Application of Information and Communication Technology in Solar-Powered Community Micro-irrigation Project, Talwara, Hoshiarpur

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Abstract

This study explored the application of ICT in a solar-powered community-based micro-irrigation project in Talwara, Hoshiarpur. The study aimed to develop a computer program and an Android application to facilitate equitable distribution and effective communication among farmers and project management. A computer program was developed to create an equitable water distribution schedule for the irrigation project. An Android application was designed to establish a robust communication network between farmers and project management. This platform enables real-time information sharing, enhancing coordination, and decision-making processes. The research findings demonstrate the positive impact of ICT adoption in the project region. After implementing the ICT-based system, significant improvements were observed in crop yields. Wheat, maize, and mustard yields increased by 31.38%, 38.90%, and 67.42%, respectively. Moreover, the project led to substantial increases in gross and net income per hectare, with increases of 37.99% and 81.41%, respectively. The integration of ICT tools in the micro-irrigation project facilitated efficient resource management, timely communication, and equitable distribution of water resources. These technological advancements resulted in substantial productivity gains, improved agricultural outcomes, and increased profitability for the participating farmers. The research outcomes highlight the potential of ICT to enhance agricultural practices, particularly in community-based micro-irrigation projects.

Introduction

The projected human population is expected to reach 10 billion by 2050 (FAO, 2017). One of the foremost challenges is to address the feeding of this expanding population. Owing to the Green Revolution and plant breeding advancements, crop yields can adequately sustain a significant portion of the global population. Nonetheless, there are indications of stagnation and even a decline in crop production attributed to the impact of climate change and the limited availability of arable land. To meet the demands of a growing population, an increase of 60% in production yields is required (Springmann et al. 2018; Karthikeyan et al. 2020). Thus, it is imperative to enhance agricultural productivity and sustainability globally. Urgent attention is needed for scientific breakthroughs and technological innovations in crop production to ensure global food security. Agriculture is vital to most developing countries' social and economic development and is the main contributor to economic growth and stability (Munyua Hilda, 2009; Bhalekar Pratima, 2015; Loizou et al. 2019; Selim et al. 2020). It is an essential economic activity in various third-world countries, where most of the population lives in rural areas and relies on agriculture as either a direct or indirect source of income (Patrick & Rosemary, 2006; Praburaj et al. 2018; Aznar et al. 2019, Utami et al. 2019). It is also an essential sector of the Indian economy. More than 80% of the population relies on agriculture and related industries. It is well known that the transmission of pertinent knowledge significantly influences the growth and productivity of the industry. Small and marginal farmers can increase their yields and earn better market prices by receiving relevant transfers of knowledge (Patil et al. 2011; Ankur & Chakrabarti, 2013; Bernard et al. 2019; Zerssa et al. 2019; Cao et al. 2020). However, poor agricultural practices, information distribution inefficiencies, record-keeping between farmers and traders, and the need for more information on best practices for farmers are just a few of the obstacles and issues facing the agricultural sector. Information and Communication Technologies (ICTs) have recently introduced numerous innovative communication methods and exchanged information and knowledge. However, poor agricultural practices, information distribution inefficiencies, record-keeping between farmers and traders, and a need for more information on best practices for farmers are just a few of the obstacles and issues that face the agricultural sector. UNESCO (Khvilon & Patru, 2002) defines ICT as "integrating informatics technology with other relevant technologies, particularly communication technology." This refers to the technology that enables electronic communication, information processing, and transmission. These technologies can provide farmers with precise and relevant information and services to enhance productivity and yield better outcomes. The technological revolution has encompassed various aspects, such as information capture, processing, storage, and display, thereby increasing productivity and competitiveness through improved access to information. The use of ICTs is a foundation for agricultural expansion in the rapidly changing world. It is widely acknowledged as a fundamental process for delivering information and tools as inputs for modern agriculture (Raghuprasad et al. 2012; Barber et al. 2018; Gaol & Gustira, 2020). ICT allows people and organizations to communicate and exchange information regardless of geological location (Mukerji, 2013). Agriculture-related ICT is a new area that aims to advance rural and agricultural development in India (Figure 1). It affects all aspects of life (Ojha et al. 2015; Navarro-Hellin et al. 2016; Ferrandez-Pastor et al. 2018; Das, 2022). This results in cutting-edge technologies to analyze and transfer data. It involves conceptualizing, developing, evaluating, and applying technologies in the rural domain, primarily focusing on agriculture (Mahant et al. 2012). The effective utilization of ICTs in rural areas relies on the preparation and willingness of the community to acquire the necessary knowledge and adopt appropriate attitudes towards these technologies.

An emerging field called "Electronic Agriculture (e-agriculture)" aims to boost agricultural and rural development through better information and communication systems. By integrating the User Interface and Knowledge Management System, e-agriculture disseminates helpful information via a Decision Support System (DSS), Management Information System (MIS), and Expert System (ES) (Lomas et al. 2000; Mangina & Vlachos, 2005; Chumjai 2006; Majid 2006; Behera et al. 2015; Bhalekar et al. 2015; Kukar et al. 2019; Zhai et al. 2020). E-agriculture adds value to the lives of farmers and end-users in sustainable development through e-governance, knowledge management portals, e-kiosks, and shared service centres at community levels (Bhalekar et al. 2015; Behera et al. 2015). Studies on e-agriculture, which utilizes information and communication technology (ICT), have demonstrated significant advancements in various areas (Rao, 2007; Singh et al. 2;015 Eitzinger et al. 2019). One example of ICT is the Solar Powered Community Lift-Micro-Irrigation Project (SPCMIP) undertaken in the Talwara and Hazipur Blocks of Hoshiarpur District, Punjab. No previous studies have been conducted on community irrigation management in the Punjab region. This study aimed to investigate the transformative impact of ICT implementation in Hoshiarpur by substantially improving farmers' agricultural yields and incomes.

Materials And Methods

Description of the study area

The Punjab Government introduced a solar-operated lift irrigation project in the Kandi area of the Hoshiarpur district to promote micro-irrigation. The Kandi region, encompassing 10% of Punjab State's land, relies primarily on rainfall for irrigation. This area faces severe water scarcity for agricultural purposes and drinking water, leading to challenging socioeconomic conditions for farmers. The region's undulating topography and steep slopes result in soil erosion and the loss of productive soil. The most critical issue in this area is the erosion of fertile soils during the monsoon season, further exacerbating the challenges farmers face owing to the lack of reliable irrigation sources and soil degradation. Additionally, the area is characterized by rocky soil, poor agricultural practices, and limited livestock resources. Compounded by its mountainous and remote location, the region suffers from unreliable electricity supply. In response to these specific challenges, the Soil and Water Conservation Department devised the "Integrated Solar Powered Community Lift-Micro Irrigation Project" in Talwara. The Punjab Government granted this project permission to address the area's issues. The project objectives include irrigating agricultural lands, improving crop intensities, enhancing efficiency through judicious use of canal water and fertilizers, increasing yields and productivity with better-quality horticulture and non-horticulture produce, reducing water losses due to evaporation, preserving farmland, and improving the socioeconomic status of farmers. The project started in January 2015 and was completed and commissioned in August 2017. It is the largest standalone solar-operated community-based lift-cum-micro-irrigation project. The total gross area is 734 ha, while the cultural command area under the project is 664 ha, comprising 14 villages. The project was entirely automated. The permissible discharge of water from the canal for irrigation purposes is 15.7 cusecs through siphon systems to sumps, which are well equipped with sensors to monitor the water level both in the canal and sump. Furthermore, nine booster stations constructed at various elevations distribute water from sump wells to fields. Three thousand seven hundred ninety-eight solar photovoltaic panels generate 1.1 megawatts of electricity, and 46 pump sets of 18 to 23 hp capacities have been placed at base and booster stations (Figures 2 and 3).

Adoption and working of the system

For proper operation, the project has been subdivided into 378 minor sections, having 1.5 hectares of area each associated through distribution lines, where each line is outfitted with Remote Terminal Units (RTU) for transfer of signal to the base station to run and manage the water supply to that line, with pre-programmed time-based sensors, allowing every section to receive a devoted volume of water for irrigation. Control valves with a 2 mm/day duty are installed in the farmer's field and controlled by the central server room. Water User Associations have been formed among farmers to distribute water. The system is also capable of manual overriding if any technical problems occur. The system operates independently using solar power and does not rely on electricity from the grid. Its functionality depends on the intensity of the solar radiation. Considering the peak sunshine hours, approximately eight hours per day, an equitable irrigation distribution schedule was developed using Python programming. This schedule consisted of four two-hour slots, resulting in eight hours of daily irrigation. The schedule is followed six days a week, ensuring that farmers receive weekly irrigation. Micro-irrigation systems were implemented, with sprinklers requiring irrigation every sixth day and drip irrigation systems requiring irrigation every second day. Provisions have been made for backlog or missed irrigation if farmers cannot irrigate their fields for technical or other reasons. An irrigation schedule was created for the five schemes, further divided into zones or lines. Provisions have been made for backlog or missed irrigation in case farmers cannot irrigate their fields for technical or other reasons. An irrigation schedule has been created for the five schemes, further divided into zones or lines. The weekly program covered all farmers within a particular zone of any scheme. The Jupyter Notebook application runs the program, displaying the timing and irrigation slots for a specified day. Users can select a date to view the irrigation schedule for a particular day. The application provides necessary information for users to plan irrigation days and times for schemes and zones (Figure 4). As all five schemes are managed and interconnected via Supervisory Control and Data Acquisition (SCADA), this Python software has been integrated with the SCADA system. Programmable Logic Controllers (PLCs) monitor the flow and pressure valves and can communicate with Remote Terminal Units (RTUs) via radio, Ethernet, GSM, RS485, or GPRS. The field valve is connected to the PLCs, which control the valve opening based on a predefined operational schedule derived from the distribution schedule and total operational hours. This program allows users to create or modify the irrigation schedule according to the specific needs of their fields, thus providing flexibility in scheduling. The application was designed to be user-friendly, enabling anyone to access, review, and modify the schedule as required.

To ensure the equitable distribution, operation, and maintenance of the project among all farmers, it was crucial to establish an effective communication system that could provide training and support. Therefore, a communication network was implemented to engage stakeholders, enabling farmers to stay informed about the project's operation and distribution schedule and plan their activities accordingly. To facilitate this communication, an Android-based application was developed. Android is a comprehensive open-source platform specifically designed for mobile devices. It is backed by Google and owned by the Open Handset Alliance, which aims to drive innovation in mobile computing and provide consumers with an enhanced, cost-effective, and superior mobile experience (O'Reilly, 2022). Built on a Linux operating system, Android offers a complete software stack for mobile devices. It provides a rich set of system services through intuitive class files known as Android APIs. These APIs grant easy access to features such as location services, web connectivity, telephony, Wi-Fi, media handling, and camera functionality. Android development tools, frameworks, and software necessary for creating mobile applications are freely available (Mixon, 2022). An Android application is portable software designed explicitly for devices powered by Google's Android platform. It can be written in multiple programming languages (GitBook 2022). The communication application developed for the beneficiaries of the SCMIP project was written in Java and leveraged a vast array of native libraries written in C++.

Android application User Interface

The mobile device application's user interface has been designed to focus on usability and convenience, catering specifically to farmers utilizing the application. Various UI components have been incorporated to serve specific purposes in different activities. The home screen, or Home Page Activity, encompasses three fragments (tabs), an action bar (menu bar), and several menu items. The visual structure of the application is presented through different layout views, including a linear layout, relative layout, and list view. User interaction with an application is facilitated through various control and input methods. Control methods encompass buttons and a spinner, whereas input methods primarily consist of text fields. Additionally, users can navigate through different activities using menu items, such as irrigation maintenance and contact.

Account Creation and Login

Farmers associated with SPCMIP can quickly register an account on the application by providing details including their name, father/husband's name, mobile number, scheme number, and line number. After entering the required information, they can proceed by clicking on the "Register" button, which initiates obtaining a one-time password (OTP). The farmers were prompted to enter their registered mobile number to receive the OTP on the login page. By clicking the "Get OTP" button, a four-digit OTP is generated and sent to the farmer via a messaging service. The farmer then enters the received OTP to log into the application. To ensure user-friendliness for farmers, the application's user interface was developed in English and Punjabi. This approach allows farmers from different language backgrounds to easily read, comprehend, and utilize the application. Suppose a farmer encounters difficulties in creating an account through an application. In this case, an alternative provision is available, where a technical person or administrator can assist in the registration process through the server (Figure 5).

The main homepage of the Android application provides users with essential information related to their profile. Additionally, users can conveniently check the status of the canal water. This feature is especially beneficial for farmers located at a significant distance from the canal, as it offers a quick and accessible means of monitoring water availability. The canal water status displayed in the application was regularly updated and regulated by the administration. At the bottom of the main page, there are three tabs: maintenance, irrigation, and contact. Selecting the "Contact Us" tab opens a new section where users can access information about the committee responsible for their scheme. This feature assists users in obtaining scheme and line number details, facilitating the scheduling of meetings or managing other schemes or line-related tasks (Figure 6).

The irrigation tab within the application enables users to submit irrigation requests. These requests are transmitted to the administration via the server and subsequent messages are sent to the user to convey the acceptance or rejection of the request. In the event of an approved irrigation request, details such as the scheduled date, time, and assigned personnel responsible for assisting with the irrigation will be displayed. However, if an irrigation request is rejected, the reason for the rejection is communicated to the user through this page. In addition, users can access their historical irrigation requests for reference. Similarly, users can initiate maintenance requests through the designated feature. Furthermore, a "tap-to-speak" functionality is provided within the maintenance request, allowing farmers to communicate their specific maintenance needs verbally. All irrigation and maintenance requests from farmers are securely stored on the server and can be accessed at any time via the Internet. This approach provides transparency in the operational processes of the project while offering convenience to the farmers, who are more engaged with the project through this Android application (Figure 7).

The application's homepage provides a comprehensive overview of user details, including relevant personal information. It also offers various options such as assigning personnel responsible for irrigation, submitting irrigation and maintenance requests, accessing records, and engaging in messaging functionalities. Additionally, the homepage provides the capability to update the canal water status, enabling real-time communication of water availability (Figure 8).

User Details

In this section, users can update their details. This feature is particularly useful for adding users who cannot access the application through their mobile devices (Figure 9). Additionally, the administrator has the authority to add a water guard, which is crucial in assisting irrigation operations.

Irrigation and Maintenance Schedule

This section lists every irrigation request submitted by the farmers. The administrator can approve the irrigation request by providing the irrigation date and time, irrigation length, and any other information. A WaterGuard (a supporting staff) will be on hand to perform irrigation on his land. If the administrator denies the farmer's request, he must provide the administrator with a written explanation of his decision (Figure 10). Similarly, the maintenance tab lists every maintenance request submitted by the farmer. The Waterguard performing the requested maintenance must be in his area at the specified time and day for the administrator to approve the request. If the administrator denies the farmer's request, he must justify it.

Past Irrigation and Maintenance Records

Access to past irrigation and maintenance records is facilitated by entering specific parameters, such as the user's name, mobile number, scheme, or line number. Upon submission of these details, the application displays comprehensive records associated with the specified entry. This functionality is valuable for effectively scheduling irrigation activities, coordinating meetings, and monitoring farmers' actions. Furthermore, the administrator can utilize these records to identify and evaluate sensitive regions that have undergone multiple maintenance procedures, allowing prompt and appropriate actions to be taken as required (Figure 11).

Short Message Service Communication

The administrator can simultaneously use the platform's messaging domain to communicate with all farmers associated with a particular scheme and line number. The administrator can deliver messages to the entire group efficiently and effectively by inputting the respective scheme and line number. This feature is instrumental in coordinating farmer meetings, fostering collaborative decision-making processes, and facilitating broader participation when individual perspectives are required.

Analysis Factors

A random sample of 300 farmers was selected, and a benchmark survey was conducted as part of the analysis (Figure 12). The yield (in metric tons per hectare) of the selected farmers was recorded for the years preceding the implementation of the project (Singh & Vatta, 2013) for the year 2015-16, as well as for the years 2018–19, 2019–20, and 2020–21. Gross income (in Indian rupees) was calculated based on the minimum support price corresponding to the yield obtained in each respective year (source: https://farmer.gov.in/mspstatements.aspx). Subsequently, net income was determined by deducting the cost of cultivation from gross income. To evaluate the significant differences in the gross and net incomes of the farmers between the pre-project and post-project years, the gross incomes of the post-project years were calculated using the minimum support price of the pre-project year (i.e., the base year). The socio-economic impact on the farmers was assessed by analyzing the difference between their socio-economic status before the project's commencement and their post-project phase, specifically in yield and income augmentation. Data for 2018-19 represents the post-project year, but before the implementation of the irrigation schedule. A communication application was developed and implemented for the interaction between the farmers and the management, and data from to 2019-20 and 2020-21 represent the post-project years after the implementation of ICT in the project.

Results And Discussion

This project has positively impacted 1,200 households, benefiting approximately 8,500 individuals. The beneficiaries comprised 3,730 women and 2,450 individuals from Scheduled Castes (SC) (NITI Aayog, 2020). The integration of Information and Communication Technology (ICT) with an advanced Android application and micro-irrigation in the Solar Powered Community-based Micro-irrigation Project demonstrated a significant positive impact on the socio-economic well-being of farmers. Implementing the Android application effectively reduced the communication gap between farmers and project management, resulting in improved project oversight compared to previous phases. Farmers can now conveniently request irrigation and field maintenance services through the application, ensuring timely support in cases of missed irrigation or field upkeep requirements. This digitalization of irrigation and maintenance processes enables the storage of all related records on a centralized server, allowing administrators to access and process requests efficiently. The application also provides comprehensive information on irrigation and maintenance records, including the status of approved or rejected requests for technical reasons, fostering transparency and enhancing communication between farmers and project management. Additionally, the application offers real-time updates on canal water availability, particularly benefiting farmers in remote areas, and provides details on Water User Associations specific to the farmers' locations. Group messaging functionalities facilitate community-level meetings and efficient dissemination of messages among groups of farmers. Notably, previous studies such as Lantzos et al. (2013), Karkhile & Ghuge (2015), Singh et al. (2015), Ranjitha et al. (2019); Athirah (2020), Shah et al. (2023) have developed android applications, demonstrating the effectiveness of ICT in farm management, agricultural yield improvement, and farm maintenance. These examples exemplify the positive impact of ICT on farmers' lives and underscore the potential of such technological interventions in agricultural systems.

Impact of ICT on Community-based micro-irrigation Project

Implementing a micro-irrigation system resulted in a noteworthy increase in farmers' yields (t/ha) (Table 1, Figure 13). The mean yield of the farmers increased from 3.57 to 4.61 t/ha for wheat from 2.26 to 2.9 t/ha for maize. A short increase in the maize yield was observed because many farmers still depend upon monsoon rains in maize for their production. However, farmers are now adopting micro-irrigation for their crops. The percent increase in crops in post-project was also observed and found to 31.38 % in wheat, 38.90 in maize, and 67.42% in mustard crops post-project compared to pre-project years. Likewise, the project positively impacted the gross incomes and net incomes per hectare, demonstrating its significance in improving the livelihoods of farmers (Table 2, Figure 14). The gross incomes/ha increased from Rs. 76,695.33 to Rs. 1,05,829.23, indicating a 37.99 percent growth compared to pre-project years. Similarly, the net incomes/hectare, which was calculated after deducting the cost of cultivation, also increased from Rs. 34,251.08 to Rs. 62,134.00, indicating 81.41 percent growth after the adoption of ICT. A one-way analysis of variance (ANOVA) with Tukey's honestly significant difference (HSD) test, conducted at a 5% significance level, revealed a significant difference in the yields and incomes of farmers between the pre- and post-project years. Moreover, previous studies have reported similar outcomes, demonstrating increased crop yields by adopting micro-irrigation systems. For instance, Wang et al. (2022) observed significant improvements in yields and water productivity by implementing a subsurface drip system. Wu et al. (2021) found that a deficit drip irrigation system could enhance tomato growth, increase marketable yield, and improve water use efficiency. Additionally, Zong et al. (2021) discovered that using degradable mulch films in drip irrigation systems increases water availability for crops, resulting in higher productivity and improved soil water retention. Another study by Ma et al. (2021) investigated the effect of drip irrigation on nitrogen coupling and dry matter accumulation, providing valuable insights into the efficient utilization of water and nitrogen in arid regions.

The irrigation of the selected farmers was executed according to a precisely designed irrigation schedule facilitated by an Android application that assisted in the operation and maintenance of the irrigation system. Subsequently, the post-project years (2019-20 and 2020-21) witnessed an evaluation of changes in crop yields and incomes. A noteworthy increase in wheat and maize yields was observed during the post-project years, thereby validating the significance and advantages of employing Communication Technology in the project. Conversely, no substantial alteration in mustard yields was observed in the post-project period owing to the limited participation of selected farmers in mustard cultivation and the relatively smaller cultivated area dedicated to mustard (Table 1, Figure 12). However, gross incomes per hectare substantially increased even in the post-project years, emphasizing the importance of information and communication technology (ICT) in solar-powered projects and its beneficial effects on farmers. Similarly, net income per hectare showed comparable and significant growth (Table 2, Figure 14). These analyses collectively establish the critical role of ICT in promoting positive changes and enhancing farmers' livelihoods.

Table 1: Mean scores of yields (t/ha) of all farmers

Mean Scores	Wheat yield	Maize yield	Mustard yield
Pre Project	3.57^{a}±1.85	2.26^{a} ± 0.66	0.29^{a}±0.42
Post Project (2018-19)	4.53^{b} ± 0.38	2.91^{b} ± 0.46	0.43^{b}±0.59
Post Project (2019-20)	4.61^{b} ±0.31	2.98^{b} ± 0.42	0.45^{b}±0.62
Post Project (2020-21).	4.69^{c}±0.32	3.14^{c}±0.39	0.48^{b}±0.67

Values are expressed as mean ± SD.

Mean values followed with different superscripts are significantly different ($p<0.05$) using Tukey's test.

Percent increase in the yields post-project overall farmers.

Crop	Wheat yield	Maize yield	Mustard yield
Post-Project (2018-19)	26.83	29.11	49.38
Post-Project (2019-20)	29.02	32.17	57.34
Post-Project (2020-21)	31.38	38.90	67.42

Table 2: Incomes/ha for all farmers

Mean scores of Gross income/ha and Net income/ha for all Farmers

Mean Scores	Gross income/ha (Rs.)	Net income/ha (Rs.)
Pre Project	$76,695.33^{a}$± 1,874.93	$34,251.08^{a}$ ± 1,710.64
Post Project (2018-19).	$1,00,971.08^{b}$ ± 849.01	$57,275.85^{b}$± 969.29
Post Project (2019-20).	$1,02,777.26^{c}$ ± 818.82	$59,082.03^{c}$ ± 918.83
Post Project (2020-21).	$1,05,829.23^{c}$±797.67	$62,134.00^{c}$±958.68

Values are expressed as mean ± SE.

Mean values followed with different superscripts are significantly different ($p<0.05$) using Tukey's test.

Percentage increase in the income/ha post-project for all farmers

Incomes	Gross income/ha	Net income/ha
Post-Project (2018-19)	31.65	67.22
Post-Project (2019-20)	34.01	72.50
Post-Project (2020-21)	37.99	81.41

The findings of this study provide compelling evidence of the substantial impact of adopting information and communication technology (ICT) and automated micro-irrigation systems (MIS) on farmers' livelihoods. Moreover, it highlights the transformative effect of this project on farmers' lives, as evidenced by the significant increase in post-project yields. Additionally, active community involvement proves advantageous for farmers. Existing research emphasizes the importance of community engagement, particularly in irrigation management. For instance, Leroy et al. (2022) studied two communities in the Venezuelan Andes and demonstrated how they adapted their irrigation management rules in response to economic, institutional, and environmental changes. The communities implemented improved water-sharing mechanisms, embraced more efficient irrigation technologies, restored infrastructure, and conserved high-altitude wetlands. Similarly, Kuntiyawichai et al. (2017) assessed community participation in the Nam Haad Left Irrigation Project (NHLIP), revealing the willingness of community members to cooperate and support initiatives to enhance and manage the NHLIP project. Ayalneh (2004) provides an illustrative example of successful irrigation management within community-level projects, showcasing adequate water and resource utilization. Other studies have reinforced the significance of implementing micro-irrigation systems at the community level. Yashashwini M.A (2016) highlights the substantial benefits of irrigation within the Hemavathi farming community. Barbir and Leal (2012) assert that micro-irrigation systems hold great potential in improving community water management, farm productivity, and household food security. Vaibhav and Ajay (2018) conducted a case study in Kodinar, Gujarat, and its surrounding areas to assess the effectiveness of MIS and traditional irrigation techniques. Takayama et al. (2018) examined the characteristics of water user associations (WUAs) that influence the success of collective action in irrigation management. Their research emphasized the need for policies to reinforce community social ties to prevent a decline in collective action for irrigation management. Huong (2021) assessed the sustainability of the community-based water resource management of irrigation for agriculture in Hau Giang province, Vietnam. With an assessment result 0.54, he represents a picture of community participation in water resource management. In conclusion, these findings strongly support the advantages of implementing MIS at the community level and suggest that similar projects could be replicated in other regions or states facing similar challenges, thereby leveraging the benefits of micro-irrigation to enhance the socioeconomic well-being of farmers.

Conclusion

This paper focuses on applying Information and Communication Technologies (ICT) to the Solar-Powered Community-based Micro-irrigation project in Talwara, Hoshiarpur. The assessment of community engagement in irrigation water management yielded significant findings, highlighting the project's positive impact on farmers' lives in the region. The study revealed a remarkable increase in yield (t/ha) and income per hectare among marginal, small, and semi-medium category farmers in the post-project years (2018-19, 2019-20, and 2020-21). These outcomes signify the community micro-irrigation project's effectiveness in improving farmers' agricultural productivity and economic conditions in Hoshiarpur. Moreover, the overall positive changes observed across all farmer categories provide strong evidence of the importance of such projects in the region. The findings of this study hold valuable implications for irrigation water management practices not only in Hoshiarpur but also in other regions facing similar agricultural challenges. As the IoT sector develops, technological advancements are expected to result in more efficient, faster, and cost-effective micro-irrigation systems. The future integration of mobile phones instead of personal computers further enhances the accessibility and usability of these systems. An example of an ICT application in Hoshiarpur demonstrates how such systems operate in real-time applications. It is a model for successfully implementing ICT-based solutions in other agricultural communities and guiding future projects in similar settings. Acknowledging the need for further research and development in this field is essential. Continued advancements in ICT and IoT technologies will contribute to the refinement and optimization of solar-powered community-based micro-irrigation systems. Moreover, addressing potential challenges and barriers to adoption, such as cost-effectiveness and user-friendliness, will ensure these initiatives' widespread implementation and long-term sustainability. This research highlights the positive outcomes and benefits of a Solar-Powered Community-based Micro-irrigation project in Talwara, Hoshiarpur. These findings emphasize the significance of community engagement and ICT in improving agricultural productivity and livelihoods. As the field progresses, the lessons learned from this study will inform future endeavours in irrigation water management, paving the way for sustainable agricultural practices and enhanced socioeconomic conditions in Hoshiarpur and beyond regions.

Declarations

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Conflict of Interest

The authors declare no conflict of interest

Data availability statement

The data supporting this study's findings are incorporated within the paper and can be assessed without restrictions from the authors upon reasonable request.

Geological Information

The project site is located at Hoshiarpur, Punjab India

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Figures

Figure 1

Role of ICT in agriculture

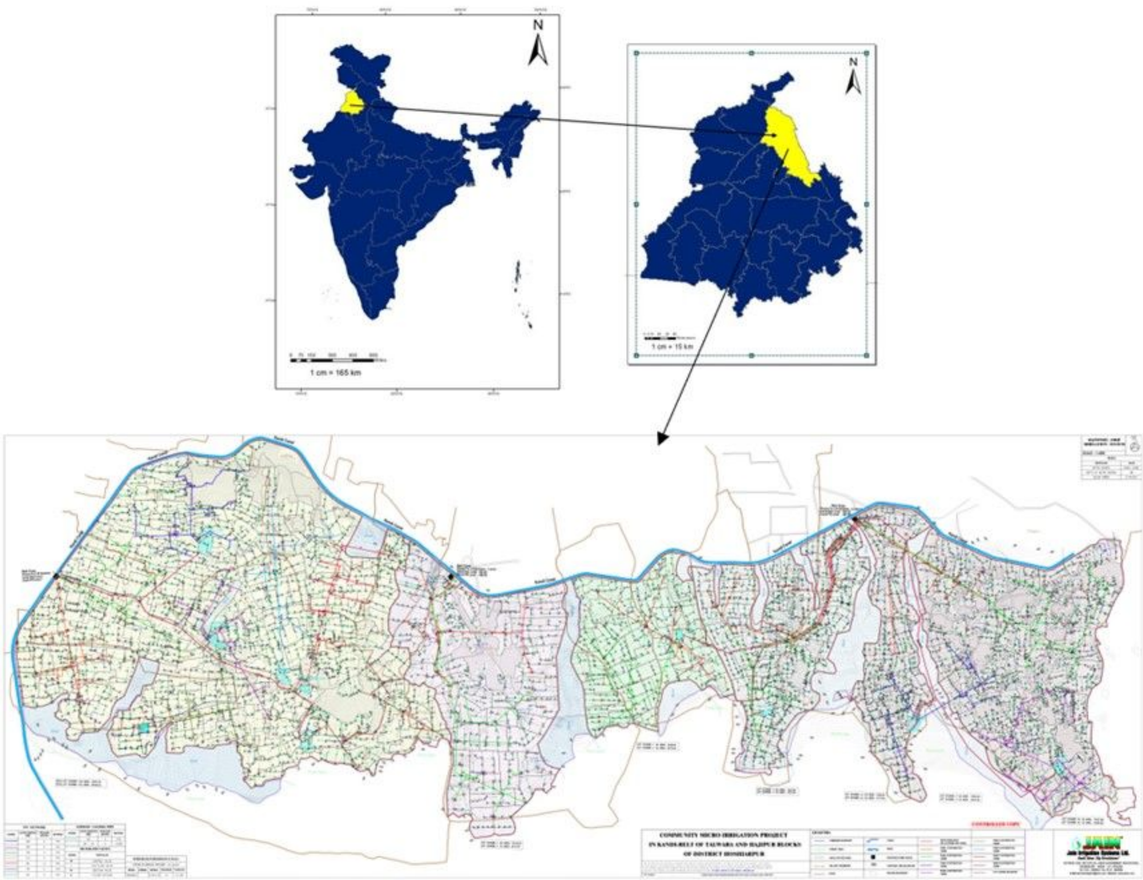


Figure 2

Layout of the study area Courtesy: Jain Irrigations Systems Ltd

Figure 3

Solar-powered community micro-irrigation project in Talwara, Hoshiarpur

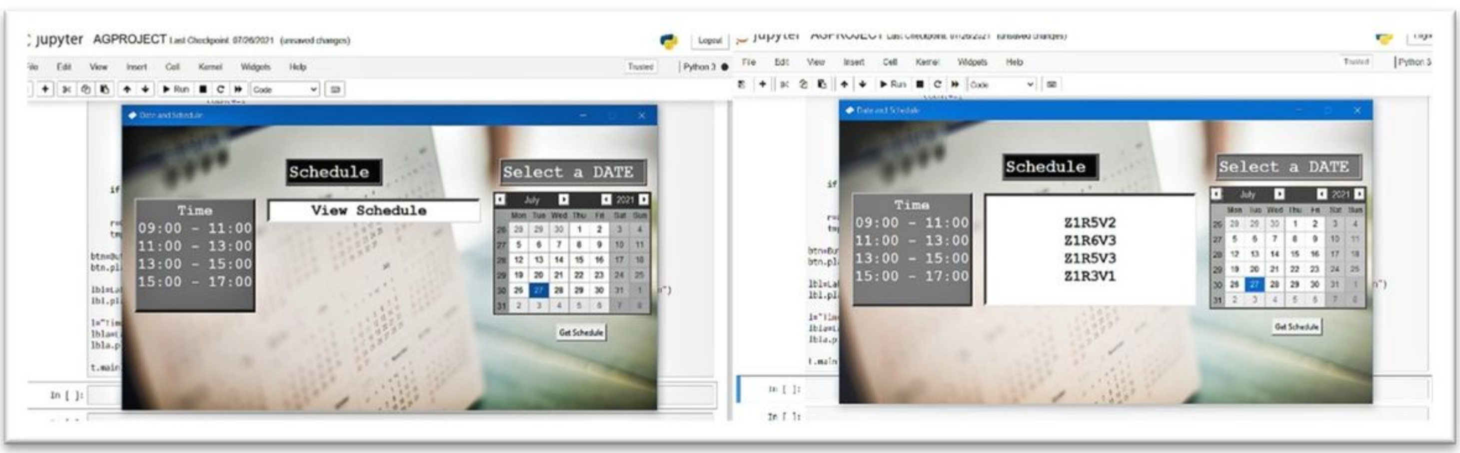


Figure 4

Irrigation schedule in Jupyter Notebook Z represents zone or scheme number, R is RTU number, and V represents valve number

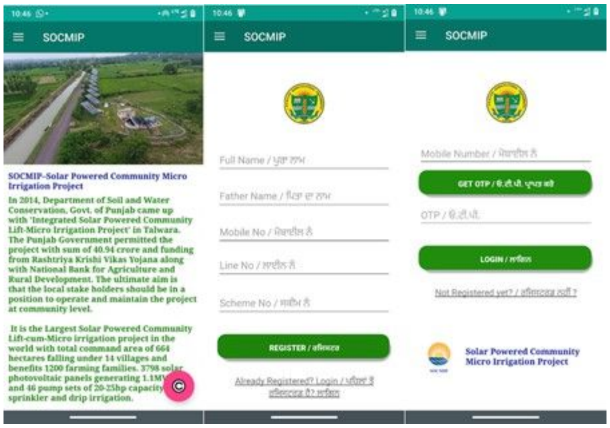


Figure 5

Home (a), registration (b), and login (c) page of the designed Android application

Main Home Page

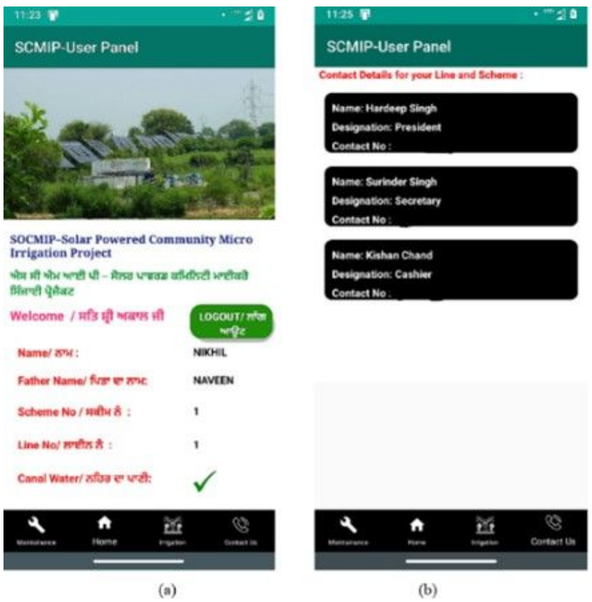


Figure 6

Main home tab (a) and Contact Us tab (b) of the designed Android application

Irrigation and Maintenance Request

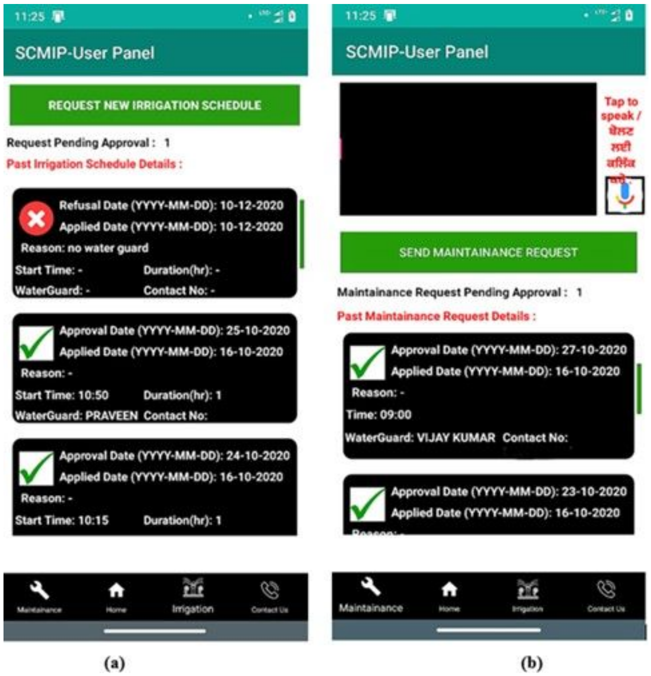


Figure 7

Irrigation (a) and maintenance tab (b) in the Android application

Database

Figure 8

Administrator Home page

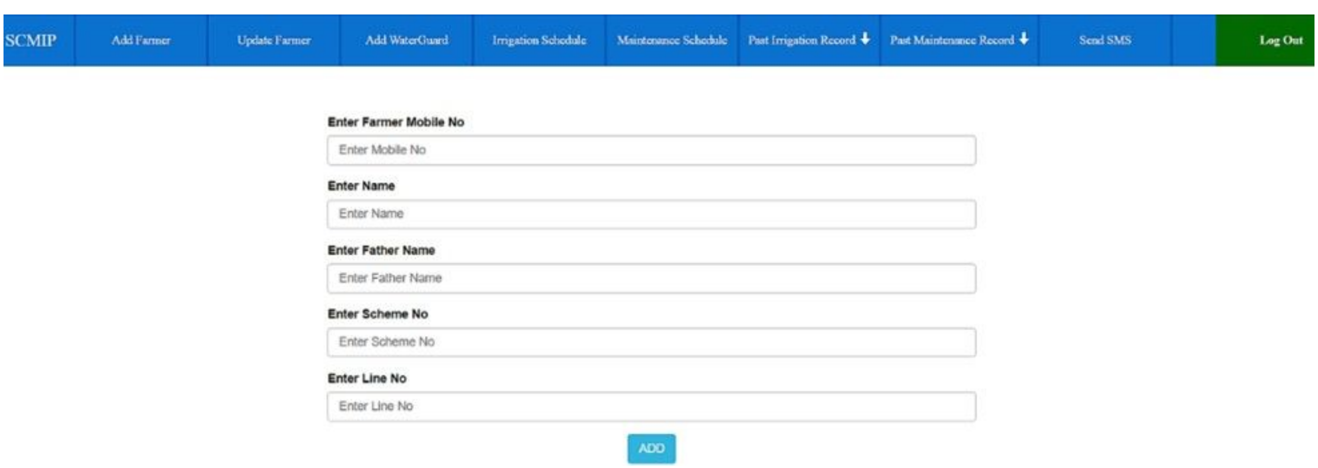
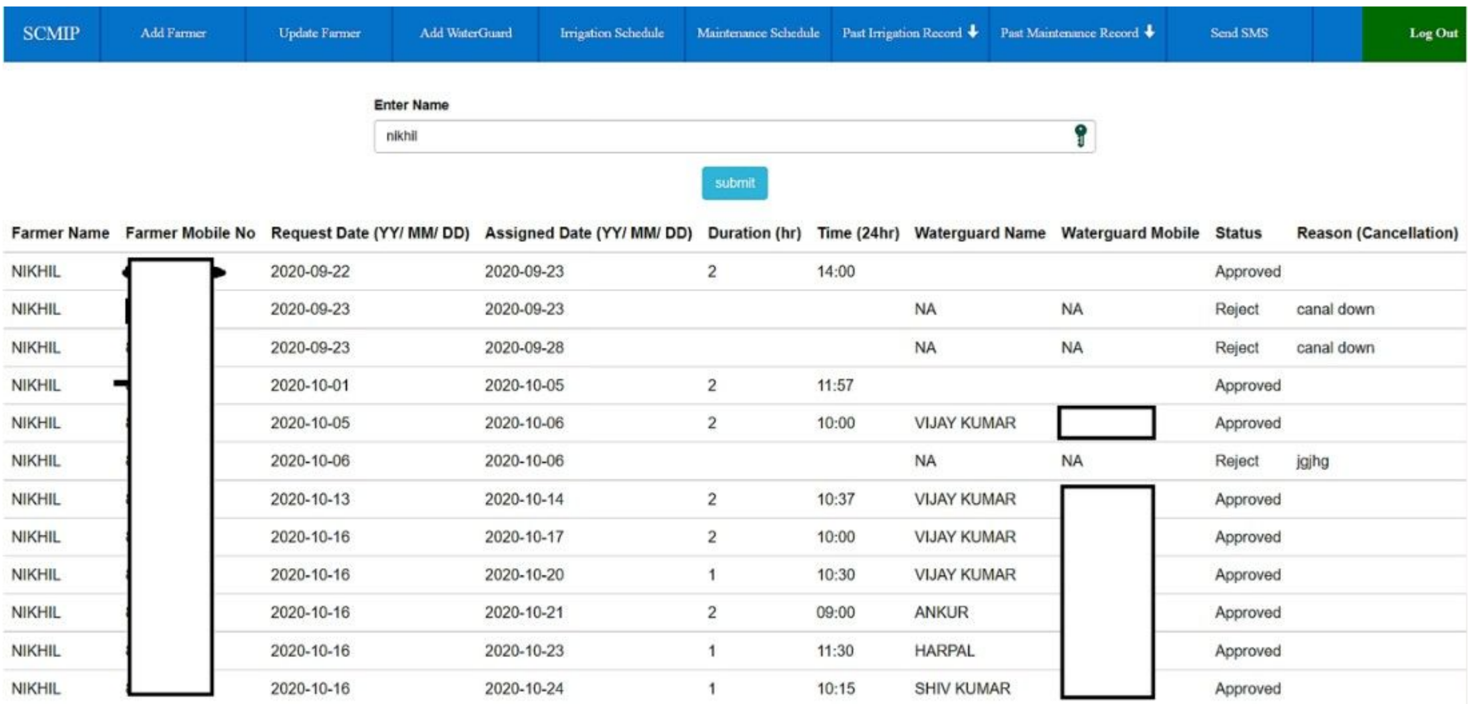


Figure 9

Update User details in the database

Figure 10

Irrigation and Maintenance Scheduling



Farmer Name	Farmer Mobile No	Request Date (YY/ MM/ DD)	Assigned Date (YY/ MM/ DD)	Duration (hr)	Time (24hr)	Waterguard Name	Waterguard Mobile	Status	Reason (Cancellation)
NIKHIL	[redacted]	2020-09-22	2020-09-23	2	14:00			Approved	
NIKHIL	[redacted]	2020-09-23	2020-09-23			NA	NA	Reject	canal down
NIKHIL	[redacted]	2020-09-23	2020-09-28			NA	NA	Reject	canal down
NIKHIL	[redacted]	2020-10-01	2020-10-05	2	11:57			Approved	
NIKHIL	[redacted]	2020-10-05	2020-10-06	2	10:00	VIJAY KUMAR	[redacted]	Approved	
NIKHIL	[redacted]	2020-10-06	2020-10-06			NA	NA	Reject	jgjhg
NIKHIL	[redacted]	2020-10-13	2020-10-14	2	10:37	VIJAY KUMAR	[redacted]	Approved	
NIKHIL	[redacted]	2020-10-16	2020-10-17	2	10:00	VIJAY KUMAR	[redacted]	Approved	
NIKHIL	[redacted]	2020-10-16	2020-10-20	1	10:30	VIJAY KUMAR	[redacted]	Approved	
NIKHIL	[redacted]	2020-10-16	2020-10-21	2	09:00	ANKUR	[redacted]	Approved	
NIKHIL	[redacted]	2020-10-16	2020-10-23	1	11:30	HARPAL	[redacted]	Approved	
NIKHIL	[redacted]	2020-10-16	2020-10-24	1	10:15	SHIV KUMAR	[redacted]	Approved	

Figure 11

Irrigation and maintenance records sorted by name

Figure 12

Baseline survey of the farmers

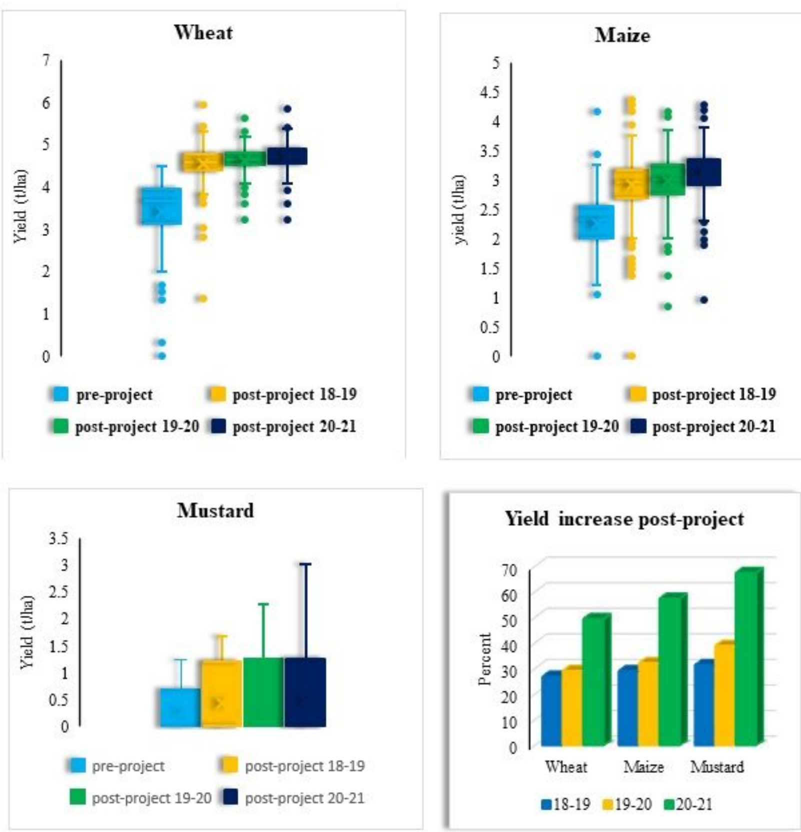


Figure 13

Yield (t/ha) and percent increase in yield post-project years of farmers

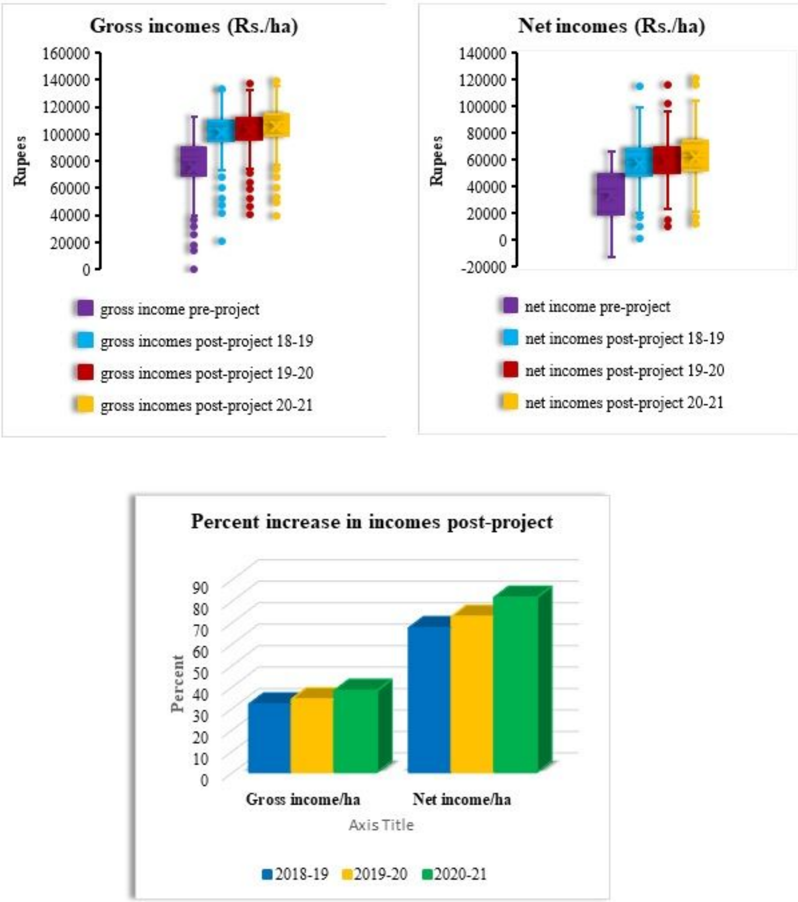


Figure 14

Gross and Net incomes (Rs./ha) and percent increase of incomes post-project

Supplementary Files

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- GA.png