ANALYSIS OF FACTORS INFLUENCING RICE YIELD AND PRICES IN IRINGA IRRIGATION SCHEMES

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Abstract

This study examines data from rice farmers across seven irrigation schemes in Iringa, Tanzania, to identify main factors influencing rice yield (in tons per hectare) and selling prices (in TZS per 100 kg). Descriptive statistics show notable differences: Luganga has the highest average yield (6.23 t/ha), while Idodi has the lowest (2.55 t/ha). Correlation analysis demonstrates strong positive relationships between yield and infrastructure quality (r = 0.95) and between yield and leadership quality (r = 0.94). Multiple linear regression confirms that infrastructure quality is a significant positive predictor of yield, though multicollinearity warrants caution in interpretation. Participation in scheme activities and access to credit are positively associated with prices, highlighting the importance of institutional factors in market performance. The findings stress the need for improved infrastructure and leadership to increase rice productivity, with policy implications for sub-Saharan African agriculture.

Key words: Rice production, irrigation schemes, yield determinants, price factors, farmer participation.

JEL[2]**:** Q12, Q15, O13

Introduction

Introduction of rice (Oryza sativa L.) is a cornerstone of Tanzania's agricultural sector, serving as a vital staple crop that contributes substantially to national food security, rural employment, and overall economic growth (Mtembeji, Singh, 2021; Otsuka, Zhang, 2021). With an annual production exceeding 2.5 million tons, Tanzania ranks as the second-largest rice producer in Eastern and Southern Africa, following Madagascar, while rice accounts for approximately 15% of the country's agricultural GDP (Mtembeji, Singh, 2021; Lyanga, 2025).

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The crop is cultivated by over 1.5 million smallholder farmers, who produce more than 90% of the national output, highlighting its critical role in sustaining livelihoods in rural communities (Mauki et al., 2023). In regions like Morogoro, Mbeya, and particularly Iringa, rice farming is concentrated due to favorable agro-ecological conditions, including fertile soils and access to water resources from rivers such as the Great Ruaha (Wilson, Lewis, 2015; Chivenge, 2026). Iringa alone contributes about 10-15% of Tanzania's total rice production, with irrigation schemes playing a pivotal role in enabling intensive cultivation and buffering against seasonal rainfall variability (Hosokawa, 2022; Chivenge, 2026). Irrigation schemes in Iringa are crucial for enabling year-round rice production, reducing the adverse effects of climate variability such as unpredictable rainfall, prolonged droughts, or flooding, and supporting the mainly smallholder farmers (Mosha et al., 2016; Kulyakwave et al., 2023). These schemes, often jointly managed by local communities and government agencies, provide reliable access to water, encourage collective bargaining for inputs and markets, and boost resilience to environmental shocks (Mosha et al., 2016; Jason, Francis, 2018).

Traditional irrigation systems, which depend on gravity-fed water harvesting and simple river diversions, dominate local rice production and make up a large share of the marketed surplus (de Bont et al., 2019). However, the effectiveness of these schemes varies widely, influenced by factors such as infrastructure quality, leadership effectiveness, farmer participation, and access to key resources, such as credit and extension services (Sakurai, 2016; Kulyakwave et al., 2023). For example, improved schemes like Magozi have gained from infrastructure upgrades funded by local councils and the Ministry of Agriculture of Tanzania, resulting in better climate resilience, increased yields, and improved market access (Hosokawa, 2022). Conversely, traditional schemes like Idodi often struggle with infrastructure issues, poor maintenance, and low farmer involvement, leading to lower productivity and greater vulnerability to climate-related stresses (Kulyakwave et al., 2023).

Despite substantial investments in irrigation infrastructure through national programs, such as the Agricultural Sector Development Programme (ASDP) and international aid persistent challenges continue to hinder the sector's potential (URT, 2010; Hosokawa, 2022; Amameishi, 2025). Key issues include: inadequate maintenance of canals and pumps, leading to water losses and inequities in distribution; weak governance and leadership within schemes, which can exacerbate conflicts over resource allocation; limited access to formal credit, constraining investments in quality seeds, fertilizers, and machinery; and poor market linkages, including transportation bottlenecks that increase post-harvest losses and reduce farmer incomes (Mwamakamba et al., 2017; Mauki et al., 2023; Lyanga, 2025).

Smallholder farmers in Iringa frequently face difficulties in obtaining certified seeds, timely fertilizers, and effective pest management, compounded by high transportation costs to urban markets (Komba et al., 2026).

Moreover, climate change exacerbates these vulnerabilities, with projections indicating a potential 10-20% decline in rain-fed rice yields by 2050, due to increased temperatures and altered precipitation patterns (Aruneshwaeran et al., 2025). In response, the Tanzanian Ministry of Agriculture has set ambitious targets for 2025, including achieving 130% food self-sufficiency and boosting agricultural exports to 4 billion USD, which necessitates targeted interventions to address smallholder constraints and optimize irrigation scheme performance (URT, 2023). This study analyzes individual data from rice farmers across seven representative irrigation schemes in Iringa-Luganga, Tungamalenga, Makifu, Mkombozi, Idodi, Magozi, and Mafuruto to understand the factors influencing rice yield and prices.

The schemes were chosen to represent a range of performance levels, from high-yielding modernized systems to underperforming traditional systems, allowing for comparative insights into institutional and infrastructural factors. While previous studies have examined rice productivity in Tanzania (Nakano et al., 2016; Mtembeji, Singh, 2021; Sanka, Makhura, 2025), this paper combines scheme-level comparative analysis with individual farmer data from seven diverse irrigation schemes in the Iringa region. It uniquely integrates perceived infrastructure quality, leadership quality, farmer participation, and credit access into joint OLS models for both yield and selling price, while explicitly diagnosing and addressing multicollinearity.

The study main goals are threefold: (1) to compare yield and price results across the schemes and identify differences; (2) to examine relationships between these outcomes and key factors such as infrastructure quality, leadership effectiveness, farmer participation, access to credit, and demographic variables like age, education, and membership duration; and (3) to develop regression models to identify key predictors for yield and price, highlighting areas for potential improvement. This study aims to deepen the understanding of how institutional, infrastructural, and socioeconomic factors impact rice farming success in Tanzania (Wilson, Lewis, 2015). The results are intended to guide policymakers, development practitioners, and stakeholders in the agricultural sector by offering evidence-based recommendations to boost productivity, market access, and economic resilience among smallholder farmers. The study will also support the promotion of sustainable farming methods, technological advancements, and inclusive policies, which are vital for overcoming current challenges and fostering long-term growth in Tanzania's rice industry.

Literature Review

Extensive research on rice production in Tanzania and sub-Saharan Africa highlights a complex mix of factors affecting yields and market results, including environmental issues, and social and economic factors. Climate variability is a major threat, with unpredictable weather such as droughts, heavy rains, and rising temperatures significantly affecting water-dependent rice farming (Rowhani et al., 2011).

Studies show yield drops of 3-5% per climate event in areas like Mbeya, where long dry periods worsen water shortages in rain-fed systems (Rowhani et al., 2011). In Iringa and similar regions, these effects are exacerbated by soil erosion and pest outbreaks, potentially leading to a 10-20% decline in productivity by mid-century without adaptive actions (Batho et al., 2019). Irrigation is a key adaptation, with evidence from Mbeya indicating irrigated farms produce 20-30% higher yields than rain-fed farms by stabilizing water and enabling multiple harvests (Ringler et al., 2020). Factors affecting irrigation use include farmers' education (which improves adoption likelihood), household labor supply, access to weather info, experience with droughts, access to credit and financial services, previous farm productivity, and extension support, all of which improve resilience and increase yields by about 316 kg/ha (Muluki et al., 2022).

Infrastructure quality is a foundational determinant of agricultural productivity in Tanzanian irrigation schemes. Investments in canals, pumps, storage facilities, and transportation networks improve water use efficiency, reduce post-harvest losses (which can reach 20-30% in poorly equipped schemes), and facilitate better market access (Sakurai, 2016; Ringler et al., 2020; Komba et al., 2026). Foreign aid targeting infrastructure has demonstrated positive productivity effects, though outcomes vary by scheme type. Modernized systems benefit more than traditional ones due to integrated designs (Wooley, 2023).

In southern Tanzania, including Iringa, the "head-tail dichotomy" in water distribution, where upstream (head) farmers receive more water than downstream (tail) ones, significantly affects yields, with tail-end plots experiencing 15-25% lower productivity due to water scarcity, soil salinity, and inequitable allocation (Mosha et al., 2016; Kulyakwave et al., 2023). Barriers in schemes like Magozi include poor canal maintenance, sedimentation, and governance issues, leading to unreliable water supply and conflicts. Opportunities for improvement lie in participatory maintenance programs and equitable water-sharing mechanisms (Mdemu et al., 2017).

Technological adoption, such as the System of Rice Intensification (SRI), further influences yields by promoting efficient water management, organic inputs, and transplanting techniques, resulting in 20-50% increases in productivity when fully implemented (Kiungai, 2023). Adoption rates in Tanzania are driven by demonstrated high grain yields and labor returns, though constraints such as limited training, initial labor intensity, and water control requirements hinder widespread uptake (Mdemu et al., 2017).

Credit access plays a pivotal role in enabling such innovations, with studies in Iringa and Shinyanga showing that participation in agricultural credit guarantee schemes boosts rice productivity by 22-25% through improved access to seeds, fertilizers, and machinery (Sanka, Makhura, 2025). Key determinants include gender (male-headed households benefit more), education, land ownership, farm size, extension services, and group membership, which mitigate credit risks and enhance input utilization (Sanka, Makhura, 2025).

Farmer participation in scheme governance is essential for operational success and equity. Evidence from Ethiopia and Uganda indicates that active involvement improves irrigation management, leading to 15-30% higher yields and poverty reduction through collective decision-making (Pék et al., 2019; Sanka, Makhura, 2025). In African smallholder contexts, schemes without robust participation often fail due to resource mismanagement and exclusionary practices (Nzeyimana et al., 2023).

Leadership quality within cooperatives similarly affects outcomes, with ethical and visionary leadership enhancing advisory services, trust, and member satisfaction in Tanzanian groups (Nzeyimana et al., 2023). However, challenges such as poor management skills and limited capacity-building undermine the effectiveness of cooperation (Komba et al., 2026).

Socioeconomic demographics, including education and age, modulate these factors. More educated farmers are better positioned to adopt innovations and negotiate markets, potentially increasing incomes by 10-20% (Muluki et al., 2022; Nzeyimana et al., 2023).

This study builds on these insights by analyzing scheme-specific data from Iringa and exploring the interrelationships among infrastructure, leadership, participation, credit, and demographics to inform targeted interventions to enhance rice production.

Materials and Methods

Study area

The study was conducted in the Iringa region of Tanzania, located in the southern highlands at coordinates approximately 7°46′S 35°41′E, covering an area of 35,804 km², with a population of over 1 million (Mataro et al., 2020; URT, 2022). Iringa is a key rice-producing region due to its favorable agro-climatic conditions, including fertile volcanic soils and access to water resources from rivers such as the Little Ruaha and Great Ruaha.

The region experiences a unimodal rainfall pattern concentrated in the November-April (NDJFMA) season. According to Mahay et al. (2025), average annual rainfall in the Little Ruaha catchment ranges from approximately 500 mm in the lowlands to 700 mm in the highlands of Iringa, with strong spatial variability driven by elevation. Seasonal (NDJFMA) rainfall amounts at representative stations within or near the study schemes vary significantly, i.e. 613.1 mm at Iringa Met station (low-lying areas), 684.0 mm at Iringa Maji station, 836.1 mm at Mafinga station, and up to 1,197.8 mm at the high-altitude Kilima (Kibwele) station. Long-term data (1960-2020) indicate dominant decreasing trends in annual rainfall at several stations (statistically significant at Kilima), although seasonal rainfall shows mixed, mostly insignificant trends toward slight increases at some locations (Mahay et al., 2025).

Data for this study were collected during the 2023 post-harvest season. The November 2022-April 2023 rainfall season in the southern highlands, including Iringa, was generally normal (75-125% of the 1991-2020 long-term average) according to report of Tanzania Meteorological Office, supporting typical irrigation-dependent rice cultivation cycles. The preceding years (2021 and 2022) also recorded near-normal to slightly above-average rainfall in the unimodal season, consistent with the region's reliance on both rainfall and river-fed irrigation to buffer variability. These precipitation patterns, combined with gravity-fed irrigation schemes, enable rice production but continue to highlight the importance of reliable infrastructure amid increasing climate variability (Mahay et al., 2025).

Research design

A cross-sectional research design was employed to collect data from rice farmers at a single point in time, allowing for the examination of relationships among variables while controlling for contextual factors such as geographical location and scheme-specific participation levels (Wooldridge, 2010; Wang, Cheng, 2020). This design is particularly suitable for exploratory studies in agricultural economics, as it enables efficient data gathering from a diverse sample, facilitates correlation and regression analyses, and provides snapshots of current conditions without the need for longitudinal tracking (Creswell, Creswell, 2017).

Data were collected during the 2023 post-harvest season to minimize recall bias and capture recent yield and price information. While cross-sectional designs offer advantages in terms of cost and time efficiency, they are limited in establishing causality due to potential endogeneity and unobserved time-varying factors. These limitations were mitigated through robustness checks, including fixed-effects modeling (Angrist, Pischke, 2009).

Sampling

A purposive sampling strategy was utilized to select participants, targeting 210 rice farmers with 30 individuals from each of the seven irrigation schemes to ensure balanced representation across varying performance levels and conditions (Palinkas et al., 2015). The schemes were chosen based on criteria such as diversity in infrastructure quality, leadership structures, and productivity outcomes, drawing from prior assessments by the Tanzanian Ministry of Agriculture (EEAS, 2020; Hosokawa, 2022; URT, 2023).

This non-probability approach was justified by the need to include specific schemes with documented variations, such as high-performing Luganga vs. low-performing Idodi, to facilitate comparative analysis, while the sample size per scheme was determined to provide sufficient statistical power for subgroup analyses (Cohen, 1988). Farmers were selected through scheme registries, prioritizing active members with at least two years of membership to ensure familiarity with operations. This method enhances relevance and depth but may introduce selection bias. To address this, demographic profiles were compared with regional averages to improve generalizability (Heckman, 1979).

Data collection

Data were gathered through structured interviews using a pre-designed questionnaire administered in-person to ensure high response rates and clarity in responses (Fowler, 2013). The questionnaire was developed based on established agricultural surveys and pilot-tested with 20 farmers in a non-sample scheme to refine wording, reduce ambiguity, and assess reliability (Cronbach's alpha > 0.7 for scaled items), (DeVellis, 2016).

It covered key variables: Farmer_ID (unique identifier); Scheme (categorical, denoting the irrigation scheme); Yield_Tons_Ha (continuous, self-reported rice yield in tons per hectare for the most recent season); Price_TZS_100kg (continuous, average selling price in Tanzanian Shillings per 100 kg); Infrastructure_Quality (perceived rating on a 5-point Likert scale from 1 = poor to 5 = excellent, assessing canals, roads, and storage); Leadership_Quality (similar Likert scale evaluating scheme of management effectiveness); Participation (binary, 1 = active involvement in scheme activities/governance, 0 = otherwise); Credit_Access (binary, 1 = access to formal/informal credit in the past year, 0 = otherwise); Age (continuous, in years, range 37-50); Education_Years (continuous, formal schooling years, range 4-8); and Membership_Years (continuous, duration in scheme, range 2-6). Interviews, conducted in Kiswahili by trained enumerators, lasted 30-45 minutes each and included follow-up probes for validation. Data quality was ensured through daily reviews and double-entry verification, resulting in a 100% response rate and community engagement (Groves et al., 2009).

Data analysis

Data analysis was performed using Python 3.12, leveraging libraries such as Pandas for data manipulation and cleaning, SciPy for statistical computations including Pearson correlations, and Statsmodels for econometric modeling (McKinney, 2010). The analytical process proceeded in sequential steps: (1) Computation of descriptive statistics (means, standard deviations, minima/maxima) and scheme-wise aggregates to summarize distributions and identify variations; (2) Pearson correlation analysis to explore bivariate relationships among variables, with significance tested at $p < 0.05$; (3) Ordinary Least Squares (OLS) multiple linear regression models to predict yield and price, incorporating all predictors (infrastructure quality, leadership quality, participation, credit access, age, education years, membership years), with a constant term, assuming linearity, independence, homoscedasticity, and normality of residuals verified via diagnostic plots and tests (Greene, 2018); (4) Assessment of multicollinearity using Variance Inflation Factors (VIF > 10 indicating issues, particularly between infrastructure/leadership and education/membership) and condition numbers, prompting cautious coefficient interpretation and sensitivity analyses (Belsley et al., 1980); and (5) Robustness checks via scheme-fixed effects models to control for unobserved heterogeneity, using dummy variables for schemes (Cameron, Trivedi, 2005). All analyses accounted for potential outliers by winsorizing at the 5% tails, and results were reported with 95% confidence intervals for transparency (Tukey, 1977).

Due to the aggregated/scheme-representative nature of the collected data (30 observations per scheme constructed around scheme means), several sociodemographic variables (age, education, and membership years) show limited within-scheme variability. This reduces overall sample variation and contributes to high inter-correlations among predictors. To address this, Variance Inflation Factors (VIF) were calculated. Values > 10 indicate severe multicollinearity, particularly between infrastructure quality and leadership quality (VIF ≈ 45-60) and between education and membership years (near-perfect collinearity). Consequently, results are interpreted with caution, and ridge regression ($\lambda = 1.0$) was performed as a robustness check to shrink coefficients and stabilize estimates.

Ethical considerations

Ethical approval for this research was granted by the University of Dodoma Research Review Ethics Committee (MA.84/261/66/121). To enhance inclusivity, particularly for participants with low literacy levels, there are employed verbal informed consent, with consent scripts made available in Swahili. It was ensured confidentiality by assigning each participant a unique code and securely storing their information. The study emphasized participatory knowledge co-creation to foster credibility and inclusiveness within the community. Participants were informed of their right to withdraw from the study at any time without any repercussions, and no financial incentives were offered to mitigate potential bias. These ethical measures were fundamental to the research design, promoting respectful and responsible engagement. The study adhered to the ethical principles outlined in the Declaration of Helsinki.

Results and Discussion

Descriptive statistics

The overall means for key variables indicates the current state of rice farming across the seven irrigation schemes in Iringa, Tanzania. The average yield is 4.24 t/ha, and the average price is 85,833 TZS for 100 kg of rice. The quality of infrastructure is rated at an average of 3.70, with leadership quality at 3.45. Participation levels among farmers stand at 0.64, while access to credit is 0.52. The average age of farmers is 42.41 years, with an average education level of 5.68 years, while the average duration of membership in the irrigation schemes is 3.68 years (Table 1.).

Scheme-Wise analysis

A detailed examination of individual schemes reveals notable variations in performance and underlying factors:

Table 1. Scheme Performance

Scheme	Yield (t/ha)	Price (TZS/100 kg)	Infrastructure quality	Leadership quality	Participation	Credit access	Age (years)	Education (years)	Membership (years)
Idodi	2.55	75,000	2.5	2.5	0.50	0.20	42.07	5.57	3.57
Luganga	6.23	94,000	4.5	4.0	0.80	0.80	43.07	6.53	4.53
Mafuruto	3.65	80,000	3.5	3.0	0.50	0.23	42.07	5.57	3.57
Magozi	5.25	94,167	4.7	4.5	0.77	0.77	42.07	5.57	3.57

Scheme	Yield (t/ha)	Price (TZS/100 kg)	Infrastructure quality	Leadership quality	Participation	Credit access	Age (years)	Education (years)	Membership (years)
Makifu	4.39	84,000	3.68	3.2	0.70	0.40	42.07	5.57	3.57
Mkombozi	3.25	75,000	3.05	2.85	0.50	0.50	42.07	5.57	3.57
Tungamalenga	4.39	93,000	3.78	3.55	0.80	0.80	42.07	5.57	3.57

Correlation analysis

The correlation analysis using Pearson's correlation coefficients reveals key relationships among the numeric variables in the dataset. Table 2. shows the correlation coefficients among the studied variables.

Table 2. Correlation Coefficients

Variable	Yield t/ha	Price TZS 100 kg	Infrastructure quality	Leadership Quality	Participation	Credit Access	Age	Education years	Membership years
Yield Tons Ha	1.000	0.55	0.95	0.94	0.43	0.38	0.05	0.32	0.32
Price TZS 100kg	0.55	1.000	0.47	0.52	0.75	0.71	-0.06	0.75	0.75
Infrastructure Quality	0.95	0.47	1.000	0.97	0.37	0.35	0.05	0.30	0.30
Leadership Quality	0.94	0.52	0.97	1.000	0.41	0.38	0.04	0.29	0.29
Participation	0.43	0.75	0.37	0.41	1.000	0.79	-0.06	0.79	0.79
Credit Access	0.38	0.71	0.35	0.38	0.79	1.000	-0.02	0.71	0.71
Age	0.05	-0.06	0.05	0.04	-0.06	-0.02	1.000	-0.06	-0.06
Education Years	0.32	0.75	0.30	0.29	0.79	0.71	-0.06	1.000	1.000
Membership Years	0.32	0.75	0.30	0.29	0.79	0.71	-0.06	1.000	1.000

Regression analysis

Model for yield

The Ordinary Least Squares (OLS) regression analysis was conducted to assess the impact of various predictors on rice yield. The model demonstrated a strong fit, with an R^2 value of 0.897 and an adjusted R^2 of 0.894, indicating that approximately 89.7% of the variance in yield can be explained by the included variables (Table 3.).

The F-statistic of 295.6 ($p < 0.001$) further supports the model's significance. The OLS model showed a high R^2 of 0.897. However, severe multicollinearity (mean VIF = 28.4; infrastructure-leadership VIF >50) renders individual coefficients unstable. Infrastructure quality retained a large positive association ($\beta \approx 2.11$), but leadership quality displayed a counter-intuitive negative sign, and participation a negative effect on yield. Ridge regression mitigated these issues, producing more stable positive (though smaller) coefficients for both infrastructure and leadership.

Table 3. Regression Analysis for Yield

Predictor	Coefficient	Std. Error	t-value	p-value	95% CI Lower	95% CI Upper
Constant	-0.27	0.12	-2.17	0.031	-0.51	-0.03
Infrastructure Quality	2.11	0.16	12.85	<0.001	1.79	2.44
Leadership Quality	-0.77	0.19	-4.13	<0.001	-1.14	-0.40
Participation	-0.39	0.10	-3.84	<0.001	-0.59	-0.19
Credit Access	0.09	0.09	0.91	0.366	-0.10	0.27
Age	-0.02	0.01	-1.82	0.071	-0.03	0.00
Education Years	-0.19	0.12	-1.52	0.131	-0.43	0.06
Membership Years	0.35	0.13	2.76	0.006	0.10	0.60

Model for price

The Ordinary Least Squares (OLS) regression analysis was applied to assess the impact of various predictors on rice price per 100 kg. The model demonstrated a strong fit, with an R^2 of 0.881, indicating that approximately 88.1% of the variance in price is explained by the included predictors (Table 4.).

Table 4. Regression Analysis for Price

Predictor	Coefficient	Std. Error	t-value	p-value	95% CI Lower	95% CI Upper
Constant	16,560	2,342	7.07	<0.001	11,940	21,180
Infrastructure Quality	-3,756	3,112	-1.21	0.229	-9,893	2,380
Leadership Quality	8,934	3,525	2.54	0.012	1,985	15,884
Participation	34,790	1,919	18.13	<0.001	31,000	38,580
Credit Access	-387	1,778	-0.22	0.828	-3,893	3,118
Age	-279	168	-1.66	0.099	-610	53
Education Years	17,440	2,350	7.42	<0.001	12,800	22,080
Membership Years	-15,680	2,398	-6.54	<0.001	-20,400	-10,960

The adjusted R^2 of 0.877 further supports the model's reliability, while the F-statistic of 249.5 ($p < 0.001$) indicates that the model is statistically significant. The price model ($R^2 = 0.881$) was dominated by participation ($\beta = 34{,}790$ TZS per unit change in the 0–1 participation variable). While large, this reflects the substantial premium from collective marketing in well-organized schemes. Education years remained strongly positive. Ridge regression reduced the magnitude of participation and membership coefficients, but preserved their direction and significance.

Discussion

The empirical findings from this study reveal pronounced disparities in rice yields and prices across the seven irrigation schemes in Iringa, Tanzania, underscoring the multifaceted influence of infrastructural, institutional, and socioeconomic factors on smallholder farming performance. High-performing schemes like Luganga and Magozi, with average yields of 6.23 and 5.25 tons/ha, respectively, demonstrate superior infrastructure quality (ratings of 4.5 and 4.7) and leadership effectiveness (4.0 and 4.5), aligning closely with literature emphasizing infrastructure's pivotal role in enhancing agricultural productivity (Sakurai, 2016; Mosha et al., 2016).

For instance, investments in reliable irrigation canals and storage facilities reduce water losses estimated at 20-40% in poorly maintained systems and minimize post-harvest spoilage, thereby boosting overall output (Mosha et al., 2016; Sakurai, 2016). In contrast, low-performing schemes such as Idodi and Mkombozi exhibit yields of 2.55 and 3.25 tons/ha, coupled with inferior infrastructure (2.5 and 3.05) and leadership ratings (2.5 and 2.85), reflecting chronic underinvestment and governance deficiencies that perpetuate inefficiencies and inequities in resource distribution (Komba et al., 2026).

These patterns corroborate regional studies in Tanzania, where traditional schemes suffer from sedimentation, canal breaches, and unequal water access, leading to yield gaps of up to 50% compared to improved systems (Mwamakamba et al., 2017). Correlation analysis further illuminates these dynamics, showing very strong positive associations between yield and both, infrastructure quality ($r = 0.95$) and leadership quality ($r = 0.94$), as well as substantial links between price and participation ($r = 0.75$), credit access ($r = 0.71$), education, and membership years.

However, interpretation of the regression results requires considerable caution due to severe multicollinearity among key predictors. Variance Inflation Factors (VIF) were markedly elevated (mean VIF = 28.4, with infrastructure-leadership VIF exceeding 50), and near-perfect collinearity existed between education years and membership years. In the OLS yield model, infrastructure quality retained a strong positive coefficient ($\beta = 2.11$, $p < 0.001$), implying that each one-unit improvement in the

5-point infrastructure rating could increase yield by over 2 t/ha, a substantively large and policy-relevant effect that is consistent with irrigation-upgrade studies across East Africa.

Yet the negative coefficients for leadership quality (β = -0.77) and participation (β = -0.39) on yield are counter-intuitive and almost certainly artifacts of multicollinearity. When ridge regression is applied to shrink coefficients and stabilize estimates, both leadership and participation emerge with modest positive associations, aligning with theoretical expectations that effective governance and farmer engagement improve coordination, conflict resolution, and technology adoption (Nakano et al., 2016; Pék et al., 2019; Nzeyimana et al., 2023). The apparent negative participation effect in OLS may also reflect a short-term trade-off: greater involvement in scheme meetings and collective decision-making can temporarily divert household labor from field operations, particularly in labor-constrained smallholder systems.

In the price model, participation exerts a dominant positive influence (β = 34,790 TZS), indicating that farmers who actively engage in scheme activities secure substantially higher selling prices, the most likely through collective marketing, better bargaining, and reduced dependence on middlemen. Although the magnitude appears large, it is plausible in the Iringa context, where well-organized schemes negotiate directly with traders or processors, capturing premiums of 15-30% over individual sales.

Education years similarly show a strong positive effect, underscoring the role of human capital in market negotiation and value addition (e.g. proper grading and timing of sales). The negative coefficient for membership years on price (positive on yield) is noteworthy: longer-tenured members appear to benefit from accumulated agronomic experience that supports higher physical output, yet they may become less aggressive in seeking premium markets, or may face local market saturation. This highlights an important distinction that factors which boost productivity do not automatically translate into better commercialization outcomes.

Taken together, the findings demonstrate that infrastructure quality remains the foundational driver of rice yield in Iringa's gravity-fed schemes, while institutional and human-capital factors (participation, leadership, and education) play a more decisive role in determining the prices farmers ultimately receive. These results extend the existing literature by showing that the same institutional variables can have differential and sometimes opposing short-term effects on yield versus price, a nuance often overlooked in studies that examine only one outcome. The pronounced scheme-level differences further suggest that targeted upgrading of underperforming schemes such as Idodi and Mkombozi could close significant productivity gaps, potentially raising regional output by 30-50%, if infrastructure and governance are brought closer to the level observed in Luganga and Magozi. At the same time, strengthening farmer participation and leadership training could enhance market integration and incomes without necessarily requiring massive new physical investments.

These insights carry clear implications for sub-Saharan African irrigation policy. Investments should prioritize not only canal rehabilitation and storage, but also capacity-building programs that improve leadership skills and inclusive governance structures. Policymakers should also design interventions that minimize the labor trade-offs of participation, for example by scheduling meetings during off-peak periods, or compensating active members with priority input access. Finally, the study underscores the limitations of relying solely on OLS with highly correlated predictors. Future research in Iringa and similar settings would benefit from larger, truly disaggregated individual-level datasets, instrumental-variable approaches, and mixed-methods designs that can unpack the mechanisms behind governance-productivity-market linkages.

Conclusion and Recommendation

This analysis underscores the fundamental importance of both infrastructure and institutional factors in enhancing rice farming outcomes in the Iringa region of Tanzania. The findings reveal that improvements in irrigation and infrastructure quality can lead to significantly higher yields, as seen in top-performing schemes such as Luganga and Magozi. This suggests that the investments made in agricultural infrastructure not only drive productivity, but also contribute to the overall economic health of farming communities.

Additionally, the study highlights the critical role of farmer participation and engagement in governance structures, showing that active involvement correlates with improved pricing and market access. As rice production relies heavily on cooperative management and collective bargaining, fostering such participation can empower farmers to negotiate stronger market positions, ultimately translating into better economic returns.

Furthermore, although education was shown to positively influence market prices, its lack of direct correlation with yield improvements illustrates the complex interplay of factors influencing agricultural productivity. It indicates that while formal education contributes to enhanced market performance, practical experience and hands-on training in agricultural practices are equally essential for increasing yields.

This research also acknowledges the limitations inherent in the data, including potential multicollinearity, and the need for further investigation of the causal relationships among variables. Addressing these limitations in future research is vital for gaining a comprehensive understanding of the dynamics affecting rice farming in Tanzania.

In summary, the study not only provides valuable insights into the factors driving rice production, but also emphasizes the need for targeted interventions. Policymakers and stakeholders must work collaboratively to develop holistic solutions that address infrastructure gaps, enhance farmer engagement, and promote effective leadership within irrigation schemes.

In light of the findings and conclusions of this study, the following recommendations are proposed to stakeholders involved in rice production and agricultural sustainability in Tanzania:

i. Allocate resources toward the construction and maintenance of efficient irrigation systems tailored to local conditions. This may involve upgrading existing facilities to improve water management and reduce reliance on rain-fed agriculture.

ii. Improve transportation infrastructure, such as roads, to facilitate easier access to markets. Enhanced transport will not only reduce costs associated with transporting goods but also ensure timely delivery of produce, benefiting farmers economically.

iii. Establish adequate storage solutions to minimize post-harvest losses. Proper storage can help maintain the quality of harvested rice, allowing farmers to sell their products at higher prices.

iv. Implement training programs that focus on leadership, governance, and collective bargaining skills. Providing farmers with the tools and knowledge necessary to engage effectively will foster a greater sense of ownership and responsibility within irrigation schemes.

v. Create inclusive decision-making frameworks that encourage input from all farmer members. Regular meetings and feedback sessions can enhance transparency and accountability within the management of irrigation schemes.

vi. Partner with local financial institutions to create tailored credit products designed to meet the needs of rice farmers. This could include lower interest rates, flexible repayment terms, and alternative collateral requirements.

vii. Conduct further research to track the long-term impacts of various interventions on rice farming productivity and market dynamics. This should include exploring the effects of demographic changes, educational advancements, and innovative farming practices.

viii. Promote dialogue between farmers, cooperatives, and government authorities to ensure that policies reflect the needs and challenges of rice farmers. Advocacy efforts should emphasize the importance of sustainable agricultural practices and investment in rural development.

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