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Leveraging IoT-Based Smart Irrigation Systems to Enhance Rice Productivity: A Case Study of Smallholder Farmers in the Muvumba Valley Irrigation Scheme, Eastern Rwanda

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ABSTRACT

This study presents the results of a needs assessment done with small-scale rice farmers in the Muvumba Valley irrigation scheme in Eastern Rwanda. The goal of the assessment was to learn about how farmers currently farm and what they need to help create a system that can help with rice production by telling them when to water and fertilize their crops. The research employed a mixed methodology. Data were collected from 325 of 2084 smallholder rice farmers in the Muvumba Valley. We made a structured questionnaire and used Kobo Toolbox to give it out. The survey asked farmers about their farming methods, how they monitor field conditions, and whether they would be open to using technology-based solutions in agriculture. We used SPSS to analyze the quantitative data and create descriptive statistics. We also used content analysis to understand farmers' experiences and feelings better. The assessment examined various aspects of rice farming, including farmers' knowledge of soil types and rice varieties, common farming methods, access to farming supplies, watering and fertilizing practices, and how weather changes affect rice production. All participants indicated that rainfall patterns have changed in recent years, making it harder to get water and affecting how they water their plants. The findings revealed that while rice farmers in the Muvumba Valley face several production challenges, there is also a strong interest in technologies that can help improve irrigation and fertilization management, where results show that 99.40% of the farmers indicated willingness to learn and use smart farming systems.

Summary

- Assessing smallholder rice farmers' needs and readiness for Internet of Things (IoT)-enabled precision irrigation and fertilization in Eastern Rwanda.
- Needs and readiness for IoT-enabled precision agriculture among smallholder rice farmers in Eastern Rwanda.
- Laying the groundwork for IoT-enabled precision irrigation and fertilization in smallholder rice systems: evidence from Eastern Rwanda.
- From manual practices to smart farming: assessing IoT readiness among smallholder rice farmers in Eastern Rwanda.

1 | Introduction

Agriculture remains a central economic activity across Africa, supporting the livelihoods of more than half of the continent's population. This importance is reflected in the African Union's Agenda 2063, which identifies agriculture as a core pillar for eliminating hunger and reducing poverty [1]. Despite agriculture's dominance, many African countries continue to experience high levels of hunger and malnutrition. The situation is particularly severe in Sub-Saharan Africa, where hunger levels are classified as serious [2]. These outcomes are often linked to systemic inefficiencies that constrain agricultural productivity [3, 4].

There is a growing consensus that digitization for agriculture (D4Ag) can transform agricultural systems in Sub-Saharan Africa by improving productivity and strengthening the sector's contribution to food and nutrition security [5]. The Internet of Things (IoT) plays a key enabling role in precision agriculture by supporting the collection of field-level sensor data and translating that data into actionable insights for farmers [6, 7]. This approach directly addresses chronic information gaps related to soil testing, irrigation scheduling, irrigation volumes, and fertilization practices [8, 9]. Without such information, farmers often experience suboptimal irrigation timing, excessive or poorly targeted fertilization, soil degradation, nutrient loss, and reduced yields, challenges that remain widespread among smallholder farmers in the region.

In Rwanda, rice is a priority food crop and an important commodity for both rural and urban households. However, ~76% of rice available in the local market is imported to meet domestic demand [10]. The National Rice Program has also noted that earlier projections of national rice demand were underestimated, underscoring the importance of increasing domestic production to support food security [11]. National statistics indicate that, as recently as 2018, domestic rice production met only about one-third of national demand, with negative economic implications [12]. Consequently, the Government of Rwanda has prioritized rice production as a strategic area for improving agricultural output, including through improved irrigation water use efficiency [13, 14].

This study presents findings from a needs assessment examining smallholder rice farmers' needs, attitudes, and readiness to adopt precision agriculture within the Muvumba Valley rice scheme. The needs assessment forms part of a broader initiative to design and develop an IoT-enabled irrigation and fertilization recommendation system tailored to smallholder rice farmers in Eastern Rwanda. Specifically, the study assessed farmers' knowledge of soil type, rice varieties, and good farming practices; access to inputs; fertilization practices; irrigation methods; observed climate impacts; and perceptions and willingness to adopt precision agriculture technologies.

Agriculture remains a foundational pillar of many African economies, supplying food and raw materials, generating employment, earning foreign exchange, and providing markets for other sectors [3]. Demand for agricultural products continues to rise, driven largely by population growth and urbanization [15]. At the same time, expanding urban land use has reduced arable land availability in some contexts and increased pressures linked to environmental degradation and resource depletion. Within this setting, precision agriculture has emerged as a strategic approach to improve efficiency by leveraging IoT technologies for more accurate monitoring and decision-making in crop and livestock systems.

IoT-enabled systems facilitate real-time data collection that can support improved irrigation scheduling, fertilizer application, pest control, and weed management. However, technology adoption without appropriate safeguards may contribute to excessive use of synthetic inputs, potentially accelerating soil acidification, groundwater contamination, and broader ecosystem degradation, ultimately undermining productivity. Real-time monitoring and data-based decision-making are therefore important for ensuring that productivity gains are achieved without compromising environmental sustainability. Data-driven agriculture has been identified as a promising pathway for improving efficiency, reducing costs, and supporting sustainable practices [16].

Microsoft's Farm Beats project illustrates the value of integrating soil sensors, satellite imagery, and machine learning to support farm management decisions [17]. Compared with yield enhancement approaches based on biological modification, data-driven agriculture focuses on variable-rate technologies and precision input management to improve yields while reducing environmental externalities [18, 19]. Across Africa, agricultural production remains predominantly rural, with smallholder farmers relying heavily on traditional production methods. Yet rural areas continue to experience declining socioeconomic competitiveness due to migration and reduced youth engagement in agriculture [15]. Smallholders face constraints including waterlogging, low soil fertility, drought, soil erosion, inadequate practices, limited market access, climate change impacts, and weak extension services, resulting in low productivity, high production costs, environmental degradation, and persistent food insecurity [20].

In Rwanda, emerging commercial solutions demonstrate the potential of precision agriculture; however, sustainability concerns persist where chemical inputs are applied excessively. Smart farming integrating IoT, artificial intelligence, and computer vision offers potential to improve efficiency, traceability, and profitability, particularly for low- and middle-income farmers. Nevertheless, adoption depends on digital infrastructure, connectivity, sensor availability, supportive policy frameworks, and farmers' digital literacy [21].

This study contributes to efforts to develop a cost-effective, data-driven agricultural system tailored for smallholder farmers in Africa, using Rwanda as the initial pilot setting. The proposed system will analyze soil quality and nutrient composition to support crop and fertilization recommendations. It will also support pest and disease monitoring by enabling early detection and real-time alerts for timely intervention. Through improved productivity, reduced operating costs, and better resource management, such systems can support sustainable agricultural development aligned with food security and environmental goals. In line with reviewer observations, this manuscript integrates recent scholarship on IoT applications in agriculture and strengthens foundational references on agricultural livelihoods and transformation dynamics [3, 15–21]. Additionally, the study area description will be supported with a satellite-based map following cartographic standards consistent with Mudatenguha et al. [22]. The study objective is to present the findings from a needs assessment examining smallholder rice farmers' needs, attitudes, and readiness to adopt precision agriculture within the Muvumba Valley rice scheme.

2 | Study Approach and Materials

2.1 | Study Area and Target Population

The study was conducted within the Mavumba catchment. Mavumba is a river in Northeastern Rwanda and Southwestern Uganda. It is part of the upper headwaters of the Nile. At 170 km long, it is one of the major rivers of Rwanda, both in size and economic importance. Its upper course provides water for tea plantations in the high altitudes of north Rwanda and Southwestern Uganda. Its lower course provides water for the dry areas of Nyagatare, facilitating irrigation of rice fields and other crops, as well as providing water for cattle in this area for cattle farming (Supporting information). The principal water resources in the catchment are as follows:

- Rainfall: the average annual rainfall is rated at 995 mm/annum, which equates to some 1560 hm^3/annum from the total land surface area of 1568 km^2.
- Surface flow: the combined average annual surface flow generated from the numerous small catchments in Rwanda stands at 6.9 m^3/s or some 193 hm^3/annum.
- Groundwater: the groundwater annual recharge/safe yield is about 111 hm^3/annum with a total storage of 1565 hm^3, which gives a mean residence time of about 14 years.

The target population was the small-scale rice farmers of the Muvumba Valley rice project. This project was established to provide irrigation for the flat land of the valley bottom to support rice farming. This project supports more than 1000 small-scale farmers with field sizes of about 1 ha. Figure 1 shows the location of the Muvumba area, and Figure 2 shows rice fields within the Muvumba catchment area.

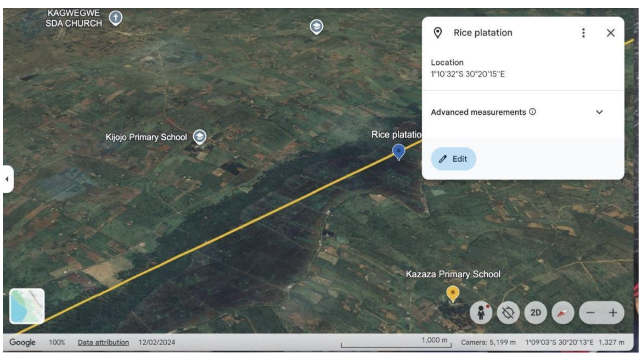

FIGURE 1 | Location of Muvumba area in Nyagatare, Eastern Province, Rwanda (1°10’32” S 30°20’15” E).

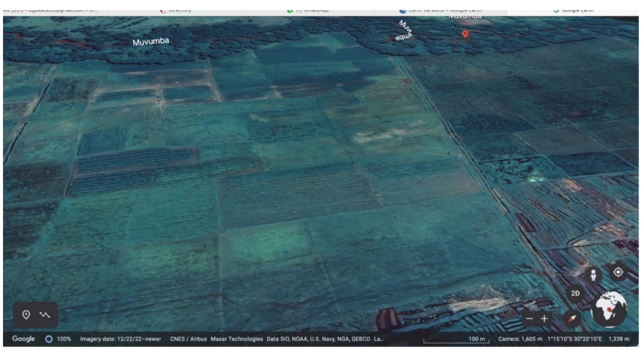

FIGURE 2 | Rice fields at the Muvumba rice farming scheme.

2.2 | Demographic

Table 1 summarizes key characteristics of rice farmers operating in the Muvumba Valley, Nyagatare District, grouped by cooperatives, gender, age range, farming experience, and land size under rice cultivation. The data shows noticeable variation in landholding size among farmers, ranging from 0.5 to 10 hectares, indicating differences in production scale within and across cooperatives. Most farmers fall within the 30–49 age range and have more than 5 years of experience, suggesting a stable and experienced rice-farming community. While male farmers constitute the majority, female participation is significant, particularly within the MUVUMBA P8 cooperative. Generally, farmers with longer experience tend to cultivate larger land areas, reflecting accumulated capacity and resource access over time. Overall, the table provides a clear profile of the human and production structure supporting rice cultivation in the Muvumba Valley.

2.3 | Data Collection

A questionnaire was created and implemented in Kobo Toolbox to streamline data gathering. An extensive review of pertinent literature preceded the tool’s design to ensure that it incorporated all essential survey components and adhered to established standards. The author’s expertise in the local agricultural landscape played a crucial role in shaping the survey. The questionnaire featured both open-ended and multiple-choice questions, allowing for the selection and ranking of various options. Respondents were sometimes given additional space to elaborate on their choices, which proved valuable for interpreting the overall results. The survey was administered digitally through Kobo Toolbox. Before the main study, the tool underwent pilot testing, followed by necessary adjustments to minimize ambiguity in responses. Questions were formulated to elicit information on various aspects, including rice farming knowledge, gender distribution among farmers, farm condition monitoring methods, irrigation systems in use, fertilization and irrigation practices, climate change impacts, the willingness to adopt smart irrigation technologies, and other relevant topics. These aspects were categorized into three main themes.

- General knowledge and experience in rice farming: Questions about the study aimed to gather information on farmers’ experience in rice farming, the types of rice varieties being grown, and the yields produced.
- Rice farm conditions assessment methods: The questions within this theme were crafted with the goal of gathering information on the techniques the farmers employ to assess the necessary conditions for rice farming. These include determining the right moisture levels for growing rice, determining soil nutrient content at the various stages of rice growth, determining the right time for fertilizer application, determining the right time for irrigation, and others.
- Knowledge on precision agriculture and farmers’ readiness: The questions in this section sort to solicit information from the rice farmers on how well they understand precision agriculture, what kind of services they would want to be included in an IoT-powered automated system, whether they would wish to be trained on the use of such a system, and other aspects.

TABLE 1 | Cooperative demographics and land size.

Cooperative	Gender	Age range	Experience (years)	Land size (ha)
MUVUMBA P8	Male	20–29	0–2	0.5
MUVUMBA P8	Male	20–29	3–5	1
MUVUMBA P8	Male	20–29	5+	1
MUVUMBA P8	Female	20–29	0–2	1
MUVUMBA P8	Female	20–29	5+	1.5
MUVUMBA P8	Male	30–39	0–2	1
MUVUMBA P8	Male	30–39	3–5	2
MUVUMBA P8	Male	30–39	5+	4
MUVUMBA P8	Female	30–39	3–5	1
MUVUMBA P8	Female	30–39	5+	4
MUVUMBA P8	Male	40–49	3–5	1
MUVUMBA P8	Male	40–49	5+	2
MUVUMBA P8	Female	40–49	5+	10
MUVUMBA P8	Male	Above 50	5+	2
COPREMU	Male	30–39	3–5	1
COPREMU	Male	30–39	5+	2.5
COPREMU	Female	30–39	3–5	0.5
COPREMU	Female	40–49	5+	1
COPREMU	Male	40–49	5+	2.5
COPREMU	Female	Above 50	5+	1.7
CODEREVAMU	Male	20–29	3–5	2.5
CODEREVAMU	Male	30–39	5+	2.9
CODEREVAMU	Male	40–49	5+	1
CODEREVAMU	Female	20–29	3–5	1.23
CODEREVAMU	Male	Above 50	5+	2.5

2.4 | Data Analysis

The data collected comprised qualitative and quantitative data. For qualitative data, a content analysis method was used for the analysis. Since the data was collected using Kobo Toolbox, partial analysis of quantitative data was done within the Kobo Toolbox system. However, to allow for further analysis, especially for quantitative data, the data were exported from Kobo Toolbox to IBM SPSS Statistics Version 23. To aid data interpretation, frequency tables were used to uncover variable characteristics. To determine the association between various variables, cross-tabulation was done for the various sets of variables.

2.5 | Sampling

The target population comprised all smallholder rice farmers within the Muvumba irrigation scheme catchment area. The number of registered rice farmers was obtained from the Nyagatare District agricultural office. The sample size was calculated using Equation (1)is as follows:

$$n = \frac{z^2 p\,(1-p)}{d^2}\,, \qquad (1)$$

where n is the sample size, z is the z-score for the desired confidence level, p is the estimated proportion of the population possessing the characteristic of interest, and d is the margin of error.

At the time of the survey, the number of registered rice farmers in Nyagatare District was 2084. The prevalence parameter was set to $p = 0.5$, with $d = 0.05$ and $z = 1.96$ (95% confidence). The resulting minimum sample size was 325.

3 | Study Findings/Results

Add a subtitle, for example, knowledge on farming practices, cooperatives, access to farm inputs, and length of growing seasons.

Based on the findings, the study participants show clear knowledge of good rice farming practices from farm preparation to seedling and the harvesting period. About 69.28% of the respondents belong to a cooperative, whilst 30.42% are not registered with any cooperative, as indicated in Figure 3. In terms of access

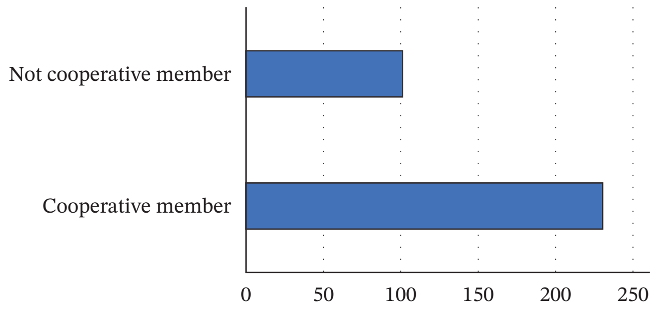

FIGURE 3 | Cooperative membership.

to farm inputs, respondents who belong to cooperatives get the inputs from the cooperative and pay back after harvesting. Those that do not belong to cooperatives obtain the inputs by purchasing them from the open market. The respondents indicated that they cultivate rice twice a year, and in terms of harvest, the average yield is 2.5 tons per hectare.

3.1 | Demographic Distribution of Respondents

Figure 4 shows the gender and age distribution of the respondents. Based on the survey findings, rice farming is dominated by male farmers, accounting for 76% of the respondents, and female farmers at 24%. Figure 5 shows the relationship between the gender and age distribution of the respondents. For both male and female rice farmers, most of them, that is, 39.76%, are in the age range of 30–39 years old, and 28.61% are in the age range of 20–29 years old.

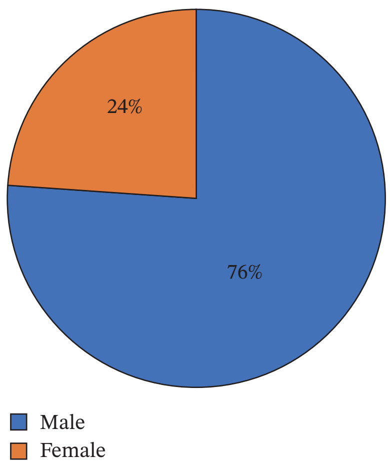

FIGURE 4 | Gender distribution of respondents.

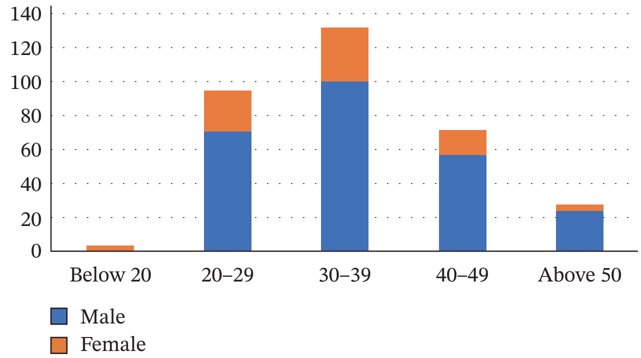

FIGURE 5 | Relationship between gender and age of respondents.

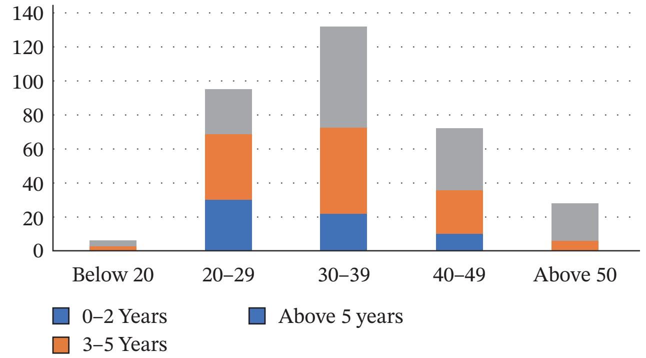

FIGURE 6 | Age distribution and farming experience of respondents.

3.2 | Age and Farming Experience Association

Figure 6 shows the association between the respondents' age and farming experience. Rice farming is dominated by a youthful population.

3.3 | Cooperative Membership

The respondents were asked whether they belonged to a cooperative or not. The findings are highlighted in Figure 3. It was found that among the population sample targeted by the study, 69.28% of respondents belong to a cooperative, whilst 30.42% do not belong to a cooperative.

3.4 | Smartphone Use

It was of interest to find out the smartphone distribution among the respondents. As shown in Figure 7, only 12.35% of the respondents own and use a smartphone, whilst 87.35% of the respondents do not own and use a smartphone.

3.5 | Soil Type and Nutritional Content Assessment

All the respondents acknowledged that they do not use any technology or employ technical methods to check the type of soil and nutritional content. The respondents were, however, able to state the type of soil present in their rice fields based on observation and by feeling the texture with their hands. As shown in Figure 8, most respondents (58.43%) reported that the soil in their fields is clay, while a considerable proportion (38.25%) indicated that they do not know the type of soil in their rice fields. A smaller percentage identified their soils as loamy (5.72%) and sandy (3.61%). These findings highlight that many farmers are not fully aware of the

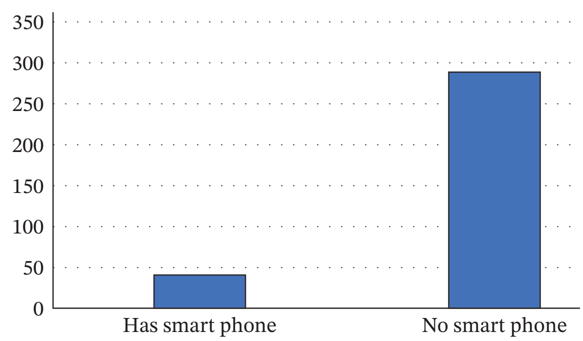

FIGURE 7 | Ownership and use of smartphones among respondents.

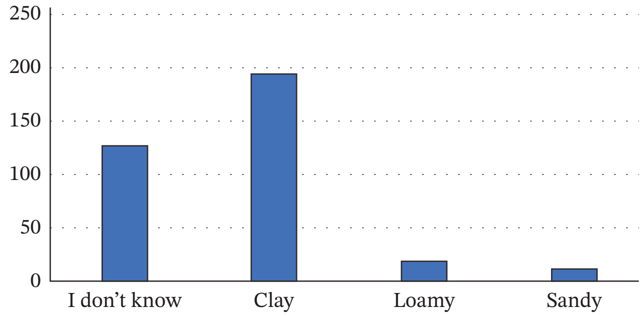

FIGURE 8 | Farmers' knowledge of soil type within their farm plots.

exact characteristics of their soil, which can affect how they manage their fields. Therefore, it is important to introduce appropriate technologies that can help farmers easily identify their soil types and make better farming decisions. This also points to a potential area for further research, particularly in linking farmers' indigenous knowledge with scientific evidence to improve soil management and enhance agricultural productivity.

3.6 | Soil Temperature Assessment

Soil temperature is one of the key elements that a farmer needs to take into consideration, especially during the planting period [23]. All the respondents acknowledged a lack of knowledge of the recommended soil temperatures during transplanting. This indicates a need for the introduction of technologies that farmers can use for measuring suitable conditions, for example, temperature, moisture, and others, during seed planting and during the various stages of rice growth.

3.7 | Rice Varieties Grown

Figure 9 shows the common rice varieties grown within the study area. It is noted that Kigori (or Posiyani) is the popular rice variety grown within the Mavumba catchment area.

3.8 | Fertilizer Use

All the respondents indicated that they use inorganic fertilizer in their fields to enhance the nutritional content of the soil. On the method of application, all the respondents indicated that they apply the fertilizer in the solid form and not in the liquid form. On the frequency of application, all the respondents indicated that they apply the fertilizer twice during each growing season. However, many farmers may not clearly know when the

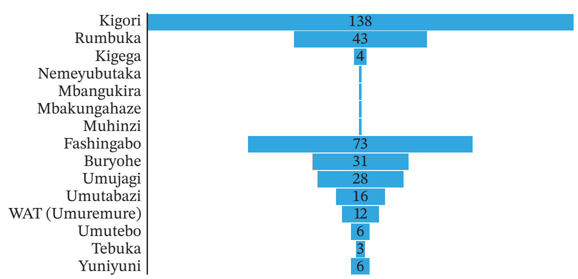

FIGURE 9 | Rice varieties grown within the Muvumba catchment area.

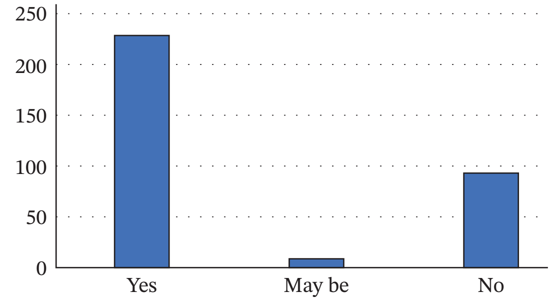

FIGURE 10 | Farmers' response to water shortage.

conditions are most suitable for fertilizer application, such as the appropriate weather conditions or the correct rice growth stages. This suggests that farmers may not always be fully aware of the best timing for applying fertilizers to achieve optimal results. Water shortage in rice fields

On whether the farmers have ever experienced water shortages that impacted rice growth in their rice fields in the past, 68.98% of the respondents stated that they have experienced water shortages, whilst 28.01% have not experienced water shortages. Figure 10 shows the respondents' distribution on this aspect.

3.9 | Irrigating Rice Fields

Due to the high-water demand of rice, irrigation is done in rice fields to supplement the natural water supply and meet the water demands of the rice crop. All the respondents indicated that they use a manual water irrigation system to water their rice plots. On frequency of irrigation, some respondents indicated that they only irrigate once per week due to a lack of water. Others indicated that they water twice a week, whilst some indicated that they irrigate three or four times a week. Among the challenges faced with the current irrigation system, they include the following:

- Unequal distribution of water from the source.
- Shortage of water and water competition.
- Improper functioning of canals.
- Fighting among farmers due to insufficient water.
- Spreading of diseases carried by the water.
- Difficult to control the water, leading to waterlogging in the fields.

3.10 | Climate Change Impact

When asked whether the farmers have noticed any changes in climate (or weather patterns) over the past years that have affected their rice crop, 81.68% answered in the affirmative. Climate change impacts have the potential to impact farming patterns and yield levels. As shown in Figure 11, among the climatic impacts that have been observed by the respondents over the years are high temperatures (24%), longer drought periods (28%), increased instances of floods (22%), and erratic rainfall (24%). The figure shows the highlighted impact of climate change within the study area.

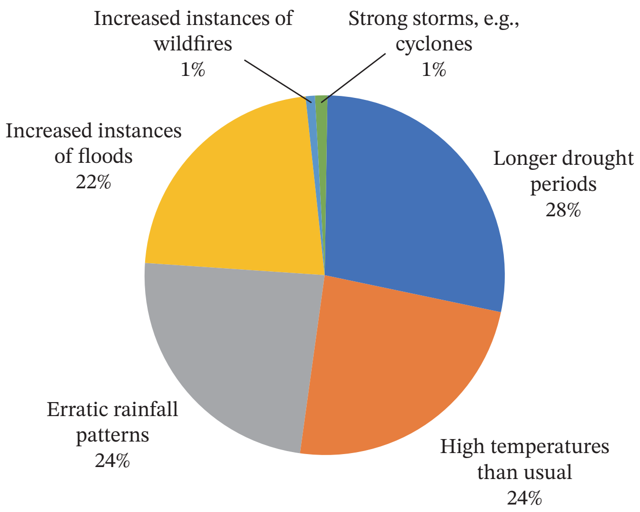

FIGURE 11 | Observed climatic change effects.

3.11 | Knowledge of and Willingness to Adopt Smart Agriculture Techniques

As can be noted from Figure 12, 81% of the respondents indicated that they are not familiar with the concept of smart agriculture. This indicates a need for capacity building among the smallholder rice farmers on smart agriculture and its impact on farming. Encouraging enough, as shown in Figure 13, 98.49% expressed the willingness to be trained and use an automated irrigation system. This indicates that there is interest among farmers to use a smart irrigation and fertilization system once it is deployed.

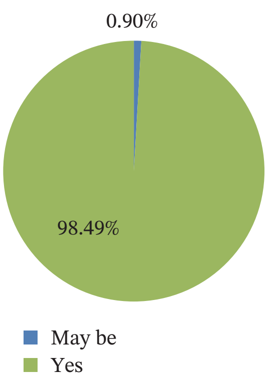

FIGURE 12 | Knowledge of smart agriculture.

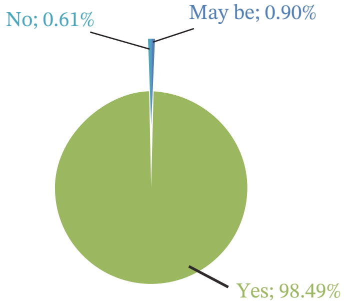

FIGURE 13 | Interest in an automated irrigation system.

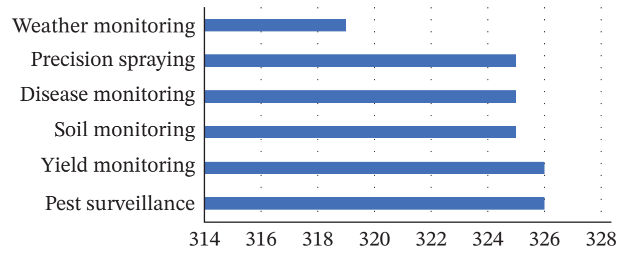

FIGURE 14 | Services needed by respondents from a smart agricultural system.

3.12 | Other Smart Services Are Needed

Apart from irrigation, the respondents further need a system that could provide additional services, such as pest surveillance (98.19%), yield monitoring (98.1%), soil monitoring (97.89%), disease monitoring (97.89%), precision spraying (97.89%), and weather monitoring (96.08%). Furthermore, 99.4% of the respondents indicated their willingness to be trained and adopt a smart agricultural system that would automate some of the farming activities and provide notifications on important environmental and climatic parameters. (see Figure 14).

4 | Discussion

Strengthening the rice sector in Sub-Saharan Africa remains urgent given rice's role as a key source of dietary energy and essential nutrients. Challenges reported by farmers in the Muvumba Valley resemble those documented in other studies, including limited irrigation water availability, which is increasingly exacerbated by climate variability and erratic rainfall patterns [24, 25]. Reported yields (2.5–5.42 t ha^{-1}) are comparable to yield ranges reported across several Sub-Saharan African contexts [26]. Although the Muvumba Valley rice scheme represents an important national investment for increasing domestic rice production, yields remain modest despite irrigation infrastructure development, including the Muvumba dam. Prior work indicates that productivity gains remain possible through improved irrigation management systems [27].

Findings indicate inadequate water management practices and limited capacity to achieve an equitable distribution of irrigation water. Unequal water distribution and water shortages were among the most frequently cited challenges. These issues are compounded by the reliance on manual irrigation systems, which can be inefficient and difficult to regulate. Several irrigation technologies have been tested in other rice systems and could be adapted to improve production outcomes.

A key finding is low awareness of smart agriculture: 81% of respondents had not heard of precision agriculture. This is consistent with limited digital access, as only 12.35% of respondents own smartphones. Nevertheless, farmers expressed strong interest in adopting an IoT-enabled automated irrigation system and receiving real-time information on soil moisture, soil nutrient levels, and weather parameters (temperature and humidity). Such interest supports the rationale for developing an automated irrigation and fertilization support system. Automation may also reduce conflict associated with unequal water distribution and manual allocation practices. However, further research is required to define irrigation scheduling parameters, including varietal thresholds and recommendations for nonponded periods [28].

Demographic findings indicate that 76% of respondents were men, and 24% were women. The relatively high representation of younger farmers (notably those aged 20–39 years) suggests that investments in skill development and capacity building could yield sustained benefits over time, including knowledge transfer to future generations. The lower representation of women suggests the need for further investigation into constraints affecting women's participation in rice farming and the design of targeted interventions.

Finally, the study confirms the limited technical knowledge of soil characteristics and nutrient status. While many respondents could describe soil type using traditional methods (visual and tactile assessment), they lacked access to tools for soil testing and nutrient measurement. Soil and nutrient knowledge are essential for determining appropriate fertilization rates and timings. Both under- and over-application may reduce yields and impose unnecessary costs; excessive use also risks environmental degradation. Improved soil monitoring and recommendation systems could therefore support both productivity and cost efficiency for smallholders.

5 | Conclusion

This study shows that smallholder rice farmers in the Muvumba Valley possess experienced knowledge but lack data-driven tools for managing irrigation, soil nutrients, and climate risks. Manual irrigation, unequal water distribution, and nonsoil-tested fertilization affect rice productivity and resource management.

Findings indicate that limited field-level control of irrigation contributes to conflict and inefficient water use. In addition, limited soil testing capacity contributes to fertilizer applications based on labor convenience rather than crop nutrient demand, increasing the risk of inefficient input use, overfertilization, and soil degradation. With two rice-growing seasons annually, soil pressure remains high, and opportunities for soil recovery may be limited.

This needs assessment forms part of a broader effort to integrate technology into smallholder rice production systems to improve yields and resource efficiency despite limited digital access and low awareness of precision agriculture. Farmers show a high willingness to adopt IoT-enabled systems. The proposed IoT-enabled system will enhance yields, equity in water use, and climate resilience in Rwanda's rice sector and support automated irrigation and provide guidance on optimal fertilizer application timing. The system is intended to improve yields to an average of 6 $t\,ha^{-1}$, representing a substantial improvement over the currently reported average yield. Overall, the findings confirm the relevance of an IoT-enabled irrigation and fertilization system given current manual irrigation practices and traditional fertilizer management approaches. The results will inform system design to ensure alignment with farmer needs and local operational realities, thereby improving usability and potential adoption.

Author Contributions

Conceptualization: Peace Bamurigire, Evariste Twahirwa, and Kambombo Mtonga. Software: Pelin Mutanguha, Jane Murerwa, James Rwigema, Sumwiza Kellen, and Musanase Christine. Writing – review and editing: Samuel G. Mushabe and Kayalvizhi Jayavel.

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Disclosure

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Ethics Statement

The authors have nothing to report.

Conflicts of Interest

The authors declare no conflicts of interest.

Data Availability Statement

The data that support the findings of this study are available upon request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

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Supporting Information

Additional supporting information can be found online in the Supporting Information section. **Supporting Information.** IoT smart farming.