, 1983). The NPV is a measure for evaluating the profitability of an investment and is calculated as follows:

$$\mathrm{NPV} = \sum_{t=0}^{n} \frac{B_t - C_t}{(1+i)^t} \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots [1]$$

Where i=discount rate, n = number of years, t = th year, Bt =benefits, Ct = costs.

An irrigation technology with a positive NPV was considered acceptable, as it yields more benefits than costs over time. The technology with the highest NPV was regarded as the most financially efficient and desirable for smallholder farmers.

The BCR was calculated as follows.

$$BCR = \frac{\sum_{t=1}^{n} \frac{B_t}{(1+i)^t}}{\sum_{t=1}^{n} \frac{C_t}{(1+i)^t}} \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots [2]$$

Where i=discount rate, n = number of years, t = th year, Bt =benefits, and Ct=costs.

An investment was accepted if the BCR was greater than 1.

The IRRs were calculated as follows.

$$\mathrm{IRR} = \sum_{t=1}^{n} \frac{\mathrm{CF_t}}{(1+\mathrm{i})^{\mathrm{t}}} \cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots [3]$$

Where i = the discount rate, n = the number of years, t = the tth year, Bt = benefits, and Ct = costs.

An investment was accepted if the IRR was greater than the market interest rate. The prevailing market prices were used to value inputs and outputs that were entered into the objective function. The discount rate that was used was the market interest rate charged by the Tanzania Agricultural Development Bank (TADB) at the time of data analysis. The financial CBA was evaluated from the farmer's point of view, and the accounting profitability of micro irrigation investments over time was determined.

After the economic indicators (Net Present Value (NPV), Benefit–Cost Ratio (BCR), and Internal Rate of Return (IRR)) are calculated, descriptive statistical analysis is employed to effectively present the results. Descriptive analysis focused on summarizing the mean values of these indicators, categorized by crop type (onion, tomato, and pepper) and irrigation technology (Furrow and Micro-Irrigation Technologies). This approach allowed for a clear comparison of the average economic outcomes associated with different crops and technologies.

Multivariate regression modelling was also employed in this study to assess the impact of crop type and irrigation technology on the net present value (NPV), benefit–cost ratio (BCR), and internal rate of return (IRR). Data were collected on crop types (categorized as onion, tomato, and pepper), irrigation methods (Furrow and micro irrigation technology (MIT)), and economic indicators (NPV, BCR, and IRR). The regression equations were specified as follows:

$$\mathrm{NPV}_i = \beta_0 + \beta_1 \text{Crop type}_\mathrm{i} + \beta_2 \text{Technology type}_\mathrm{i} + \varepsilon_\mathrm{i} \cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots [4]$$
$$BCR_i = \beta_0 + \beta_1 \text{Crop type}_\mathrm{i} + \beta_2 \text{Technology type}_\mathrm{i} + \varepsilon_\mathrm{i} \cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots [5]$$
$$\mathrm{IRR}_i = \beta_0 + \beta_1 \text{Crop type}_\mathrm{i} + \beta_2 \text{Technology type}_\mathrm{i} + \varepsilon_\mathrm{i} \cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots [6]$$

A multivariate regression was applied to estimate the coefficients, which indicated the magnitude and direction of the relationships. Statistical significance was evaluated via p values, with a threshold of 0.05. All analyses were conducted to identify the contributions of crop type and irrigation technology to economic performance in horticulture production.

4.0 RESULTS AND DISCUSSION

This section presents the findings from the study and their interpretations, focusing on the descriptive statistics of the benefits and costs of micro irrigation technologies (MITs) compared with furrow irrigation. It also covers benefit–cost analysis over five years, changes in the net present value (NPV) and benefit–cost ratio (BCR) across time, and the influence of crop type and irrigation technology on financial performance metrics.

4.1 Descriptive statistics of the benefits and costs of micro irrigation technologies per year

In Table 1, the descriptive statistics show the benefits and costs of different micro irrigation technologies compared with furrow irrigation for various crops. For onions, sprinklers yielded a significantly greater benefit of 4,975,483.68 Tanzanian shillings (TZS) than furrow irrigation did (3,699,120.71 TZS). However, sprinklers have a substantially greater cost at 34,429,731.50 TZS than furrows at 10,452,741.91 TZS, leading to a greater benefit difference in favour of furrows at 6,533,563.49 TZS. This finding is consistent with studies indicating that while advanced irrigation technologies such as drip and sprinkler systems offer higher productivity, they also involve significant capital investments (Limpamont *et al.,* 2024; Mupaso *et al*., 2014). For tomatoes, drip provided a greater benefit of 7,351,521.51 TZS, whereas the furrow method provided 4,825,181.14 TZS. The cost disparity was even more pronounced, with drips costing 48,880,047.50 TZS and furrowing 19,601,197.37 TZS. This suggests that drips have a greater potential return but at a greater upfront cost, a trend highlighted in the works of (Ali *et al*., 2020; Srivastava *et al*., 2003) on sustainable agricultural investments. Similarly, compared with furrow irrigation, drip irrigation had a greater benefit (6,200,079.15 TZS) but also a greater cost (47,907,796.61 TZS) (4,717,672.67 TZS and 30,625,706.67 TZS, respectively), indicating a consistent pattern across crops. The differences observed underscore the trade-off between investment and returns, a point emphasized by (Barroso & Maio, 2024; Singh et al., 2024) regarding agricultural technology adoption in developing countries.

Table 1: Descriptive statistics of the benefits and costs of irrigation technologies per acre (TZS)

Crop	Technology	No. Farmers	Estimated Average per Acre (TZS)		
			Benefit	Cost	Difference
Onion	Sprinkler	40	4,975,483.68	34,429,731.50	29,454,247.83
	Furrow	95	3,699,120.71	10,452,741.91	6,533,563.49
Tomato	Drip	100	7,351,521.51	48,880,047.50	41,528,525.99
	Furrow	171	4,825,181.14	19,601,197.37	14,776,016.23
Pepper	Drip	59	6,200,079.15	47,907,796.61	41,707,717.46
	Furrow	75	4,717,672.67	30,625,706.67	25,908,034.00

4.2 Benefit–cost analysis of micro irrigation technologies for the 5 years of investment per Acre

Table 2 presents the benefit–cost analysis of the two irrigation technologies over five years. For onions, the NPV for sprinklers was 32,973,365.83 TZS, which was significantly higher than that of the furrow method (10,052,681.49 TZS), indicating that while sprinklers had a higher cost, it resulted in a greater long-term return. The benefit–cost ratio (BCR) for sprinklers was 2.75, which was still positive but less favourable than that of the furrow method, which had a BCR of 6.70, indicating that furrow irrigation provides a better return per unit cost. The internal rate of return (IRR) for sprinklers (7%) was lower than that for furrows (13%), suggesting that despite the greater benefits from sprinklers, furrow irrigation might be more cost-effective over the short term, as noted by (Palanisami & Nagothu, 2024) in their analysis of cost efficiency in agricultural projects. For tomatoes, drip's NPV (45,047,643.99 TZS) and BCR (4.03) were again higher than those of furrows (18,295,134.23 TZS and 7.73, respectively), but furrows had a higher IRR (11%) than drip (9%), showing that while drip offers higher returns, the initial investment may not justify the returns in some cases. Similarly, for peppers, drip provides an NPV of 45,226,835.46 TZS and a BCR of 6.46 TZS, which are more favourable than furrow's NPV of 29,427,152.00 TZS and a BCR of 2.75; however, the IRR for drip (8%) was lower than that for furrow's (7%). This pattern of varying NPVs, BCRs, and IRRs reflects the differing levels of risk and returns associated with adopting more advanced technologies, as put by (Hussain *et al.,* 2022; Thrikawala *et al.,* 2022).

Table 2: Benefit–cost analysis of micro irrigation technologies for 5 years of investment per Acre (TZS)

Crop	Technology	No. Farmers	Estimated Average per Acre (TZS)		
			NPV	BCR	IRR
Onion	Sprinkler	40	32,973,365.83	2.75	0.07
	Furrow	95	10,052,681.49	6.70	0.13
Tomato	Drip	100	45,047,643.99	4.03	0.09
	Furrow	171	18,295,134.23	7.73	0.11
Pepper	Drip	59	45,226,835.46	6.51	0.08
	Furrow	75	29,427,152.00	2.75	0.07

4.3 Changes in NPV between 1–5 years of investment per Acre at the 10% discount rate

Figures 1 and illustrate the changes in NPV over the 5-year investment period, showing how these metrics evolve with time. A discount rate of 10% reduces the perceived value of future benefits, making earlier years of investment more critical for technology adoption. This trend aligns with the findings of Chizmar *et al*., (2020) that technology adoption benefits increase in the long term but may not be immediately profitable in the early stages. The visual trend confirms that although MITs require a significant initial investment, the returns in the later years make it a more profitable choice for farmers with a longer investment horizon.

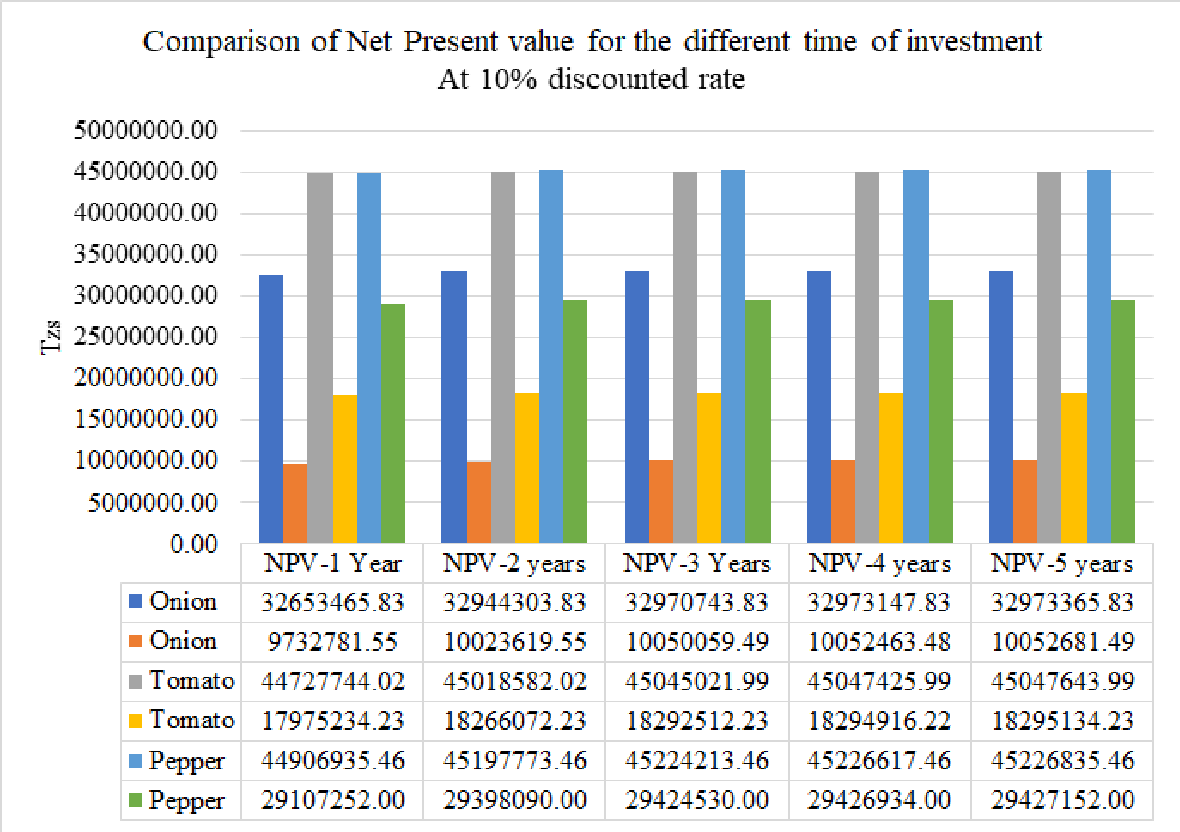

Figure 1: Changes in NPV between 1 and 5 years of investment per Acre at a 10% discount rate

4.4 Changes in BCR between 1–5 years of investment per Acre at the 10% discount rate

Figures 2 illustrate the changes in BCR over the 5-year investment period, showing how these metrics evolve with time. A discount rate of 10% reduces the perceived value of future benefits, making earlier years of investment more critical for MITs adoption. This trend, where the benefit cost ratios improve over time for all crops, aligns with the findings of Yadav A. *et al*., (2022) that agricultural technology adoption benefits increase over the long-term period but may not be immediately profitable in the early stages.

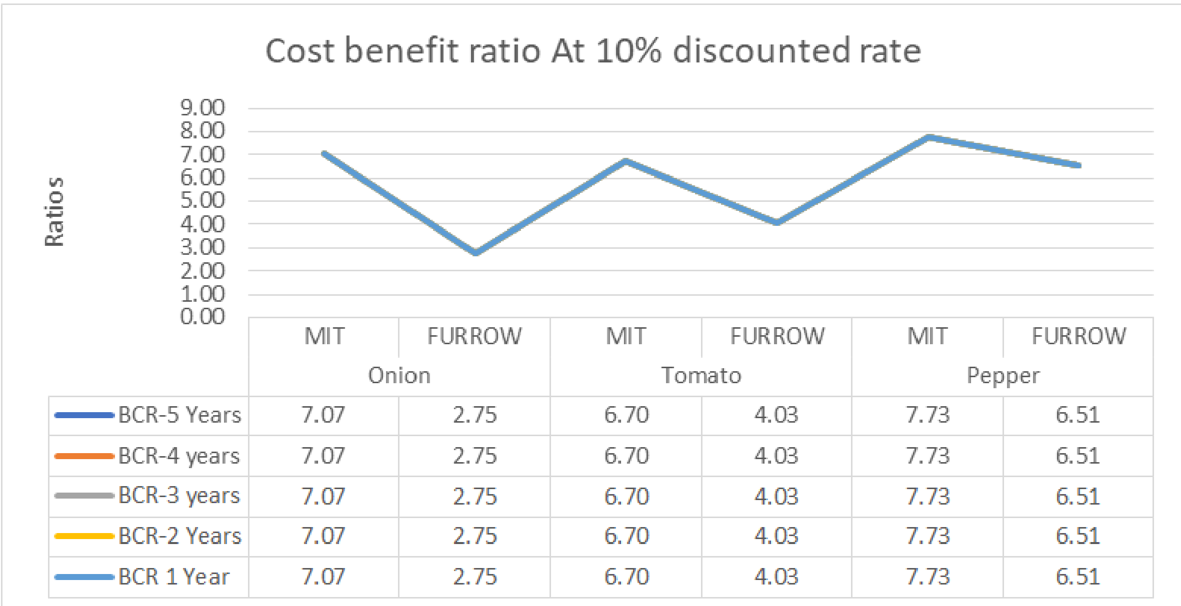

Figure 2: Cost benefit ratios for different times of investment at the 10% discount rate

4.5 Influence of crop type and technology use on NPV, BCR and IRR

Table 3 presents the results of regression modelling examining the influence of crop type and irrigation technology on NPV, BCR, and IRR. The regression results show that crop type significantly influences the NPV, with onions and tomatoes yielding higher NPVs than peppers do, as indicated by the coefficient of 8,118,490.60 for crop type (Onion, Tomato vs. Pepper), which is statistically significant (p value = 0.001). This suggests that onions and tomatoes are more profitable crops when drip irrigation is used. Furthermore, the choice of irrigation method also significantly influences the NPV, with furrow irrigation resulting in a negative coefficient (-22,975,249.70), suggesting that it has a lower long-term return than drip irrigation does. Similar trends were observed in the BCR and IRR, where the choice of crop and technology (furrow vs. MIT) had a significant impact. For the BCR, the negative coefficient for furrow (-2.659) and the positive coefficient for crop type (1.318 for onion/tomato vs. pepper) indicate that advanced technologies are more effective with higher-value crops such as onion and tomato. The IRR results follow a similar pattern, with MITs showing a more favourable return for onions and tomatoes than furrow irrigation does. These findings corroborate those of previous studies, such as those by (Chizmar *et al*., 2020; Palanisami & Nagothu, 2024; Thrikawala *et al*., 2022), which highlight the importance of both crop selection and technology choice in maximizing agricultural returns on investment.

Table 3: Regression modelling of the influence of crop type and technology use on the NPV, BCR and IRR

Dependent Variable	Independent Variable	Coefficient (β)	Standard Error	p value
NPV	Crop Type (Onion, Tomato vs Pepper)	8118490.599	752620.519	0.001
	Irrigation Method (Furrow vs MIT)	-22975249.700	1101143.329	0.001
BCR	Crop Type (Onion, Tomato vs Pepper	1.318	0.136	0.001
	Irrigation Method (Furrow vs MIT)	-2.659	0.199	0.001
IRR	Crop Type (Onion, Tomato vs Pepper	0.889	0.087	0.001
	Irrigation Method (Furrow vs MIT)	-3.459	0.127	0.001

5. CONCLUSION

This study aimed to assess the economic viability of micro irrigation technologies (MITs) compared with traditional furrow irrigation systems for different crops, including onion, tomato, and pepper. On the basis of the descriptive statistics and benefit–cost analysis, the findings show that while MITs provide greater overall benefits in terms of total returns, they are associated with significantly higher initial costs. The net benefits derived from MITs were greater for crops such as onion and tomato, but the cost efficiency (BCR) and internal rate of return (IRR) tended to favour furrow irrigation, especially for pepper cultivation.

The regression analysis further revealed that crop type and irrigation method were significant determinants of financial outcomes. Crops such as onions and tomatoes generally show greater profitability than peppers do, with furrow irrigation being more cost-effective for pepper cultivation. The choice of irrigation method plays a critical role in the long-term sustainability of investments, as furrow irrigation has better cost efficiency in the early years, even though the MIT shows greater long-term returns.

These findings suggest that while MITs hold promise for increased productivity and profitability in the long run, furrow irrigation may be a more feasible option for farmers looking for immediate returns, particularly in regions where initial investments in irrigation infrastructure are a major constraint. While furrow irrigation may offer immediate returns, the importance of modern micro irrigation technologies cannot be overstated, particularly in this era of increasing water stress. Moreover, MITs contribute to long-term profitability by increasing crop yields, increasing water productivity, and reducing labour costs. Although initial investments may be greater, the benefits of MITs in conserving water and ensuring resilience against drought conditions make them indispensable for achieving sustainable horticultural farming and food security in the face of growing environmental challenges. Policymakers should consider these findings when developing strategies for agricultural development, ensuring that both short-term cost-effectiveness and long-term sustainability are prioritized in the adoption of irrigation technologies.

6. RECOMMENDATIONS

Based on the analysis of NPV, BCR, and IRR for pepper, tomato, and onion farming under the micro irrigation and furrow irrigation methods, several recommendations are proposed.

First, the adoption of micro irrigation technologies should be promoted because of their superior profitability and sustainability. Compared with furrow irrigation, which has a greater NPV, BCR, and IRR, micro irrigation has significant economic advantages. To enhance adoption, governments and development partners should provide subsidies or financial incentives to reduce initial installation costs. Additionally, forming public–private partnerships can facilitate access to affordable irrigation systems, whereas targeted awareness campaigns and training programs can educate farmers on the long-term benefits of adopting these technologies.

Second, farmers should be equipped with knowledge to manage key variables influencing project profitability, as revealed through economic analysis. Yield, price, and cost variations significantly affect financial outcomes, making it essential to provide training on yield optimization techniques such as the use of improved seeds and effective crop management practices. Access to timely market information can help farmers respond effectively to price changes, whereas strategies such as the bulk purchasing of inputs can assist in controlling costs. Such capacity-building efforts enhance farmers' resilience to external shocks, improving the overall viability of their farming projects.

Finally, efforts should focus on promoting crops with higher returns on investment. The analysis indicates that tomato and onion farming under micro irrigation achieves greater profitability than peppers do, suggesting that a strategic focus on these crops in regions where micro irrigation is feasible, such as northern Tanzania. Financial and technical support for tomato and onion farmers can maximize returns, contributing to improved livelihoods and economic development in farming communities. These targeted interventions, when implemented effectively, will enable sustainable agricultural practices and increased profitability for smallholder farmers.

REFERENCES

- Absanto, G., Mkunda, J., & Nyangarika, A. (2025a). Modern Versus Traditional Irrigation Systems: Implications for Technical Efficiency and Input-Output Relationship in Northern Tanzania's Horticulture Sector. *Global Academic Journal of Economics and Business*, *7*(01), 1–13. https://doi.org/10.36348/gajeb.2025.v07i01.001
- Absanto, G., Mkunda, J., & Nyangarika, A. (2025b). Toward an Ideal Framework for Assessing Economic Viability of Micro-Irrigation Technologies: A Systematic Review. *Global Academic Journal of Economics and Business*, *7*(01), 14–27. https://doi.org/10.36348/gajeb.2025.v07i01.002
- Absanto, G., Mkunda, J., & Nyangarika, A. (2025c). Transforming Smallholder Agriculture Amid Water Scarcity: A Systematic Review of the Socio-Economic Benefits of Micro-Irrigation Technologies. *Global Academic Journal of Humanities and Social Sciences*, *7*(01), 35–50. https://doi.org/10.36348/gajhss.2025.v07i01.005
- Adebayo, O., Bolarin, O., Oyewale, A., & Kehinde, O. (2018). Impact of irrigation technology use on crop yield, crop income and household food security in Nigeria: A treatment effect approach. *AIMS Agriculture and Food*, *3*(2), 154–171. https://doi.org/10.3934/agrfood.2018.2.154
- Agbenyo, W., Jiang, Y., Jia, X., Wang, J., Ntim-Amo, G., Dunya, R., Siaw, A., Asare, I., & Twumasi, M. A. (2022). Does the Adoption of Climate-Smart Agricultural Practices Impact Farmers' Income? Evidence from Ghana. *International Journal of Environmental Research and Public Health*, *19*(7), 3804. https://doi.org/10.3390/ijerph19073804
- Ali, A., Xia, C., Jia, C., & Faisal, M. (2020). Investment profitability and economic efficiency of the drip irrigation system: Evidence from Egypt *. *Irrigation and Drainage*, *69*(5), 1033–1050. https://doi.org/10.1002/ird.2511
- Barroso, P., & Maio, P. (2024). The risk–return tradeoff among equity factors. *Journal of Empirical Finance*, *78*, 101518. https://doi.org/10.1016/j.jempfin.2024.101518
- Bhatti, M. A., Godfrey, S. S., Divon, S. A., Aamodt, J. T., Øystese, S., Wynn, P. C., Eik, L. O., & Fjeld-Solberg, Ø. (2022). Micro-Investment by Tanzanian Smallholders' in Drip Irrigation Kits for Vegetable Production to Improve Livelihoods: Lessons Learned and a Way Forward. *Agriculture*, *12*(10), 1732. https://doi.org/10.3390/agriculture12101732
- Chizmar, S., Castillo, M., Pizarro, D., Vasquez, H., Bernal, W., Rivera, R., Sills, E., Abt, R., Parajuli, R., & Cubbage, F. (2020). A Discounted Cash Flow and Capital Budgeting Analysis of Silvopastoral Systems in the Amazonas Region of Peru. *Land*, *9*(10), 353. https://doi.org/10.3390/land9100353
- Dewedar, O. M., Plauborg, F., Marwa, M. A., El-shafie, A. F., & Ragab, R. (2021). Improving water saving, yield, and water productivity of bean under deficit drip irrigation: Field and modelling study using the SALTMED model*. *Irrigation and Drainage*, *70*(2). https://doi.org/10.1002/ird.2539
- Drèze, J., & Stern, N. (1987). *Chapter 14 The theory of cost-benefit analysis* (pp. 909–989). https://doi.org/10.1016/S1573-4420(87)80009-5
- FAO. (2020). *The State of Food and Agriculture 2020*. FAO. https://doi.org/10.4060/cb1447en
- Gorain, S., Singh, D. R., Kumar, P., Venkatesh, P., & Jha, G. K. (2020). Economics of Sugarcane and Banana Cultivation under Drip Irrigation System: A Case Study of Northern Maharashtra. *Economic*

Affairs (New Delhi), *65*(2). https://doi.org/10.46852/0424-2513.2.2020.3

- Gwambene, B., Liwenga, E., & Mung'ong'o, C. (2023). Climate Change and Variability Impacts on Agricultural Production and Food Security for the Smallholder Farmers in Rungwe, Tanzania. *Environmental Management*, *71*(1), 3–14. https://doi.org/10.1007/s00267-022-01628-5
- Hussain, A., Majeed, S., Hassan, A., Khathian, M. A., Khan, M. Z. U., Raza, I., & Bajkani, J. K. (2022). Adoption and Cost-benefit Analysis of Drip Irrigation foProduction of High-Value Crops in Pakistan. *Proceedings of the Pakistan Academy of Sciences: Part B*, *59*(1). https://doi.org/10.53560/PPASB(59-1)690
- Kiruthika, S., & Suresh Kumar, D. (2020). Socio-economic impacts of the adoption of MIS (Micro-irrigation system) among small and marginal farmers of Coimbatore district, India. *Journal of Applied and Natural Science*, *12*(3), 312–318. https://doi.org/10.31018/jans.v12i3.2312
- Limpamont, A., Kittipanya-ngam, P., Chindasombatcharoen, N., & Cavite, H. J. M. (2024). Towards agri-food industry sustainability: Addressing agricultural technology adoption challenges through innovation. *Business Strategy and the Environment*, *33*(7), 7352–7367. https://doi.org/10.1002/bse.3871
- Lugamara, C. B., J.K. Urassa, P.M. Dontsop Nguezet, & C. Masso. (2022). Determinants of Smallholder Farmers' Adoption and Willingness to Pay for Improved Legume Technologies in Tanzania. *Tanzania Journal of Agricultural Science* , *20*(2), 245–260.
- Lutz, C., & Tadesse, G. (2017). African farmers' market organizations and global value chains: competitiveness versus inclusiveness. *Review of Social Economy*, *75*(3), 318–338. https://doi.org/10.1080/00346764.2017.1300317
- Mangisoni, J. H. (2006). *Impact of Treadle Pump Irrigation Technology on Smallholder Poverty and Food Security in Malawi: A Case Study of Blantyre and Mchinji Districts An input to the Study on Agricultural Water Management Technologies for Small Scale Farmers in Southern Africa: An Inventory and Assessment of Experiences, Good Practices and Costs*.
- Martínez-Arteaga, D., Arias Arias, N. A., Darghan, A. E., & Barrios, D. (2023). Identification of Influential Factors in the Adoption of Irrigation Technologies through Neural Network Analysis: A Case Study with Oil Palm Growers. *Agriculture*, *13*(4), 827. https://doi.org/10.3390/agriculture13040827
- Mattoussi, W., Mattoussi, F., & Larnaout, A. (2023). Optimal subsidization for the adoption of new irrigation technologies. *Economic Analysis and Policy*, *78*, 1126–1141. https://doi.org/10.1016/j.eap.2023.04.020
- Mupaso, N., Manzungu, E., Mutambara, J., & Hanyani-Mlambo, B. (2014). THE IMPACT OF IRRIGATION TECHNOLOGY ON THE FINANCIAL AND ECONOMIC PERFORMANCE OF SMALLHOLDER IRRIGATION IN ZIMBABWE. *Irrigation and Drainage*, *63*(4), 430–439. https://doi.org/10.1002/ird.1820
- Namara, R. E., Nagar, R. K., & Upadhyay, B. (2007). Economics, adoption determinants, and impacts of micro-irrigation technologies: Empirical results from India. *Irrigation Science*, *25*(3). https://doi.org/10.1007/s00271-007-0065-0
- Ng'atigwa, A. A., Hepelwa, A., Yami, M., & Manyong, V. (2020). Assessment of Factors Influencing Youth Involvement in Horticulture Agribusiness in Tanzania: A Case Study of Njombe Region. *Agriculture*, *10*(7), 287. https://doi.org/10.3390/agriculture10070287
- Palanisami, K., & Nagothu, U. S. (2024). *Up-Scaling Micro Irrigation* (pp. 175–201). India's Water Future in a Changing Climate. https://doi.org/10.1007/978-981-97-1785-9_9
- PARTHASARATHI, G., S., & S., & S. L. (2015). Impacts of Micro Irrigation Subsidies in Tamil Nadu from the World Bank. In *Sustainable Micro Irrigation Design Systems for Agricultural Crops: Methods and Practices*.
- Rouzaneh, D., Yazdanpanah, M., & Jahromi, A. B. (2021). Evaluating micro-irrigation system performance through assessment of farmers' satisfaction: implications for adoption, longevity, and water use efficiency. *Agricultural Water Management*, *246*. https://doi.org/10.1016/j.agwat.2020.106655
- SAXENA, R., KANWAL, V., KHAN, M., VERMA, S., & B, G. (2022). Gains from Improved Technology Adoption in Disadvantaged Regions: Evidences from Bundelkhand Region. *The Indian Journal of Agricultural Sciences*, *92*(6). https://doi.org/10.56093/ijas.v92i6.101951
- Singh, G., Gandhi, V. P., & Jain, D. (2024). Micro-irrigation adoption and the Jevons' Paradox: A study from four states of India. *Agricultural Water Management*, *303*, 109040. https://doi.org/10.1016/j.agwat.2024.109040
- Sissoko, P., Synnevag, G., & Aune, J. B. (2022). Effects of low-cost agricultural technology package on income, cereal surplus production, household expenditure, and food security in the drylands of Mali. *AIMS Agriculture and Food*, *7*(1), 22–36. https://doi.org/10.3934/agrfood.2022002
- Srivastava, R. C., Verma, H. C., Mohanty, S., & Pattnaik, S. K. (2003). Investment decision model for drip irrigation system. *Irrigation Science*, *22*(2). https://doi.org/10.1007/s00271-003-0072-8

- Thrikawala, S., Batzlen, C., & Korale-Gedara, P. (2022). Cost-Benefit Analysis of Irrigation Projects. In *Agricultural Policy Analysis* (pp. 295–330). Springer Singapore. https://doi.org/10.1007/978-981-16-3284-6_12
- UN. (2015). *Millennium development goals*.
- URT. (2021). *National Horticulture Development Strategy and Action Plan2021-2031.* .
- Vanghele C. (2019). Management of the Economic Efficiency of Irrigation. *Ovidius" University Annals, Economic Sciences Series, XIX*(2), 602-606.
- Wang, H., Wang, N., Quan, H., Zhang, F., Fan, J., Feng, H., Cheng, M., Liao, Z., Wang, X., & Xiang, Y. (2022). Yield and water productivity of crops, vegetables and fruits under subsurface drip irrigation: A global meta-analysis. In *Agricultural Water Management* (Vol. 269). https://doi.org/10.1016/j.agwat.2022.107645
- Wise, W. S. (1983). Economic Analysis of Agricultural Projects. By J. P. Gittinger. Baltimore and London: Johns Hopkins University Press (1982), 2nd edition, pp. 505, £28.25. *Experimental Agriculture*, *19*(3), 281–281. https://doi.org/10.1017/S0014479700022894
- World Bank. (2019). *Adapting Agriculture to Climate Change: A Role for Public Policies.*
- Xiuling, D., Qian, L., Lipeng, L., & Sarkar, A. (2023). The Impact of Technical Training on Farmers Adopting Water-Saving Irrigation Technology: An Empirical Evidence from China. *Agriculture*, *13*(5), 956. https://doi.org/10.3390/agriculture13050956
- Yadav A., Sharma N., Upreti H, & Das Singhal G. (2022). Techno-economic analysis of irrigation systems for efficient water use in the backdrop of climate change. *Current Science*, *122*(6), 664-673.
- Yazdanpanah, M., Klein, K., Zobeidi, T., Sieber, S., & Löhr, K. (2022). Why Have Economic Incentives Failed to Convince Farmers to Adopt Drip Irrigation in Southwestern Iran? *Sustainability (Switzerland)*, *14*(4). https://doi.org/10.3390/su14042055
- Zou, X., Li, Y., Cremades, R., Gao, Q., Wan, Y., & Qin, X. (2013). Cost-effectiveness analysis of water-saving irrigation technologies based on climate change response: A case study of China. *Agricultural Water Management*, *129*. https://doi.org/10.1016/j.agwat.2013.07.004