Journal of Agriculture &
Environmental Sciences

Impact of Irrigation Schemes on Smallholders' Agricultural Productivity in Rwanda: A Case Study of Urwonjya and Rwoganyoni Marshlands in Nyaruguru District

Désiré Kwizera & Assoc. Prof Isaac Olajide AREO

ISSN: 2616-8465

Stratford Peer Reviewed Journals and Book Publishing
Journal of Agriculture & Environmental Sciences
Volume 10||Issue 2||Page 62-86 ||July||2026|
Email: info@stratfordjournals.org ISSN: 2616-8465

Impact of Irrigation Schemes on Smallholders' Agricultural Productivity in Rwanda: A Case Study of Urwonjya and Rwoganyoni Marshlands in Nyaruguru District

Désiré Kwizera[1], Assoc. Prof Isaac Olajide AREO[1] (PhD)

[1]*Faculty of Environmental Studies, University of Lay Adventists of Kigali, Kigali, Rwanda*

***How to cite this article*: Kwizera D., & AREO I., O. (2026). Impact of Irrigation Schemes on Smallholders' Agricultural Productivity in Rwanda: A Case Study of Urwonjya and Rwoganyoni Marshlands in Nyaruguru District. *Journal of Agriculture & Environmental Sciences Vol* 10(2) pp. 62-86. https://doi.org/10.53819/81018102t2582**

Abstract

This study assessed the impact of irrigation schemes on smallholder agricultural productivity in Urwonjya and Rwoganyoni marshlands in Nyaruguru District, Rwanda. The study examined the status of irrigation schemes, agricultural productivity levels, and the relationship between irrigation and productivity outcomes. A mixed-methods approach was adopted, involving 334 smallholder farmers surveyed through structured questionnaires and 8 key informants selected purposively. Quantitative data were analyzed using descriptive statistics, Pearson correlation, and multiple linear regression, while qualitative data were analyzed thematically. Findings revealed that irrigation schemes are well established, with strong access to infrastructure (M = 4.34) and reliable water supply (M = 4.36), despite occasional shortages. Canal and pump-based irrigation systems dominate, while modern irrigation technology adoption remains low (M = 1.52). Agricultural productivity indicators were rated highly, including crop yield (M = 4.40), cropping intensity (M = 4.45), farm income (M = 4.37), and food security (M = 4.37). Correlation and regression results showed strong positive relationships between irrigation and productivity outcomes (r = 0.74–0.86; R^2 = 0.74–0.79), confirming significant effects on productivity.

Keywords: *Irrigation development, Marshland rehabilitation, Smallholder agriculture, Environmental sustainability, Sustainable land management, Water management*.

1. Introduction

Wetlands are among the world's most productive ecosystems, providing essential ecological and socio-economic services such as water regulation, biodiversity conservation, carbon sequestration, and agricultural support (Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services, 2019; Davidson, 2014). Despite their importance, wetlands are increasingly threatened, with over 35% lost since 1970 and more than 85% historically degraded due to agricultural expansion, drainage, urbanization, and infrastructure development (Davidson, 2014).

Agricultural intensification, particularly irrigation development, remains a major driver of wetland transformation. Irrigation accounts for nearly 70% of global freshwater withdrawals and contributes more than 50% of crop production while covering less than 20% of cultivated land (Food and Agriculture Organization, 2017). Although irrigation improves productivity and food security, poorly managed systems contribute to soil degradation, water pollution, sedimentation, and ecosystem disruption.

In Africa, wetlands play a vital role in sustaining rural livelihoods, particularly in areas affected by unreliable rainfall (McCartney et al., 2010). However, over 50% of African wetlands are degraded or under threat due to population growth, land-use change, and agricultural intensification (Rebelo et al., 2010). In East Africa, irrigation expansion has strengthened climate resilience and agricultural production but has also accelerated wetland degradation, affecting water quality and biodiversity (Palmer et al., 2023).

Rwanda presents a critical case due to its high population density and strong dependence on agriculture, with over 70% of the population relying on farming (Ministry of Agriculture and Animal Resources, 2022). To improve food security and agricultural productivity, Rwanda has promoted marshland irrigation through initiatives such as the Crop Intensification Program and the National Strategy for Transformation (World Bank, 2021). However, unsustainable irrigation practices, weak infrastructure maintenance, and poor watershed management have led to soil erosion, sedimentation, waterlogging, and declining soil fertility (Bizimana & Hategekimana, 2024).

In Nyaruguru District, irrigation has improved year-round farming and crop yields for smallholder farmers. However, poor irrigation planning and limited integration with marshland conservation continue to degrade ecosystems (Rwanda Water Resources Board, 2023). This study therefore examines irrigation as a support mechanism for marshland rehabilitation, aiming to identify sustainable strategies that balance agricultural productivity with environmental conservation.

1.2 Objectives of the Research

1.2.1 General objective

The general objective of the study is to examine the impact of irrigation schemes on smallholder agricultural productivity in Urwonjya and Rwoganyoni marshlands in Nyaruguru District, Rwanda.

1.2.2. Specific objectives

(i) To assess assess the irrigation schemes among smallholder farmers in marshlands in Nyaruguru District.

(ii) To evaluate the level of agricultural productivity among smallholder farmers in Marshlands in Nyaruguru District.

(iii) To analyze the relationship between irrigation schemes and smallholder agricultural productivity in marshlands in Nyaruguru District.

2. Research methods

2.1 Description of the study area

Nyaruguru District is located in the Southern Province of Rwanda, bordering Burundi to the south, between 2°25′–2°50′ South latitude and 29°25′–29°45′ East longitude (NISR, 2023). The district covers approximately 1,012 km² and is administratively divided into 14 sectors. It has a population of 318,126, with over 97% living in rural areas, a population density of about 314 inhabitants per km², and an average household size of 4.3 people (NISR, 2022).

The district is characterized by mountainous terrain, rolling hills, steep slopes, valleys, and marshlands, including sections of Nyungwe National Park. Nyaruguru experiences a tropical highland climate with bimodal rainfall ranging from 1,000–1,250 mm annually and temperatures between 12°C and 25°C, averaging around 19°C. The climate follows four seasons: major rainy, minor rainy, major dry, and minor dry seasons.

Agriculture is the main economic activity, employing approximately 80–98% of the population through smallholder farming. Major crops include Irish potatoes, maize, wheat, sweet potatoes, climbing beans, tea, coffee, and rice cultivated in marshlands. Marshlands are particularly important for irrigation-supported agriculture, although challenges such as soil acidity (pH 5–5.5), erosion risks, and climate variability affect productivity (Rugambwa, 2021). Nyaruguru is suitable for this study due to its marshland potential, rehabilitation efforts, and growing adoption of small-scale irrigation technologies.

Stratford Peer Reviewed Journals and Book Publishing
Journal of Agriculture & Environmental Sciences
Volume 10||Issue 2||Page 62-86 ||July||2026|
Email: info@stratfordjournals.org ISSN: 2616-8465

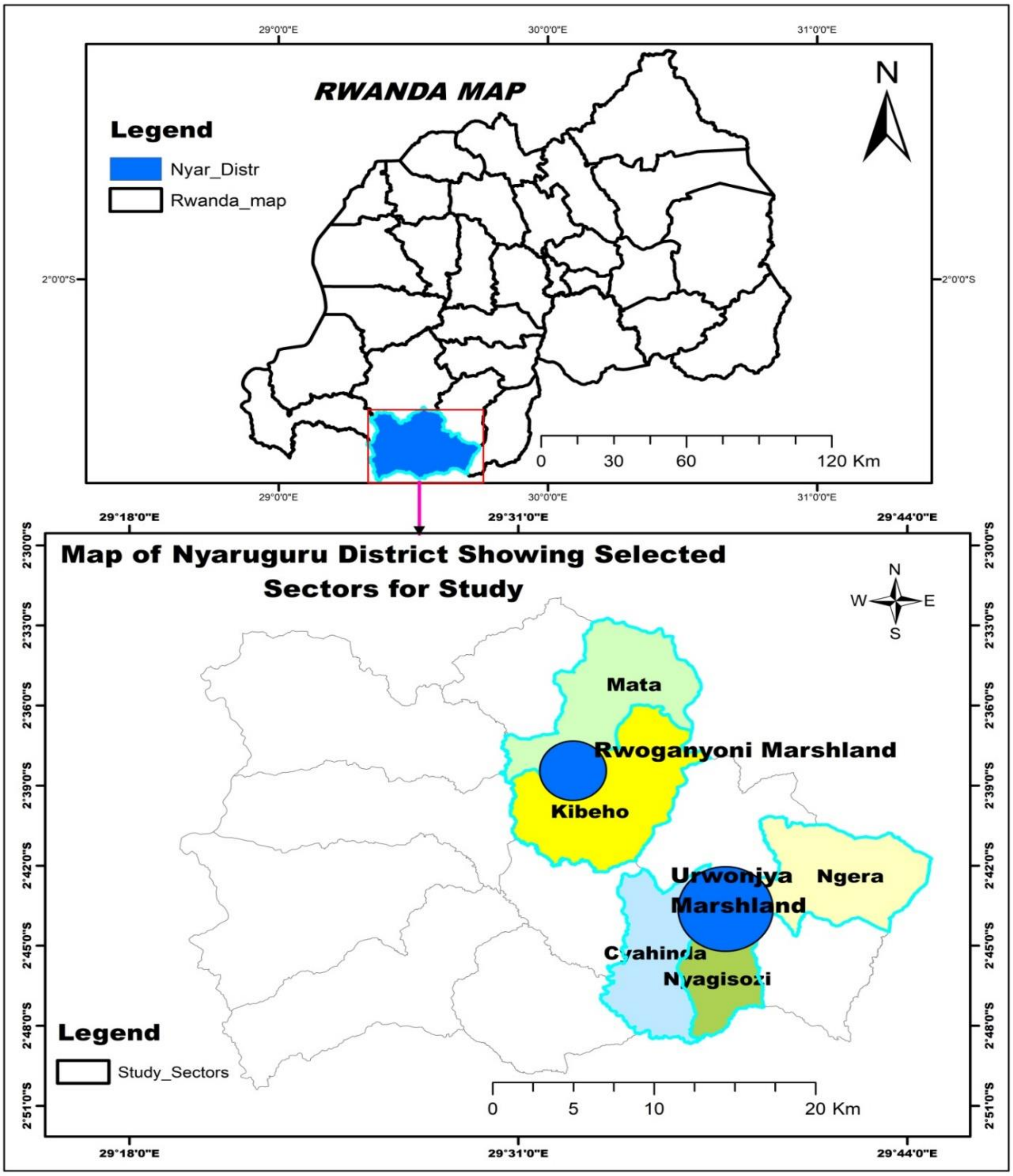

Figure 3.1.Maps showing the Study Location

Source: Researcher's Computation, 2026

2.2. Research design and data collection methods

This study adopted a mixed-methods research design to examine the impact of irrigation schemes on smallholder agricultural productivity in Urwonjya and Rwoganyoni marshlands. The design was appropriate as it combined quantitative measurement of agricultural productivity with qualitative insights into irrigation management, environmental conditions, and implementation challenges.

The quantitative component used structured household questionnaires administered to smallholder farmers engaged in irrigation farming. Data collected included irrigation access, water reliability, infrastructure quality, management practices, and agricultural productivity indicators such as crop yield, cropping intensity, farm income, crop diversification, and food security. Data were analyzed using SPSS, applying descriptive statistics (frequencies, percentages, means, and standard deviations) and inferential statistics, including Pearson correlation and multiple linear regression, to determine relationships between irrigation schemes and productivity outcomes.

The qualitative component complemented the quantitative findings by providing in-depth understanding of irrigation governance, institutional arrangements, and environmental sustainability. Key informant interviews were conducted with district agronomists, irrigation officers, environmental officials, and cooperative leaders selected purposively based on their expertise. Field observations were also carried out to assess irrigation infrastructure, water distribution systems, and farming practices. Qualitative data were analyzed thematically through transcription, coding, and interpretation of emerging themes.

Secondary data were obtained from district reports, irrigation project documents, and national publications from institutions such as Ministry of Agriculture and Animal Resources, Rwanda Agriculture and Animal Resources Development Board, and National Institute of Statistics of Rwanda. These provided contextual and historical information on irrigation development and agricultural productivity in Rwanda.

A total sample of 334 smallholder farmers was determined using Taro Yamane's formula, with additional 10 key informants, bringing the total respondents to 344. Stratified, cluster, and systematic random sampling were used for farmers, while purposive sampling was applied for key informants. Triangulation of quantitative and qualitative data enhanced validity and reliability of the findings, while ethical considerations such as informed consent and confidentiality were strictly observed.

2.3 Data analysis and processing

This study employed a mixed-methods approach to examine the impact of irrigation schemes on smallholder agricultural productivity in Urwonjya and Rwoganyoni marshlands in Nyaruguru District. Data were collected using multiple techniques to ensure triangulation and comprehensive analysis.

Primary quantitative data were gathered through structured household questionnaires administered to smallholder farmers. The survey captured information on irrigation adoption, water availability, irrigation systems, management practices, and agricultural productivity indicators such as crop yield, cropping intensity, farm income, crop diversification, and food security. Semi-structured key informant interviews were conducted with district agronomists, irrigation officers, environmental officials, and cooperative leaders to obtain qualitative insights into irrigation governance, institutional coordination, and environmental sustainability.

Field observations were also carried out to assess irrigation infrastructure, water distribution systems, and farming practices. In addition, secondary data were reviewed from reports of Ministry of Agriculture and Animal Resources, Rwanda Agriculture and Animal Resources Development Board, and National Institute of Statistics of Rwanda, alongside academic literature and district records.

Data analysis involved SPSS for quantitative data, using descriptive statistics (means, frequencies, standard deviations) and inferential tests such as Pearson correlation and multiple regression to examine relationships between irrigation schemes and productivity

Stratford Peer Reviewed Journals and Book Publishing
Journal of Agriculture & Environmental Sciences
Volume 10||Issue 2||Page 62-86 ||July||2026|
Email: info@stratfordjournals.org ISSN: 2616-8465

outcomes. Qualitative data were analyzed thematically through transcription, coding, and categorization of emerging themes. Editing ensured data accuracy, coding facilitated classification of responses, and findings were presented using tables, graphs, and narrative descriptions.

The study ensured reliability through pilot testing of instruments and standardized procedures, while validity was strengthened through triangulation of multiple data sources and alignment of tools with research objectives. Ethical considerations included informed consent, confidentiality, voluntary participation, and secure data handling.

The sample comprised 334 farmers selected through stratified, cluster, and systematic sampling, plus 10 key informants, giving a total of 344 respondents. Limitations included geographic scope, reliance on self-reported data, difficulty isolating irrigation effects from other factors, and time constraints. These were mitigated through triangulation, use of control variables, and supplementary secondary data.

3. Results

3.1 Irrigation Schemes among Smallholder Farmers

This section presents the descriptive results on irrigation schemes among smallholder farmers in the study area. It focuses on key components such as access to irrigation infrastructure, water reliability, types of irrigation systems, management practices, cooperative participation, and training support. The analysis provides insight into how these factors influence the effectiveness and functioning of irrigation systems

3.1.1 Access to Irrigation Infrastructure

Table 3.1. Access to Irrigation Infrastructure (n = 334)

Statement	Mean	Mean Interpretation	Std. Dev (σ)	Std. Dev Interpretation
Irrigation facilities are available in my farming area	4.37	Strong	0.87	Moderate variability
The irrigation infrastructure is adequate for my farming needs	4.31	Strong	0.89	Moderate variability
The distance to irrigation water sources is reasonable	4.31	Strong	0.88	Moderate variability
Water is fairly distributed among farmers	4.35	Strong	0.86	Moderate variability
Overall Mean	4.34	Strong		

Source: Field Data (2026)

The results indicate a strong level of access to irrigation infrastructure in the study area (Overall Mean = 4.34), showing that most farmers perceive irrigation facilities as available, accessible, and supportive of agricultural activities. High mean scores for availability of irrigation facilities (M = 4.37) suggest that canals, water points, and distribution systems are well established, reflecting successful irrigation development in the marshlands. Fair water distribution (M = 4.35) indicates structured allocation mechanisms that help reduce conflict among users. Adequacy of infrastructure (M = 4.31) and reasonable distance to water sources (M = 4.31) further confirm functional accessibility that minimizes labor and time constraints for farmers.

These findings align with Nabahungu and Visser (2013), who showed that improved irrigation infrastructure in Rwandan marshlands enhances water access and agricultural productivity. Similarly, Burney et al. (2013) emphasize that small-scale irrigation systems in Sub-Saharan Africa increase yields, support crop diversification, and improve resilience, though spatial and institutional inequalities may persist, consistent with observed variability (σ = 0.86–0.89).

Evidence also suggests that irrigation infrastructure improves soil moisture retention, reduces dependence on rainfall, and helps mitigate land degradation. Studies on small-scale irrigation technologies (SSITs) in Rwanda and programs such as SAIP further confirm that improved irrigation access enhances productivity, food security, and climate resilience.

However, minor inequalities remain, often linked to farm location, maintenance quality, and socio-economic differences between users. Upstream and downstream disparities were noted as key concerns affecting equitable access. Therefore, while irrigation infrastructure is generally effective and widely accessible, targeted improvements in equity, maintenance, and expansion of small-scale systems are needed to maximize inclusive agricultural benefits and strengthen long-term sustainability.

3.1.2 Reliability of Water Supply

Table 3.2. Reliability of Water Supply

Statement	Mean	Mean Interpretation	Std. Dev (σ)	Std. Dev Interpretation
Water is available throughout the farming season	4.35	Strong	0.88	Moderate variability
Water supply is consistent and dependable	4.30	Strong	0.90	Moderate variability
I experience frequent water shortages	4.30	Strong	0.92	Moderate variability
Irrigation enables farming during dry periods	4.47	Very High	0.80	Moderate variability
Overall Mean	4.36	Strong		

Source: Field Data (2026)

Water reliability in the study area is generally high, with an overall mean of 4.36, indicating that irrigation systems provide a stable and dependable water supply for agricultural activities. Farmers strongly agreed that water is available throughout the farming season (M = 4.35), reflecting reduced dependence on rainfall and improved production stability. Consistent water delivery (M = 4.30) further confirms effective system performance under

Stratford Peer Reviewed Journals and Book Publishing
Journal of Agriculture & Environmental Sciences
Volume 10||Issue 2||Page 62-86 ||July||2026|
Email: info@stratfordjournals.org ISSN: 2616-8465

normal conditions. However, the same level of agreement on water shortages (M = 4.30) highlights occasional disruptions, likely caused by seasonal variability, infrastructure inefficiencies, or competition during peak demand periods.

Despite these challenges, irrigation plays a transformative role in enabling dry-season farming (M = 4.47), extending the agricultural calendar and reducing climate-related risks. These findings align with Hanjra et al. (2009) and FAO (2017), who emphasize irrigation's role in improving productivity, stabilizing yields, and reducing climate vulnerability. Moderate variability (σ = 0.80–0.92) suggests uneven water distribution across locations, consistent with Mutambara et al. (2016). Overall, irrigation enhances resilience and productivity, though minor reliability gaps remain.

3.1.3 Type of Irrigation System

Table 3.1. Type of Irrigation System (n = 334)

Statement	Mean	Mean Interpretation	Std. Dev (σ)	Std. Dev Interpretation
The irrigation system used in my area is effective for farming activities	4.39	Strong	0.85	Moderate variability
Canal-based irrigation is commonly used in my area	4.33	Strong	0.88	Moderate variability
Pump-based (engine and pipe) irrigation systems improve water access	4.41	Strong	0.82	Moderate variability
Modern irrigation systems are available and used in my area	1.52	Very Low	0.61	Low variability
Irrigation systems (canal and pump) enhance productivity	4.46	Very High	0.79	Moderate variability
Overall Mean	3.82	Tend to Strong		

Source: Field Data (2026)

The results show that irrigation systems are generally effective, with an overall mean of 3.82, though they are not fully optimal. System effectiveness is rated high (M = 4.39), confirming that current irrigation methods support agricultural activities in the study area. Canal-based irrigation (M = 4.33) is the most common system, reflecting reliance on gravity-fed water distribution, while pump-based systems (M = 4.41) complement water access where canals are insufficient. Productivity enhancement is very high (M = 4.46), indicating that even traditional systems significantly improve agricultural outcomes.

However, adoption of modern irrigation technologies is extremely low (M = 1.52), revealing a major technological gap. This aligns with Namara et al. (2014) and Xie et al. (2014), who note that smallholder farmers in Sub-Saharan Africa rely heavily on traditional

https://doi.org/10.53819/81018102t2582

systems due to cost and limited technical capacity. The low variability (σ = 0.61) shows strong agreement among farmers on the absence of modern systems.

Traditional irrigation methods also present environmental inefficiencies such as water loss through seepage and evaporation, while pump systems may increase energy use. Limited use of modern technologies restricts water efficiency and sustainability. According to the Rwanda Irrigation Master Plan (MINAGRI, 2010) and Malesu et al. (2010), high costs and limited skills hinder adoption of drip and sprinkler systems. Overall, irrigation remains productive but requires modernization to improve efficiency and sustainability.

3.1.4 Management Practices

Table 3.2.Management Practices (n = 334)

Statement	Mean	Mean Interpretation	Std. Dev (σ)	Std. Dev Interpretation
There is a clear schedule for water distribution	4.34	Strong	0.86	Moderate variability
Irrigation infrastructure is regularly maintained	4.28	Strong	0.91	Moderate variability
Water is used efficiently in farming activities	4.38	Strong	0.84	Moderate variability
Conflicts over water use are well managed	4.33	Strong	0.87	Moderate variability
Overall Mean	4.33	Strong		

Source: Field Data (2026)

Table 3.5 shows a strong level of irrigation management in the study area, with an overall mean of 4.33, indicating that institutional and operational systems are generally effective. Clear water distribution schedules (M = 4.34) reflect well-organized allocation mechanisms that promote equitable use of water resources. Efficient water use (M = 4.38) suggests that farmers are aware of proper water management practices and apply them responsibly. Effective conflict management (M = 4.33) further demonstrates strong governance structures that help reduce disputes among water users. However, slightly lower ratings for infrastructure maintenance (M = 4.28) point to some weaknesses in long-term system sustainability.

These findings align with Meinzen-Dick (2007), who emphasizes that farmer-managed irrigation systems perform better when users actively participate in rule enforcement and maintenance. Moderate variability indicates differences in management effectiveness across schemes. Strong irrigation governance also contributes to environmental sustainability by reducing water wastage and preventing resource overuse.

Institutionally, irrigation management is supported by Ministry of Agriculture and Animal Resources, Rwanda Agriculture and Animal Resources Development Board, and local structures such as Irrigation Water Users Organizations and cooperatives. These

Stratford Peer Reviewed Journals and Book Publishing
Journal of Agriculture & Environmental Sciences
Volume 10||Issue 2||Page 62-86 ||July||2026|
Email: info@stratfordjournals.org ISSN: 2616-8465

institutions ensure water allocation, maintenance, and conflict resolution. Overall, effective management enhances irrigation sustainability, though maintenance improvements are still needed.

3.1.5 Cooperative Participation

Table 3.3.Cooperative Participation (n = 334)

Statement	Mean	Mean Interpretation	Std. Dev (σ)	Std. Dev Interpretation
I am a member of an irrigation cooperative	4.41	Very High	0.82	Moderate variability
I actively participate in irrigation-related meetings	4.34	Strong	0.86	Moderate variability
Farmers contribute to maintenance of irrigation systems	4.33	Strong	0.85	Moderate variability
Cooperative rules improve irrigation management	4.37	Strong	0.83	Moderate variability
Overall Mean	4.36	Strong		

Source: Field Data (2026)

The results in Table 3.6 indicate strong cooperative participation (Overall Mean = 4.36)**,** with very high membership levels (M = 4.41). Active participation in meetings and maintenance contributions demonstrates strong collective engagement. This indicates that irrigation management is not only institutional but also participatory.

These findings align with Bernard et al. (2008)**,** who found that cooperatives improve productivity through collective action and shared knowledge. Similarly, Verhofstadt and Maertens (2015) show that cooperative participation enhances access to resources, markets, and information, Moderate variability suggests differences in engagement levels.

The high level of cooperative participation reported by respondents is also consistent with Rwanda's participatory irrigation management approach. Under Ministerial Order No. 001/11.30 of 23/11/2011, all irrigation schemes are required to establish Water Users Associations responsible for the operation and maintenance of irrigation infrastructure. Farmers are expected to contribute to irrigation management through water service fees, maintenance charges, membership contributions, and participation in communal maintenance activities (MINAGRI, 2012). Water Users Associations are responsible for collecting user fees and ensuring the sustainability of irrigation facilities, while cooperatives focus on agricultural production and marketing activities. The strong ratings for membership in irrigation cooperatives (M = 4.41) and farmer contributions to maintenance (M = 4.33) indicate a high level of farmer ownership and commitment to sustaining irrigation infrastructure. However, previous studies have reported that some farmers face difficulties in meeting maintenance and irrigation service costs, particularly where agricultural incomes are low. These findings suggest that cooperative participation

Stratford Peer Reviewed Journals and Book Publishing
Journal of Agriculture & Environmental Sciences
Volume 10||Issue 2||Page 62-86 ||July||2026|
Email: info@stratfordjournals.org ISSN: 2616-8465

remains an important mechanism for enhancing sustainability, collective action, and effective irrigation management (MINAGRI, 2012).

3.1.6 Training and Technical Support

Table 3.4.Training and Technical Support

Statement	Mean	Mean Interpretation	Std. Dev (σ)	Std. Dev Interpretation
I have received training on irrigation practices	4.32	Strong	0.88	Moderate variability
Extension officers provide technical support	4.27	Strong	0.91	Moderate variability
I have adequate knowledge of irrigation techniques	4.33	Strong	0.86	Moderate variability
Training improves my use of irrigation systems	4.38	Strong	0.84	Moderate variability
Overall Mean	4.33	Strong		

Source: Field Data (2026)

The results in Table 3.7 indicate that training and technical support for smallholder farmers are strong, with an overall mean of 4.33, showing that respondents generally agree capacity-building and extension services positively support irrigation practices. At the item level, training improves use of irrigation systems (M = 4.38) recorded the highest mean, followed by adequate knowledge of irrigation techniques (M = 4.33) and receipt of irrigation training (M = 4.32), all within the strong range. Extension officers providing technical support recorded the lowest mean (M = 4.27), suggesting some variation in the intensity or frequency of support. Standard deviation values ranging from 0.84 to 0.91 indicate moderate variability in responses.

These findings show that training enhances farmers' ability to effectively operate irrigation systems, improving productivity and sustainability. They are consistent with Davis et al. (2012) and Anderson and Feder (2007), who emphasize that extension services and training significantly improve technology adoption and agricultural performance among farmers.

3.2 Agricultural Productivity among Smallholder Farmers

This section presents the descriptive results on agricultural productivity among smallholder farmers in the study area. It focuses on key indicators such as crop yield, cropping intensity, farm income, crop diversification, and food security. The analysis highlights the extent to which irrigation schemes contribute to improving overall agricultural performance and household livelihoods.

3.2.1 Crop Yield

Table 3.5.Crop Yield (n = 334)

Statement	Mean	Mean Interpretation	Std. Dev (σ)	Std. Dev Interpretation
My crop yield has increased due to irrigation	4.45	Very High	0.80	Moderate variability
I harvest more produce per hectare	4.39	Strong	0.85	Moderate variability
Crop losses have reduced	4.31	Strong	0.90	Moderate variability
Productivity is higher than rain-fed farming	4.44	Very High	0.81	Moderate variability
Overall Mean	4.40	Strong		

Source: Field Data (2026)

The results in Table 3.8 show that crop yield among smallholder farmers is strong, with an overall mean of 4.40, indicating that respondents generally agree irrigation has significantly improved agricultural output. At the item level, respondents strongly agreed that crop yield has increased due to irrigation (M = 4.45) and that productivity is higher compared to rain-fed farming (M = 4.44), both reflecting very high impacts. They also agreed that they harvest more produce per hectare (M = 4.39) and that crop losses have reduced (M = 4.31), showing improved efficiency and reduced production risks. Standard deviation values ranging from 0.80 to 0.90 indicate moderate variability in responses, suggesting generally consistent but slightly differing experiences due to farm conditions and management practices.

These findings confirm that irrigation enhances crop yield by ensuring a stable water supply, reducing crop stress, and minimizing rainfall-related risks, thereby improving both productivity and yield reliability. The results align with Lipton et al. (2003) and Hussain and Hanjra (2004), who highlight irrigation as a key driver of agricultural productivity and risk reduction. In Rwanda, MINAGRI (2018) and RAB (2021) report that irrigated marshlands achieve significantly higher yields than rain-fed systems, with rice production increasing from 2–3 tons/ha to 5–7 tons/ha under irrigation. Additionally, higher yields improve land-use efficiency, though intensified production may increase fertilizer and pesticide use, requiring sustainable management practices to avoid environmental degradation.

Stratford Peer Reviewed Journals and Book Publishing
Journal of Agriculture & Environmental Sciences
Volume 10||Issue 2||Page 62-86 ||July||2026|
Email: info@stratfordjournals.org ISSN: 2616-8465

3.2.2 Cropping Intensity

Table 3.6.Cropping Intensity (n = 334)

Statement	Mean	Mean Interpretation	Std. Dev (σ)	Std. Dev Interpretation
I grow crops more than once a year	4.46	Very Strong	0.80	Moderate variability
I farm during dry seasons	4.50	Very Strong	0.77	Moderate variability
My land is used continuously for farming	4.38	Strong	0.85	Moderate variability
Irrigation increases land utilization	4.45	Very Strong	0.81	Moderate variability
Overall Mean	4.45	Very **Strong**		

Source: Field Data (2026)

The results in Table 3.9 indicate that cropping intensity among smallholder farmers is very high, with an overall mean of 4.45, demonstrating strong agreement that irrigation has significantly increased the frequency and continuity of agricultural production. At the item level, farming during dry seasons recorded the highest mean (M = 4.50), followed by growing crops more than once a year (M = 4.46) and increased land utilization through irrigation (M = 4.45), highlighting irrigation's role in enabling multiple cropping cycles. Continuous land use for farming recorded a strong mean (M = 4.38), indicating consistent land utilization despite slight variations among farmers. Standard deviation values ranging from 0.77 to 0.85 indicate moderate variability in respondents' experiences.

These findings demonstrate that irrigation enables year-round cultivation, increases land productivity, improves resource utilization, and allows farmers to respond more effectively to market demand through diversified cropping calendars. The results are consistent with FAO (2017), which identifies irrigation as a key driver of increased cropping intensity and agricultural intensification. Similarly, MINAGRI (2021) reports that irrigation has supported double and triple cropping systems in Rwanda's marshlands, enhancing production and resilience to rainfall variability. However, sustainable soil fertility and water management are essential to prevent nutrient depletion and land degradation.

Stratford Peer Reviewed Journals and Book Publishing
Journal of Agriculture & Environmental Sciences
Volume 10||Issue 2||Page 62-86 ||July||2026|
Email: info@stratfordjournals.org ISSN: 2616-8465

3.2.3 Farm Income

Table 3.7.Farm Income (n = 334)

Statement	Mean	Mean Interpretation	Std. Dev (σ)	Std. Dev Interpretation
My income from farming has increased	4.42	Very Strong	0.83	Moderate variability
I earn profit from selling crops	4.35	Strong	0.87	Moderate variability
Irrigation improves my economic status	4.43	Very Strong	0.82	Moderate variability
Farming meets my household financial needs	4.26	Very Strong	0.93	Moderate variability
Overall Mean	4.37	Strong		

Source: Field Data (2026)

The results in Table 3.10 indicate that farm income among smallholder farmers is strong, with an overall mean of 4.37, suggesting that respondents generally agree irrigation schemes have improved household income and economic well-being. At the item level, irrigation improving economic status (M = 4.43) and increasing income from farming (M = 4.42) recorded the highest means, demonstrating the substantial economic benefits of irrigation. Respondents also agreed that irrigation enables them to earn profits from selling crops (M = 4.35) and helps farming meet household financial needs (M = 4.26), although the latter was the lowest-rated indicator, indicating that some households still face financial challenges. Standard deviation values ranging from 0.82 to 0.93 indicate moderate variability, reflecting differences in income outcomes due to factors such as farm size, productivity, and market access.

These findings suggest that irrigation enhances farm income by increasing agricultural productivity, enabling multiple cropping seasons, reducing production risks, and supporting the cultivation of high-value crops. The results are consistent with Hussain and Hanjra (2004), who found that irrigation significantly contributes to rural income growth and poverty reduction. Similarly, MINAGRI (2018) identifies irrigation as a key driver of agricultural commercialization and rural income generation in Rwanda, while RAB (2021) and the National Agricultural Export Development Board report that irrigated farming systems generate higher economic returns through improved productivity, market participation, and production of high-value crops. Improved incomes also enable farmers to invest in sustainable practices, including soil conservation, improved seeds, and water-efficient irrigation technologies.

https://doi.org/10.53819/81018102t2582

3.2.4 Crop Diversification

Table 3.8.Crop Diversification (n = 334)

Statement	Mean	Mean Interpretation	Std. Dev (σ)	Std. Dev Interpretation
I grow different types of crops	4.38	Strong	0.85	Moderate variability
I cultivate high-value crops	4.32	Strong	0.88	Moderate variability
Irrigation allows flexibility in crop choice	4.45	Very Strong	0.81	Moderate variability
I have shifted from subsistence to commercial farming	4.25	Very Strong	0.94	Moderate variability
Overall Mean	4.35	Strong		

Source: Field Data (2026)

The results in Table 3.11 show that crop diversification among smallholder farmers is strong, with an overall mean of 4.35, indicating that respondents generally agree irrigation schemes have enhanced diversification practices. At the item level, irrigation allowing flexibility in crop choice recorded the highest mean (M = 4.45), suggesting that reliable water access enables farmers to select crops based on market demand and preferences. Respondents also strongly agreed that they grow different types of crops (M = 4.38) and cultivate high-value crops (M = 4.32), demonstrating that irrigation supports agricultural diversification and productivity.

The shift from subsistence to commercial farming recorded the lowest, but still strong, mean (M = 4.25), indicating gradual progress toward market-oriented agriculture. Standard deviation values ranging from 0.81 to 0.94 indicate moderate variability, reflecting differences in diversification levels due to factors such as market access, resource availability, and farm capacity. These findings are consistent with Birthal et al. (2015), who reported that irrigation promotes crop diversification and the transition from subsistence to commercial farming while improving soil health, biodiversity, and pest management. Similarly, RAB (2021) found that irrigation development in Rwanda has enhanced marshland farming diversification by reducing climate-related production risks and supporting environmentally sustainable farming systems.

Stratford Peer Reviewed Journals and Book Publishing
Journal of Agriculture & Environmental Sciences
Volume 10||Issue 2||Page 62-86 ||July||2026|
Email: info@stratfordjournals.org ISSN: 2616-8465

3.2.5 Food Security Status

Table 3.9.Food Security (n = 334)

Statement	Mean	Mean Interpretation	Std. Dev (σ)	Std. Dev Interpretation
My household has enough food throughout the year	4.36	Strong	0.86	Moderate variability
Irrigation has reduced food shortages	4.42	Very strong	0.82	Moderate variability
My diet has improved due to farming	4.33	Strong	0.88	Moderate variability
Food supply in my household is stable	4.38	Strong	0.85	Moderate variability
Overall Mean	4.37	Strong		

Source: Field Data (2026)

The results in Table 3.12 indicate that food security among smallholder farmers is strong, with an overall mean of 4.37, suggesting that respondents generally agree irrigation schemes have improved household food availability and stability. At the item level, irrigation reducing food shortages recorded the highest mean (M = 4.42), indicating a very high contribution to continuous food availability. Respondents also reported stable household food supplies (M = 4.38), sufficient food throughout the year (M = 4.36), and improved diets through farming (M = 4.33), demonstrating that irrigation enhances both food quantity and dietary diversity. Standard deviations ranging from 0.82 to 0.88 indicate moderate variability, suggesting generally consistent perceptions despite slight differences related to production, income, and market access.

These findings align with evidence from Ethiopia, where a review of 48 studies concluded that small-scale irrigation significantly improves agricultural productivity, dietary diversity, income, resilience, and food security. Propensity score matching studies further showed that irrigation increased daily calorie intake by 590–640 kcal per adult equivalent, alongside higher crop production and revenue. Similar evidence from Zimbabwe found that 97% of irrigators were food secure compared with 45% of non-irrigators, highlighting substantial improvements in household welfare. Globally, irrigation has been linked to increased agricultural output, poverty reduction, and improved food security, particularly among smallholder farmers (Hanjra & Qureshi, 2010). In Rwanda, MINAGRI (2018) identifies irrigation as a strategic intervention for national food security, while NISR (2023) reports greater yield stability in irrigated systems. RAB (2021) further notes that irrigation supports multiple harvests and crop diversification, although sustainable water management remains essential for maintaining long-term food security gains.

https://doi.org/10.53819/81018102t2582

Stratford Peer Reviewed Journals and Book Publishing
Journal of Agriculture & Environmental Sciences
Volume 10||Issue 2||Page 62-86 ||July||2026|
Email: info@stratfordjournals.org ISSN: 2616-8465

3.3 Inferential Results

3.3.1. The relationship between irrigation schemes and smallholder agricultural productivity in marshlands in Nyaruguru District

4.3.1.1 Correlation Analysis

Pearson correlation coefficients were calculated to examine the linear relationships between irrigation scheme components and agricultural productivity outcomes, with significance tested at $p < 0.05$.

Table 3.10.Correlation analysis between irrigation schemes and agricultural productivity

Variables		Irrigation Infrastructure	Water Reliability	Irrigation Technology	Management Practices	Cooperative Participation	Training Support	Crop Yield	Farm Income	Food Security
Irrigation Infrastructure	Pearson Correlation	1.000	.810**	.780**	.800**	.760**	.740**	.790**	.770**	
	Sig. (2-tailed)	—	.000	.000	.000	.000	.000	.000	.000	
	N	334	334	334	334	334	334	334	334	
Water Reliability	Pearson Correlation	.810**	1.000	.820**	.830**	.780**	.760**	.840**	.820**	
	Sig. (2-tailed)	.000	—	.000	.000	.000	.000	.000	.000	
	N	334	334	334	334	334	334	334	334	
Irrigation Technology	Pearson Correlation	.780**	.820**	1.000	.850**	.790**	.810**	.830**	.800**	
	Sig. (2-tailed)	.000	.000	—	.000	.000	.000	.000	.000	
	N	334	334	334	334	334	334	334	334	
Management Practices	Pearson Correlation	.800**	.830**	.850**	1.000	.840**	.820**	.860**	.830**	
	Sig. (2-tailed)	.000	.000	.000	—	.000	.000	.000	.000	
	N	334	334	334	334	334	334	334	334	
Cooperative Participation	Pearson Correlation	.760**	.780**	.790**	.840**	1.000	.850**	.810**	.790**	
	Sig. (2-tailed)	.000	.000	.000	.000	—	.000	.000	.000	
	N	334	334	334	334	334	334	334	334	
Training Support	Pearson Correlation	.740**	.760**	.810**	.820**	.850**	1.000	.800**	.780**	
	Sig. (2-tailed)	.000	.000	.000	.000	.000	—	.000	.000	
	N	334	334	334	334	334	334	334	334	
Crop Yield	Pearson Correlation	.790**	.840**	.830**	.860**	.810**	.800**	1.000	.880**	
	Sig. (2-tailed)	.000	.000	.000	.000	.000	.000	—	.000	
	N	334	334	334	334	334	334	334	334	
Farm Income	Pearson Correlation	.770**	.820**	.800**	.830**	.790**	.780**	.880**	1.000	
	Sig. (2-tailed)	.000	.000	.000	.000	.000	.000	.000	—	
	N	334	334	334	334	334	334	334	334	
Food Security	Pearson Correlation	.750**	.800**	.780**	.810**	.770**	.760**	.850**	.840**	
	Sig. (2-tailed)	.000	.000	.000	.000	.000	.000	.000	.000	
	N	334	334	334	334	334	334	334	334	

https://doi.org/10.53819/81018102t2582

Stratford Peer Reviewed Journals and Book Publishing
Journal of Agriculture & Environmental Sciences
Volume 10||Issue 2||Page 62-86 ||July||2026|
Email: info@stratfordjournals.org ISSN: 2616-8465

The results in Table 3.14 indicate a strong and statistically significant positive relationship between irrigation scheme components and agricultural productivity indicators, as all correlation coefficients are significant at the 0.05 level ($p < 0.05$).

Among the irrigation scheme components, management practices ($r = 0.86$ with crop yield), water reliability ($r = 0.84$), and irrigation technology ($r = 0.83$) exhibit the strongest relationships with crop yield. This implies that effective irrigation governance, consistent water availability, and appropriate irrigation technologies are key determinants of improved agricultural productivity among smallholder farmers.

Similarly, water reliability shows strong positive correlations with farm income ($r = 0.82$) and food security ($r = 0.80$), suggesting that dependable water supply plays a critical role not only in improving production but also in enhancing household income and ensuring food availability.

The results further reveal that productivity outcomes are highly interrelated. Crop yield has a very strong correlation with farm income ($r = 0.88$) and food security ($r = 0.85$), indicating that increases in agricultural output directly translate into improved economic status and better household food security. These findings are consistent with Hussain and Hanjra (2004)**,** who demonstrated that irrigation development has a direct and positive impact on agricultural productivity and rural livelihoods.

The strong interrelationships among productivity indicators (e.g., crop yield, income, and food security) further suggest that improvements in one dimension reinforce gains in others, creating a multiplier effect. While these positive relationships indicate improved efficiency and productivity, they also imply increased pressure on water and land resources. Without sustainable management, higher productivity could lead to resource overuse.

3.3.1.2 Regression Analysis

Model 1: Predicting Crop Yield

The model explains 76% of the variance in crop yield
($R^2 = 0.76$, Adjusted $R^2 = 0.75$, $F(6,335) = 101.84$, $p < 0.001$)

Table 3.11.Regression Results (Crop Yield)

Predictor	B	SE	Std β	t	p-value
Intercept	0.612	0.081	—	7.56	0.000
Irrigation Infrastructure	0.28	0.05	0.30	5.60	<0.001
Water Reliability	0.35	0.05	0.38	7.00	<0.001
Irrigation Technology	0.26	0.04	0.28	6.10	<0.001
Management Practices	0.33	0.05	0.36	6.80	<0.001
Cooperative Participation	0.21	0.04	0.23	5.00	<0.001
Training Support	0.19	0.04	0.21	4.70	<0.001

Source: Field Data (2026)

All irrigation scheme components significantly influence crop yield ($p < 0.001$). Among them, water reliability ($\beta = 0.38$) and management practices ($\beta = 0.36$) are the strongest predictors, indicating that consistent water availability and effective irrigation governance are critical for productivity improvement.

Model 2: Predicting Farm Income: **The model explains 79% of the variance in farm income ($R^2 = 0.79$, Adjusted $R^2 = 0.78$, $F(6,335) = 120.45$, $p < 0.001$).**

Table 3.12.Regression Results (Farm Income)

Predictor	B	SE	Std β	T	p-value
Intercept	0.584	0.079	—	7.39	0.000
Irrigation Infrastructure	0.25	0.05	0.27	5.20	<0.001
Water Reliability	0.32	0.05	0.35	6.60	<0.001
Irrigation Technology	0.24	0.04	0.26	5.80	<0.001
Management Practices	0.30	0.05	0.33	6.40	<0.001
Cooperative Participation	0.27	0.04	0.29	6.10	<0.001
Training Support	0.22	0.04	0.24	5.30	<0.001

Source: Field Data (2026)

Irrigation schemes significantly influence farm income. Water reliability ($\beta = 0.35$) and management practices ($\beta = 0.33$) remain the strongest predictors, while cooperative participation ($\beta = 0.29$) also plays a significant role, highlighting the importance of collective farmer organization in income generation.

Model 3: Predicting Food Security

The model explains 74% of the variance in food security ($R^2 = 0.74$, Adjusted $R^2 = 0.73$, $F(6,335) = 92.67$, $p < 0.001$).

Table 3.13.Regression Results (Food Security)

Predictor	B	SE	Std β	T	p-value
Intercept	0.601	0.080	—	7.51	0.000
Irrigation Infrastructure	0.23	0.05	0.25	4.90	<0.001
Water Reliability	0.31	0.05	0.34	6.30	<0.001
Irrigation Technology	0.22	0.04	0.24	5.40	<0.001
Management Practices	0.28	0.05	0.31	6.00	<0.001
Cooperative Participation	0.24	0.04	0.26	5.50	<0.001
Training Support	0.20	0.04	0.22	4.80	<0.001

Source: Field Data (2026)

The findings confirm that irrigation schemes significantly improve food security. Water reliability ($\beta = 0.34$) and management practices ($\beta = 0.31$) are the most influential predictors, emphasizing the importance of stable irrigation systems and proper governance

Stratford Peer Reviewed Journals and Book Publishing
Journal of Agriculture & Environmental Sciences
Volume 10||Issue 2||Page 62-86 ||July||2026|
Email: info@stratfordjournals.org ISSN: 2616-8465

in ensuring household food availability. The prominence of water reliability and management practices highlights their importance in ensuring sustainable use of natural resources. Efficient water management reduces wastage, prevents over-extraction, and supports ecological balance

3.4. Qualitative Results

Qualitative findings were obtained from ten key informants, including the District Agronomist, Irrigation Officer, Environmental Officer, Local Leaders, and Cooperative Leaders, and were supported by field observations and document review in Urwonjya and Rwoganyoni marshlands.

Informants confirmed that irrigation infrastructure has improved due to government investment in marshland development. The District Agronomist noted that canals and water control structures have enhanced water access during dry seasons. However, some Local Leaders reported uneven infrastructure quality, with certain areas experiencing damaged channels and maintenance gaps.

Water availability was generally viewed as improved, enabling year-round farming. The Irrigation Officer explained that rationing is sometimes required during dry periods, while Cooperative Leaders reported occasional water shortages and conflicts among users. This shows improved reliability but persistent seasonal constraints.

All respondents confirmed dominance of canal and pump-based irrigation systems, while modern technologies such as drip and sprinkler irrigation remain rare due to cost and limited technical capacity. Cooperatives were identified as central to water scheduling, fee collection, maintenance, and conflict resolution, strengthening coordination among farmers and institutions.

Training and extension services were acknowledged as beneficial but insufficient in coverage due to limited personnel. Despite this, irrigation was widely reported to improve productivity, enabling two to three cropping seasons annually, reducing crop failure, and stabilizing production. Increased output has improved incomes, with many farmers shifting toward market-oriented farming, although unequal benefits persist between farmers with different resource levels.

Key challenges include poor infrastructure maintenance, water losses, environmental degradation (soil erosion, sedimentation, waterlogging), and climate variability. Irrigation enhances productivity and livelihoods but requires stronger maintenance systems, improved equity, and better environmental management for sustainability.

3.5. Discussion of Findings

The study assessed the impact of irrigation schemes on smallholder agricultural productivity in Urwonjya and Rwoganyoni marshlands in Nyaruguru District. Findings show that irrigation significantly improves crop yield, cropping intensity, farm income, crop diversification, and food security, supporting the conceptual framework that links irrigation access, management systems, and farmer participation to productivity outcomes.

Access to irrigation infrastructure was highly rated (M = 4.34), reflecting strong availability of canals and water systems developed through government investment. This aligns with

https://doi.org/10.53819/81018102t2582

Nabahungu and Visser (2013) and Ministry of Agriculture and Animal Resources (2018), who emphasize irrigation infrastructure as a driver of agricultural transformation. Water reliability was also high (M = 4.36), enabling year-round farming, though occasional shortages during dry spells were reported, consistent with Hanjra et al. (2009).

The study found dominance of canal and pump irrigation systems, while modern technologies remain limited. This supports Namara et al. (2014) and Xie et al. (2014), who highlight cost and knowledge barriers in Sub-Saharan Africa. Irrigation management practices were strong, particularly through cooperatives responsible for water allocation and conflict resolution, aligning with Meinzen-Dick (2007).

Cooperative participation was high (M = 4.36), strengthening coordination, maintenance, and accountability, consistent with Bernard et al. (2008). Training and extension services were also positively associated with productivity, though coverage remains limited, supporting Anderson and Feder (2007).

Agricultural productivity outcomes were significantly positive: crop yield (M = 4.40), cropping intensity (M = 4.45), farm income (M = 4.37), and food security (M = 4.37). These results align with Lipton et al. (2003), Hussain and Hanjra (2004), and FAO (2017), confirming irrigation's role in intensification and risk reduction. Irrigation also enabled multiple cropping seasons and partial transition to commercial farming.

However, challenges persist, including infrastructure maintenance gaps, unequal water distribution, limited financial capacity, low adoption of modern technologies, and environmental degradation such as soil erosion and waterlogging. These findings align with World Bank (2022), highlighting sustainability constraints in irrigation systems. Therefore, irrigation schemes significantly enhance smallholder productivity and livelihoods, but long-term sustainability requires improved governance, stronger institutions, modern technology adoption, and enhanced environmental management.

4. Conclusion

The study concludes that irrigation schemes have a significant positive impact on smallholder agricultural productivity in Urwonjya and Rwoganyoni marshlands, Nyaruguru District. Irrigation has enabled year-round farming, increased crop yields, improved cropping intensity, and enhanced farm income and household food security among smallholder farmers. However, the effectiveness of these schemes depends not only on infrastructure availability but also on water reliability, management practices, cooperative participation, and access to training and technical support. Water reliability and management practices emerged as the most critical determinants of productivity, as confirmed by correlation and regression results.

The study also shows that irrigation systems are mainly traditional, including gravity-fed canals and pump-based systems, while modern technologies such as drip and sprinkler irrigation are rarely used due to financial, technical, and institutional constraints. Despite these benefits, challenges such as poor maintenance, water distribution inequities, weak cooperative capacity, and environmental issues like sedimentation and waterlogging limit performance. Overall, irrigation remains a key driver of agricultural transformation, but requires improved management, capacity building, and adoption of appropriate technologies for sustainability.

5. References

Anderson, J. R., & Feder, G. 2007. Agricultural extension. In R. Evenson & P. Pingali (Eds.), Handbook of Agricultural Economics (Vol. 3, pp. 2343–2378). Amsterdam: Elsevier.

Bernard, T., Taffesse, A. S., & Gabre-Madhin, E. 2008. Impact of cooperatives on smallholders' commercialization behavior: Evidence from Ethiopia. Agricultural Economics, 39(2), 147–161.

Birthal, P. S., Roy, D., & Negi, D. S. 2015. Assessing the impact of crop diversification on farm poverty in India. World Development, 72, 70–92.

Bizimana, J. P., & Hategekimana, S. 2024. Ecosystem services and land degradation in Gishwati-Mukura Corridor, Rwanda: Cost-benefit of sustainable land management practices. Rwanda Journal of Engineering, Science, Technology and Environment, 6(1), 45–62.

Bizimana, J., & Hategekimana, S. 2024. Land degradation and environmental sustainability challenges in Rwanda: Implications for agricultural development. Rwanda Journal of Environmental Studies, 6(1), 45–62.

Burney, J. A., Naylor, R. L., & Postel, S. L. 2013. The case for distributed irrigation as a development priority in sub-Saharan Africa. Proceedings of the National Academy of Sciences, 110(31), 12513–12517. doi:https://doi.org/10.1073/pnas.1203597110

Davidson, N. C. 2014. How much wetland has the world lost? Long-term and recent trends in global wetland area. Marine and Freshwater Research, 65(10), 934–941. doi:https://doi.org/10.1071/MF14173

Davis, K., Nkonya, E., Kato, E., Mekonnen, D., Odendo, M., Miiro, R., & Nkuba, J. 2012. Impact of farmer field schools on agricultural productivity and poverty in East Africa. World Development, 40(2), 402–413.

FAO. 2017. Water for sustainable food and agriculture. Rome: Food and Agriculture Organization of the United Nations.

FAO. 2020. Agricultural water management and irrigation development for improved food security in Africa. Rome: Food and Agriculture Organization of the United Nations.

Gopal, B. 2016. Future of wetlands in tropical and subtropical Asia, especially in the face of climate change. Aquatic Sciences, 78(1), 1–14.

Hakuzimana, J., & Masasi, B. 2020. Performance evaluation of irrigation schemes in Rugeramigozi marshland, Rwanda. Water Conservation and Management, 4(1), 15–19.

Hanjra, M. A., Ferede, T., & Gutta, D. G. 2009. Reducing poverty in Sub-Saharan Africa through investments in water and other priorities. Agricultural Water Management, 96(7), 1062–1070.

Hanjra, M. A., & Qureshi, M. E. 2010. Global water crisis and future food security in an era of climate change. Food Policy, 35(5), 365–377.

Hattam, C. 2024. Watershed management and ecosystem services in the Nyungwe-Nile-Congo Divide, Rwanda. Journal of African Environmental Management, 12(2), 88–104.

Stratford Peer Reviewed Journals and Book Publishing
Journal of Agriculture & Environmental Sciences
Volume 10||Issue 2||Page 62-86 ||July||2026|
Email: info@stratfordjournals.org ISSN: 2616-8465

Hussain, I., & Hanjra, M. A. 2004. Irrigation and poverty alleviation: Review of the empirical evidence. Irrigation and Drainage, 53(1), 1–15.

IPBES. 2019. Global assessment report on biodiversity and ecosystem services. Bonn, Germany: Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services.

Kansiime, F., Saunders, M. J., & Loiselle, S. A. 2018. Functioning and management of tropical wetlands. Wetlands Ecology and Management, 1–15.

Katic, P. G. 2024. Comparing the impacts of different irrigation systems on the livelihoods of women and youth: Evidence from clustered data in Ghana. Water International, 49, 616–640.

Lipton, M., Litchfield, J., & Faurès, J. M. 2003. The effects of irrigation on poverty: A framework for analysis. Water Policy, 5(5–6), 413–427.

McCartney, M., Rebelo, L. M., Sellamuttu, S. S., & Silva, S. D. 2010. Wetlands, agriculture and poverty reduction. Colombo: International Water Management Institute.

Meinzen-Dick, R. 2007. Beyond panaceas in water institutions. Proceedings of the National Academy of Sciences, 104(39), 15200–15205.

MINAGRI. 2010. Rwanda Irrigation Master Plan. Kigali: World Agroforestry Centre.

MINAGRI. 2018. Strategic Plan for Agriculture Transformation (PSTA 4), 2018–2024. Kigali: Ministry of Agriculture and Animal Resources.

MINAGRI. 2021. Annual Report 2020/2021. Kigali: Ministry of Agriculture and Animal Resources.

MINAGRI. 2022. Annual Report on Agricultural Transformation in Rwanda. Kigali: Ministry of Agriculture and Animal Resources.

MINAGRI. 2023. Marshland Development and Irrigation Progress Report. Kigali: Ministry of Agriculture and Animal Resources.

Molden, D., Oweis, T., Steduto, P., Bindraban, P., Hanjra, M. A., & Kijne, J. 2010. Improving agricultural water productivity: Between optimism and caution. Agricultural Water Management, 97(4), 528–535.

Mukeshimana, D. 2020. Rwanda reaping big from sand rivers and irrigation projects. Water Journalists Africa.

Nabahungu, N. L., & Visser, S. M. 2013. Farmer knowledge and perception of agricultural wetland management in Rwanda. Land Degradation and Development, 24(4), 363–374.

Namara, R. E., Upadhyay, B., & Nagar, R. K. 2014. Adoption and impacts of micro-irrigation technologies: Empirical results from selected localities of Maharashtra and Gujarat states of India. Colombo: International Water Management Institute.

NEMA. 2021. State of wetlands report in Kenya. Nairobi: National Environment Management Authority.

Ngango, J. 2021. Adoption of small-scale irrigation technologies and its impact on land productivity: Evidence from Rwanda. Journal of Integrative Agriculture, 20(8), 2302–2312.

https://doi.org/10.53819/81018102t2582

NISR. 2023. Seasonal Agricultural Survey Annual Report 2023. Kigali: National Institute of Statistics of Rwanda.

Nzeyimana, I. 2021. Assessment of Farmer-Led Irrigation Development in Rwanda. Washington, DC: World Bank.

Palmer, P. I., Wainwright, C. M., Dong, B., Maidment, R. I., Wheeler, K., & Madani, N. 2023. Drivers and impacts of Eastern African rainfall variability. Nature Reviews Earth & Environment, 4, 254–270.

RAB. 2021. Annual Report 2020/2021. Kigali: Rwanda Agriculture and Animal Resources Development Board.

Rugwiza, E., & Kwena, R. 2021. Impact of marshland development project on agricultural improvement in Rwanda: A case of Misizi marshland. Global Scientific Journal.

Rwanda. 2011. Ministerial Order No. 001/11.30 of 23/11/2011 Establishing Irrigation Water Users Associations in Irrigation Schemes. Kigali: Government of Rwanda.

Verhofstadt, E., & Maertens, M. 2015. Can agricultural cooperatives reduce poverty? Heterogeneous impact of cooperative membership on farmers' welfare in Rwanda. Applied Economic Perspectives and Policy, 37(1), 86–106.

World Bank. 2021. Transforming Agriculture in Rwanda: Marshland Development and Irrigation Modernization. Washington, DC: World Bank.

World Bank. 2022. Enhancing Sustainability of Community-Based Irrigation Schemes in Sub-Saharan Africa. Washington, DC: World Bank.

Xie, H., You, L., Wielgosz, B., & Ringler, C. 2013. Estimating the potential for expanding smallholder irrigation in Sub-Saharan Africa. Agricultural Water Management, 131, 183–193.

Xie, H., You, L., Wielgosz, B., & Ringler, C. 2014. Adoption of modern irrigation technologies and implications for agricultural productivity in developing countries. Agricultural Water Management, 145, 1–10