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Impact of Community-Based Water Management on the Livelihoods of Smallholder Farmers in Kirehe District, Rwanda

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ABSTRACT

Access to reliable water is a key determinant of agricultural productivity and household welfare among smallholder farmers in drought-prone Eastern Rwanda. This study assessed the socio-economic impact of the Community-Based Water Management Project (CBWMP) on smallholder farmers in Kirehe District. Guided by Integrated Water Resources Management, the Sustainable Livelihoods Framework and Community-Based Resource Management theory, the study adopted a mixed-methods descriptive–correlational design. Quantitative data were collected from 304 participating farm households, selected from a population of 1,267 using Slovin's formula, through a structured five-point Likert questionnaire; qualitative data were obtained through key informant interviews with 22 project staff and focus group discussions. Data were analysed using descriptive statistics, Pearson correlation, multiple linear regression and thematic analysis. Results show that the project was well implemented, with high mean scores for access to irrigation water (4.20), water use efficiency (4.24), community participation (4.19), infrastructure development (4.23) and training and capacity building (4.24). Farmers also reported strong improvements in crop yield (4.24), household income (4.21), food security (4.23), livelihood diversification (4.22), health and nutrition (4.22) and overall livelihood (4.30). A strong positive association was found between CBWMP implementation and socio-economic livelihood ($r = .959$, $p < .001$), and the five project components jointly explained 94.9% of the variance in livelihood outcomes ($R^2 = .949$). Community participation and access to irrigation water were the strongest predictors. The study concludes that community-based water management is an effective pathway for rural livelihood improvement and recommends expanding irrigation infrastructure, sustaining farmer training, deepening inclusive participation and conducting longitudinal impact evaluations.

Keywords: *Community-based water management; irrigation; smallholder farmers; food security; livelihoods; Rwanda*

1. Introduction

Smallholder farming worldwide is under growing pressure from climate variability, rising populations and competition for scarce water. One response has been to hand greater responsibility for water to the communities that use it, an approach known as Community-Based Water Management (CBWM). Evidence from Tamil Nadu, India, shows that such arrangements can enlarge the irrigated area, allow more crops per year and raise the profits of small and marginal farmers (Kiruthika et al., 2022). African experience points in the same direction: in Zimbabwe, schemes combining drip lines, solar pumps and micro-jets now let farmers grow several crops a year, with gains in yields, earnings and ability to cope with drought (FAO, 2025).

In Rwanda, community-based water interventions are increasingly adopted in the drought-prone Eastern Province, where cooperatives use solar pumps to stabilise water supply and enhance productivity (Uwizeye, 2023). In Bugesera District, smallholders participating in a solar-powered small-scale irrigation scheme were about 31 percentage points more technically efficient than comparable non-participants (Benjamin et al., 2025). Kirehe District, located in the south-east of the country, faces similar constraints: most farming remains rain-fed, maize yields remain far below national targets, and a large share of farmers depend entirely on seasonal rainfall (NISR, 2024; MINAGRI, 2025). Limited water access exacerbates food insecurity, poor nutrition and vulnerability to climate shocks, and prevents households from diversifying livelihoods or adopting higher-value crops (NISR, 2023; RAB, 2025).

The Kirehe Community-Based Water Management Project (CBWMP, also known as KWAMP) was introduced to improve water availability through irrigation access, water use efficiency, community participation, infrastructure development and farmer training. However, existing studies in Rwanda have focused mainly on infrastructure or technical performance, leaving limited evidence on how community-led water interventions affect productivity, income, food security and overall livelihoods (Habiyaremye et al., 2022; Uwizeye, 2023). This study addresses that gap. Its general objective was to assess the socio-economic impact of the CBWMP on the livelihoods of smallholder farmers in Kirehe District. The specific objectives were to (i) assess the implementation of the CBWMP; (ii) examine the socio-economic status of participating smallholder farmers; and (iii) determine the relationship between the CBWMP and farmers' socio-economic outcomes.

2. Literature Review

2.1 Theoretical framework

Three bodies of theory frame the analysis. The first is Integrated Water Resources Management (IWRM), which treats water, land and related resources as a single system to be governed jointly so that economic and social benefits are shared fairly while ecosystems are protected (Katusiime & Schütt, 2020). In the Kirehe context, IWRM helps explain why better access to irrigation, more careful water use, sound infrastructure and farmer training should translate into higher farm output.

Second, the Sustainable Livelihoods Framework (SLF) holds that livelihood outcomes result from the interaction of human, natural, financial, social and physical capital within a vulnerability context and an enabling institutional environment (Natarajan et al., 2022). In this study, training strengthens human capital, infrastructure strengthens physical capital and participation strengthens social capital, enabling households to pursue strategies that raise income, food security, nutrition and diversification.

Third, Community-Based Resource Management (CBRM) theory, rooted in Ostrom's (1990) principles for governing common-pool resources, argues that local communities can manage shared resources effectively when they have clearly defined rules, collective decision-making, monitoring and conflict-resolution mechanisms (Mbele & Mubangizi, 2021). CBRM explains the role of water user committees and community ownership in sustaining the project. Together, the three theories suggest that the five CBWMP components (independent variables) influence crop yield, household income, food security, livelihood diversification, health and nutrition and overall socio-economic livelihood (dependent variables), moderated by policy factors such as the national irrigation and land-use policies.

2.2 Empirical review and research gap

Empirical studies consistently associate irrigation and community-based water management with better agricultural and welfare outcomes. In China's Yellow River Basin, water management reforms through water user associations and contracting reduced water use without lowering crop production or incomes where managers were given incentives to save water (Wang et al., 2005). In Peru, improved irrigation canals increased productivity and reduced rural out-migration but paid little attention to participation and gender (Fernandez et al., 2018).

In Africa, small-scale irrigation schemes improved food security in Shurugwi District, Zimbabwe (Mhembwe et al., 2019), and in Mberengwa District 97% of irrigators were food secure compared with 45% of non-irrigators (Mupaso et al., 2024). In Limpopo Province, South Africa, local institutional actors such as irrigation committees, extension services and community maintenance support significantly improved scheme yields (Mwadzingeni et al., 2020), yet a survey of 76 public schemes found that only about one-third were fully utilised, with dilapidated infrastructure the main constraint (van Koppen et al., 2017). Evidence from Uganda links irrigation access to higher household income and food security (Atuhairwe et al., 2020). In Rwanda, an independent evaluation of the Kirehe project found increased production of rice, maize, vegetables and milk, but weak market linkages and limited connection to rural financial institutions (IFAD, 2019).

Three gaps emerge from this literature. Conceptually, most studies examine a single outcome, such as yield or income, rather than an integrated set of livelihood outcomes including food security, diversification and health. Methodologically, many rely on purely quantitative cross-sectional designs that overlook the institutional and participatory dynamics captured by qualitative methods. Analytically, few studies model the combined effect of all components of a community-based water project on livelihoods. This study responds by combining survey, interview and focus group evidence and by analysing all five CBWMP components jointly.

3. Methodology

3.1 Study area

Kirehe District lies in the extreme south-east of Rwanda in the Eastern Province, bordering Tanzania and Burundi. It covers about 1,176 km² and is divided into 12 sectors, 60 cells and about 612 villages (NISR, 2022). The 2022 census recorded a population of 460,860, of whom about 94% live in rural areas (NISR, 2022). Agriculture engages more than 90% of the population, mainly maize, beans, cassava, sweet potatoes, bananas and rice in swampy areas; landholdings are small and farming is largely rain-fed, making households vulnerable to drought (MINAGRI, 2021; Mukamuhirwa, 2020).

3.2 Research design, population and sampling

A mixed-methods descriptive–correlational design was adopted (Creswell, 2014; Kothari, 2004). The descriptive component documented the status of CBWMP implementation and livelihood outcomes, while the correlational component tested relationships between them. The target population comprised

1,267 smallholder farm households participating in the CBWMP, 3 district-level staff, 12 sector-level staff and 60 cell-level officers. The farmer sample was determined using Slovin's formula, $n = N / (1 + Ne^2)$, with N = 1,267 and e = 0.05, giving 304 households, selected through stratified and purposive sampling. A census was applied to the 15 district and sector staff, and 7 cell-level officers were purposively selected, giving a total of 326 respondents (Table 1).

Table 1: Population and sample distribution

Category	**Population**	**Sample**	**Sampling technique**
Smallholder farmer households in CBWMP	1,267	304	Stratified and purposive
District-level staff	3	3	Census
Sector-level staff	12	12	Census
Cell-level officers	60	7	Purposive
Total	**1,342**	**326**	**Mixed**

Source: Kirehe District, 2025

3.3 Data collection instruments

Primary data were collected through a structured questionnaire administered to farmers, measured on a five-point Likert scale (1 = strongly disagree to 5 = strongly agree); semi-structured key informant interviews with district, sector and cell officials; focus group discussions of 6–12 farmers each; and field observation of irrigation infrastructure and water distribution. Secondary data were drawn from project records, Kirehe District reports, MINAGRI administrative records and NISR publications.

3.4 Validity and reliability

Content validity was established through expert review of the instruments; the Content Validity Index was 67/74 = .905 (90.5%), above the 70% threshold. Reliability was tested through a pilot study with 15 farmers from comparable sectors who were not part of the final sample. Cronbach's alpha coefficients ranged from .78 to .86 across constructs, with an overall coefficient of .82, indicating good internal consistency (Table 2).

Table 2: Reliability of study constructs

Construct	**Cronbach's alpha**	**Items**
Access to irrigation water	.82	5
Water use efficiency	.79	5
Community participation	.81	5
Infrastructure development	.84	5
Training and capacity building	.83	5
Crop yield/production	.85	4
Household income	.80	4
Food security	.78	4

Construct	Cronbach's alpha	Items
Livelihood improvement and diversification	.82	4
Health and nutrition improvement	.79	4
Overall socio-economic livelihood	.86	4
Overall instrument	**.82**	**49**

Source: Pilot study results, 2026

3.5 Data analysis

Quantitative data were edited, coded and analysed in SPSS. Descriptive statistics (frequencies, percentages, means and standard deviations) summarised respondent characteristics and perceptions; means were interpreted as weak (1.00–2.49), moderate (2.50–3.49) or strong (3.50–5.00). Pearson correlation tested the strength and direction of relationships at $p \leq .05$, and multiple linear regression estimated the combined effect of the five CBWMP components on socio-economic livelihood using the model $Y = \beta_0 + \beta_1X_1 + \beta_2X_2 + \beta_3X_3 + \beta_4X_4 + \beta_5X_5 + \varepsilon$, where Y is socio-economic livelihood, X_1 access to irrigation water, X_2 water use efficiency, X_3 community participation, X_4 infrastructure development and X_5 training and capacity building. Qualitative data from interviews and focus groups were analysed thematically and used to triangulate the quantitative results.

3.6 Ethical considerations

Before fieldwork began, the researcher obtained a letter of introduction from UNILAK and permission from the Kirehe District administration. Respondents were told the purpose of the study, took part voluntarily and gave oral or written consent. Questionnaires carried no names or other identifiers, and the data were kept securely and used only for this research.

4. Results and Discussion

4.1 Characteristics of respondents

Table 3 summarises the farmer respondents. The sample was gender-balanced (52.0% male, 48.0% female), predominantly middle-aged (63.1% aged 31–50), mostly married (74.0%) and had mainly primary (41.4%) or secondary (35.2%) education. Most households had 4–9 members, crop farming was the main livelihood for 88.8%, and 62.9% had participated in the project for four years or more, giving them sufficient exposure to assess its effects. Focus groups noted that, although women and men farm alike, men are more represented in formal water user committees.

Table 3: Characteristics of farmer respondents (n = 304)

Characteristic	Frequency	Percent
Sex: Male	158	52.0
Sex: Female	146	48.0
Age: 18–30 years	12	3.9
Age: 31–40 years	91	29.9
Age: 41–50 years	101	33.2
Age: 51–60 years	67	22.0
Age: above 60 years	33	10.9

Characteristic	Frequency	Percent
Marital status: Single	46	15.1
Marital status: Married	225	74.0
Marital status: Widowed	33	10.9
Education: No formal education	61	20.1
Education: Primary	126	41.4
Education: Secondary	107	35.2
Education: TVET	8	2.6
Education: Tertiary	2	.7
Household size: 1–3	49	16.1
Household size: 4–6	142	46.7
Household size: 7–9	109	35.9
Household size: 10+	4	1.3
Main livelihood: Crop farming	270	88.8
Main livelihood: Livestock	22	7.2
Main livelihood: Business	12	3.9
Years in CBWMP: 1–3	113	37.2
Years in CBWMP: 4–6	113	37.2
Years in CBWMP: above 6	78	25.7

Source: Primary data, 2026

4.2 Implementation of the CBWMP

District and ministry records show steady progress in all project components between 2020 and 2024 (Table 4). Access to irrigation water rose from 45% to 88%, water use efficiency from 40% to 90%, community participation from 50% to 92%, infrastructure development from 42% to 90% and training coverage from 38% to 89%, indicating a transition from an early implementation phase to a mature system.

Table 4: Trends in CBWMP implementation indicators, 2020–2024 (%)

Year	Irrigation access	Water use efficiency	Participation index	Infrastructure index	Training coverage
2020	45	40	50	42	38
2021	55	52	60	55	50
2022	68	65	72	70	68
2023	78	80	85	83	82
2024	88	90	92	90	89

Source: Kirehe District CBWMP Survey Report, 2025; MINAGRI administrative records, 2020–2024

Farmers' perceptions confirm these trends (Table 5). All five components recorded strong mean scores between 4.19 and 4.24, and no respondent disagreed with any implementation statement. The highest-rated items were that capacity-building programmes help farmers adopt new technologies (mean = 4.41), that efficient water use has improved crop productivity (4.37) and that farmers are involved in irrigation decisions (4.33). The lowest, though still strong, were participation in water management meetings (3.96) and reliable access to water throughout all seasons (4.07), where 14.8% of respondents were not sure in each case.

Table 5: Farmers' perceptions of CBWMP implementation (n = 304)

Component	Not sure (%)	Agree (%)	Strongly agree (%)	Mean	SD
Access to irrigation water	5.9	68.2	25.9	4.20	.518
Water use efficiency	2.2	71.2	26.6	4.24	.467
Community participation	5.9	68.8	25.1	4.19	.508
Infrastructure development	2.2	72.6	25.2	4.23	.466
Training and capacity building	3.6	68.9	27.4	4.24	.491

Source: Primary data, 2026. Values are averages of the five items in each construct; no respondent selected 'disagree' or 'strongly disagree'.

Qualitative evidence supports these results. Farmers explained that canals and reservoirs have reduced dependence on rainfall and made water availability more predictable, although some still face shortages during peak dry periods. Participants reported that training helped them to "use less water but produce more crops", while noting that advanced technologies such as drip irrigation remain costly and that training is sometimes too general for specific crops. Decision-making was described as more inclusive than before the project, although meeting attendance is irregular during busy farming periods.

These findings are consistent with evidence that user-based water management can improve water use without sacrificing output (Wang et al., 2005) and that local institutions such as irrigation committees and community maintenance improve the performance of smallholder schemes (Mwadzingeni et al., 2020). Unlike the Peruvian case, where infrastructure investment was not matched by attention to equity (Fernandez et al., 2018), farmers in Kirehe rated both infrastructure and the fairness of water distribution highly (mean = 4.14), suggesting that the project combines physical investment with participatory governance, as CBRM theory would predict.

4.3 Socio-economic status of participating farmers

Secondary data show marked livelihood gains over the project period (Table 6). Average crop yield rose from 2.1 to 4.4 tonnes per hectare, average household income from RWF 420,000 to RWF 910,000 per year, and the food security, livelihood diversification and health and nutrition indices rose to 90%, 88% and 90% respectively by 2024.

Table 6: Trends in socio-economic livelihood indicators, 2020–2024

Year	Crop yield (t/ha)	Household income (RWF/year)	Food security index (%)	Diversification index (%)	Health & nutrition index (%)
2020	2.1	420,000	62	45	50
2021	2.6	510,000	68	55	58
2022	3.1	620,000	75	65	68
2023	3.8	760,000	83	78	82
2024	4.4	910,000	90	88	90

Source: Kirehe District CBWMP Survey Report, 2025; MINAGRI administrative records, 2020–2024

Survey results corroborate these trends (Table 7). All six livelihood dimensions recorded strong mean scores above 4.20. Every respondent agreed or strongly agreed that their crop yield had increased since the project started (mean = 4.30) and that irrigation has reduced hunger periods in their household (4.26). All respondents reported higher household income from improved farming (4.15), and the highest-rated statements were that overall livelihood had improved due to the CBWMP (4.45) and that the project contributes to better hygiene and sanitation (4.41). Relatively lower agreement was recorded on whether access to project resources is equitable among farmers (4.11), where 10.9% were not sure.

Table 7: Farmers' perceptions of socio-economic outcomes (n = 304)

Outcome	Not sure (%)	Agree (%)	Strongly agree (%)	Mean	SD
Crop yield/production	2.7	70.3	27.0	4.24	.485
Household income	2.7	74.1	23.2	4.21	.457
Food security	4.5	67.7	27.8	4.23	.515
Livelihood diversification	1.8	74.1	24.1	4.22	.443
Health and nutrition	2.7	72.3	25.0	4.22	.453
Overall socio-economic livelihood	2.7	64.9	32.4	4.30	.496

Source: Primary data, 2026. Values are averages of the four items in each construct.

Focus group participants described being able to cultivate in multiple seasons, sell surplus produce, start small livestock and vegetable businesses and afford better food and health care. As one group summarised, the project has "transformed farming into a stable livelihood rather than a survival activity". These results mirror findings that irrigation improves food security and income in Zimbabwe (Mhembwe et al., 2019; Mupaso et al., 2024) and Uganda (Atuhairwe et al., 2020), as well as the production gains documented for the Kirehe project (IFAD, 2019), and they are consistent with the SLF proposition that strengthened physical, human and social capital translate into broader welfare gains (Natarajan et al., 2022).

4.4 Relationship between the CBWMP and farmers' socio-economic outcomes

Pearson correlation results (Table 8) show strong, positive and statistically significant relationships ($p < .01$) between every CBWMP component and every livelihood outcome, with coefficients ranging from .923 to .990. Infrastructure development was most strongly associated with crop yield ($r = .990$) and livelihood diversification ($r = .972$), while community participation was most strongly associated with food security ($r = .980$). At the aggregate level, CBWMP implementation was strongly correlated with overall socio-economic livelihood ($r = .959$, $p < .001$).

Table 8: Pearson correlations between CBWMP components and livelihood outcomes (n = 304)

CBWMP component	Crop yield	Household income	Food security	Diversification	Health & nutrition
Access to irrigation water	.958**	.954**	.969**	.927**	.952**
Water use efficiency	.970**	.958**	.971**	.954**	.964**
Community participation	.955**	.934**	.980**	.923**	.961**
Infrastructure development	.990**	.959**	.939**	.972**	.939**
Training and capacity building	.952**	.957**	.968**	.939**	.951**

*Source: Primary data, 2026. ** Correlation is significant at the .01 level (2-tailed).*

The multiple regression model (Table 9) was statistically significant, $F(5, 298) = 1104.48$, $p < .001$. The five CBWMP components jointly explained 94.9% of the variance in socio-economic livelihood ($R^2 = .949$; adjusted $R^2 = .948$). All five components were positive and significant predictors. Based on standardised coefficients, community participation had the strongest effect ($\beta = .744$, $p < .001$), followed by access to irrigation water ($\beta = .616$, $p < .001$), water use efficiency ($\beta = .507$, $p < .001$) and infrastructure development ($\beta = .493$, $p < .001$), while training and capacity building had a smaller but significant effect ($\beta = .154$, $p = .028$).

Table 9: Multiple regression of socio-economic livelihood on CBWMP components

Predictor	B	Std. error	Beta (β)	t	Sig.
(Constant)	.647	.077	–	8.407	.000
Access to irrigation water	.647	.106	.616	6.136	.000
Water use efficiency	.597	.144	.507	4.150	.000
Community participation	.800	.092	.744	8.739	.000
Infrastructure development	.585	.077	.493	7.551	.000
Training and capacity building	.165	.075	.154	2.208	.028

Model summary: $R = .974$, $R^2 = .949$, adjusted $R^2 = .948$, SE = .0992. ANOVA: regression SS = 54.337 (df = 5, MS = 10.867), residual SS = 2.932 (df = 298, MS = .010), $F = 1104.484$, $p < .001$. Dependent variable: socio-economic livelihood. Source: Primary data, 2026.

These results support all three theories. The strong role of community participation reflects CBRM's emphasis on collective choice and local ownership, and is consistent with evidence that farmer involvement improves equity, efficiency and sustainability in irrigation schemes (Mwadzingeni et al., 2020). The effects of irrigation access, efficiency and infrastructure align with IWRM's emphasis on coordinated, efficient allocation (Katusiime & Schütt, 2020), and the breadth of outcomes affected supports the SLF view that livelihood improvement depends on several forms of capital at once. The smaller effect of training suggests that its contribution operates partly through the other components, consistent with evidence that extension support works alongside irrigation access rather than replacing it (Mwadzingeni et al., 2020; Benjamin et al., 2025). Interview and focus group participants reinforced this integrated interpretation, observing that "all components of the project work together, not separately".

4.5 Limitations

The findings rest largely on self-reported perceptions from project participants, which may be subject to social desirability and positive response bias; this is reflected in the absence of any disagreement responses and in the very high correlation coefficients. The cross-sectional survey design and the lack of a non-participant comparison group mean that the associations reported should not be interpreted as definitive causal effects. The five project components are also highly inter-related, which may inflate the explained variance and limit the precision of individual regression coefficients. Future studies should use comparison groups, panel data and objective measures of yield and income.

5. Conclusion and Recommendations

This study concludes that the Community-Based Water Management Project has been effectively implemented in Kirehe District and is strongly associated with improved livelihoods among participating smallholder farmers. Access to irrigation water, efficient water use, community participation, infrastructure development and training were all rated highly, and farmers reported substantial gains in crop yield, household income, food security, livelihood diversification and health and nutrition. The strong statistical relationship between project components and livelihood outcomes, supported by qualitative evidence, indicates that integrated, community-led water management is an effective pathway for rural socio-economic transformation in drought-prone areas.

Four recommendations follow. First, government and development partners should strengthen policy support, coordination and monitoring of community-based water management initiatives and scale the model to other drought-prone districts. Second, irrigation infrastructure should be expanded, modernised and regularly maintained, with attention to affordable water-saving technologies for poorer farmers. Third, training and extension services should become more practical, continuous and tailored to specific crops and local conditions. Fourth, stakeholders should deepen inclusive participation, particularly women's representation in water user committees, to sustain ownership, transparency and equitable access. Future research should adopt longitudinal and quasi-experimental designs and examine gender and climate dimensions of community-based water management.

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Conflict of Interest

The authors declare no conflict of interest.

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