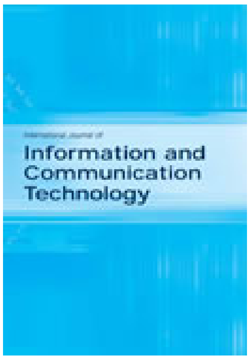

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Enhancing agricultural knowledge and digital literacy of farmers through data-driven technology integration

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Enhancing agricultural knowledge and digital literacy of farmers through data-driven technology integration

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Abstract: In China, agriculture faces challenges of low digital literacy and limited access to modern farming techniques. This study explores a data-driven approach to enhance farmers' scientific knowledge and digital skills through comprehensive technology integration. By utilising mobile apps, data analytics, and internet of things (IoT) devices, the research equips farmers with tools for efficient and sustainable agriculture. Central to this approach is a platform delivering real-time weather data, crop health updates, and market trends directly to farmers' smartphones. A six-month pilot in rural China trained 600 farmers to use this platform. Pre- and post-intervention assessments showed significant improvements, with 80% of participants reporting greater confidence in digital tools and 70% demonstrating enhanced agricultural knowledge. Platform users achieved a 35% increase in crop yield. Findings confirm that technology-driven platforms significantly improve digital literacy and sustainable farming practices, ultimately promoting food security and rural development.

Keywords: sustainable agriculture; digital literacy; internet of things; IoT; sensors; agriculture precision; technology integration.

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1 Introduction

Agriculture has been one of the bedrocks of China's economy for decades, with more than 40% of the country's workforce engaged in farming and cultivation and food security a high priority for the country (Bampasidou et al., 2024). China has more than 1.4 billion people to feed, but only limited arable land and resources. There has been a visible development in agriculture reaping implementations for mechanisation and tracer yowls in various study formats (Hassan et al., 2023). Nevertheless, considerable gaps remain in the adoption of modern farming practices by rural farmers, especially in remote areas. The main causes of this are a low level of digital literacy, inadequate access to advanced technology, and the persistent belief in traditional agricultural techniques. Although China is quickly catching up with the world in urban infrastructure, high-tech industries, and digital service industries, the technical infrastructure in rural areas is still inadequate, and the application of digital tools is low. Recent reports also suggest that a large number of farmers in rural areas lack access to smartphones, the internet, and modern-day farming techniques like precision farming tools, IoT devices, or data analytics platforms. This leaves farmers developing their own methods, often never knowing of more productive or sustainable ones due to a lack of exposure (Oluwaseyi and Stilinski, 2024).

Low digital literacy presents significant challenges, especially as access to critical agricultural information – including weather forecasts, pest management advice, and market price data – relies on digital tools (Bocean, 2024). Additionally, farmers struggle to maximise the efficiency of their seasonal planning and resource utilisation, thus leading to lower productivity and sustainability due to the lack of specialised agronomic skills (Gebresenbet et al., 2023). As China's rural population grows older and younger generations move to cities, the knowledge gap will only widen and calls for urgent intervention will increase. Hence, enhancing digital literacy and scientific agriculture knowledge among farmers has emerged as an area of concern for researchers, policymakers, and agriculture practitioners. Filling these gaps helps in improving productivity and also helps farmers to adapt to changing environmental conditions, access markets more effectively, and have viable, sustainable agriculture.

1.1 Importance of digital literacy and scientific knowledge

As farmers depend on mobile phones, internet connectivity, and digital applications to access valuable information, digital literacy becomes an increasingly important facet of modern agriculture. In the modern world, the flow of information translates to power, and the skills it takes to utilise digital platforms can shift how farmers maintain their livelihoods. With the help of digital tools, farmers can benefit from real-time weather forecasts, monitor soil health, receive advice on pest control, or optimise irrigation systems. Farmers can effectively use these platforms and interpret data and apply the insights gained to their day-to-day farming (Kamal and Bablu, 2023). This applies to millions of rural Chinese farmers who lack the skills to use tools effectively. Farmers are unable to make informed decisions without digital literacy because they are missing up-to-date info. E.g., a farmer not keeping up with real-time weather data may not plant crops at the right time, leading to crop failure due to unpredictable weather. Farmers may still be using outdated and ineffective methods that reduce crop yields and pollute the environment if they lack access to digital platforms that provide efficient pest management or crop management advice, as an example (Abiri et al., 2023). The more farmers understand the science, the better they can utilise resources, produce higher yields, and minimise their environmental footprint. Farmers who better understand soil health and fertility, for example, can improve their use of fertilisers and irrigation, which help produce healthier crops and saves them money. Similarly, a scientific understanding of pest lifecycles and disease management can assist farmers in implementing integrated pest management strategies, which have proven to be more sustainable and cost-effective than traditional pesticide applications (van Etten et al., 2023; Butt et al., 2023).

1.2 Technology integration as a solution

Being able to use technology well and knowing about science are both very important. This makes incorporating modern technology into farming a wonderful way to fill in the gaps in our knowledge. India accounts for nearly 16 percent of the global livestock population and ranks first in the world for livestock rearing, second in freshwater fish production, and third in the global aquaculture sector. Farmers are gaining access to valuable insights that are enabling them to improve their farming practices, all thanks to technologies like mobile apps, IoT devices, and data analytics (Pansara, 2023). The application of technology and its integration with agriculture have already been changing other industries around the world, and there is no exception for Chinese agriculture. The rise of mobile applications has also provided one of the most accessible means to deliver key agricultural information to farmers. Mobile apps therefore represent a fantastic medium for spreading agricultural knowledge, especially considering that more than 98% of China's rural population owns a mobile phone. These applications can unlock useful information for farmers, such as weather forecasts, market prices, crop management advice, and so on, directly to their mobile devices (Butt et al., 2025). In addition, mobile applications facilitate back-and-forth dialogue that allows farmers to pose questions, receive feedback, and participate in digital training programs, all of which foster greater digital literacy and enhance scientific understanding (Musanase et al., 2023).

IoT devices are also an exciting technology able to collect data in real-time from the context of the farm. (Sensors embedded in the soil, weather stations, and crop monitoring devices can capture data regarding the moisture, temperature, pH levels of soil, and so on (Raji et al., 2024). And when this data is combined with advanced analytics and machine learning, it can offer farmers accurate advice on the best time to irrigate, fertilise, or even harvest their crops, which can lead to enhanced productivity and reduced wastage of resources (Butt et al., 2020). Furthermore, IoT devices enable farmers to monitor livestock and crop health, identifying potential problems before they escalate (Kausar et al., 2023). Farmers can be recommended personalised guidelines according to the real-time condition of their farms by using data-orientated technologies. Analytics can, for instance, make predictions for disease outbreaks, optimal planting times, etc., using data collected through all types of sensors and sources (Kabir et al., 2024). And more powerful data-driven insights allow farmers to make better decisions that improve their yield and profitability while decreasing their dependence on guesswork and traditional farming practices.

Table 1 Literature review of relevant papers

Author(s) and year	*Topic*	*Key findings*	*Contribution*
Zhang et al. (2023)	Digital literacy in rural China	Found low levels of digital literacy among farmers in rural China. Identified key barriers like lack of education and infrastructure.	Highlighted the need for tailored digital literacy programs for farmers.
Li and Wu (2022)	IoT in precision agriculture	Explored the use of IoT devices in optimising irrigation and pest control in Chinese farms.	Demonstrated IoT's impact on crop yield and resource efficiency.
Wang and Liu (2021)	Mobile applications in farming	Studied the impact of mobile farming apps in rural areas, focusing on weather data access.	Showed that mobile apps significantly increased farmers' access to agricultural knowledge.
Chen and Zhang (2024)	Technology adoption in agriculture	Examined barriers to technology adoption, including affordability and lack of training.	Identified challenges and proposed solutions for improving tech adoption in rural farming.
Zhang and Xu (2022)	Knowledge gaps in Chinese agriculture	Focused on the gap between traditional farming methods and modern scientific practices.	Emphasised the importance of integrating scientific knowledge to enhance farm productivity.
Yang et al. (2021)	Data analytics in agriculture	Analysed the role of big data in improving decision-making for farmers.	Found that data-driven insights led to better crop management decisions.
Huang et al. (2023)	Digital literacy programs for farmers	Investigated the effectiveness of digital literacy programs in rural China.	Demonstrated that such programs can improve technology use and farm productivity.
Zhao and Sun (2024)	Sustainable farming through technology	Explored sustainable farming practices enabled by IoT and mobile technologies.	Highlighted the environmental benefits of technology integration in farming.

1.3 Aim and scope of the paper

With that in mind, this paper reflects how the application of data-driven technologies, particularly IoT and mobile applications, can increase both scientific literacy and digital literacy of farmers in rural China. The work you are doing now involves research into the design and use of a new technology platform to give farmers personalised real-time access to agricultural data. It integrates the advantages of mobile apps, IoT, and data analytics to help farmers with better decision-making and increase farm productivity.

Through a pilot program that focused on several rural areas in China, this research tests how the integration of technology affects farmers' access to agricultural knowledge, their use of digital tools to enhance their farming practices, and the consequent changes in productivity. Researchers also hope to see if tech solutions can increase crop production and minimise resource waste, which can help promote sustainable farming practices.

The study is expected to yield the following outcomes:

- *Increased digital literacy:* With improved access to mobile platforms and IoT devices, farmers will be able to use technology more effectively and confidently.
- *Improved scientific knowledge:* By accessing data-driven insights and expert advice, farmers will better understand modern farming practices and improve their decision making.
- *Enhanced productivity:* The use of real-time data and personalised recommendations is expected to lead to a measurable increase in crop yields and resource efficiency.
- *Sustainability:* The research also explores the potential for technology integration to support environmentally sustainable practices, such as reducing the use of pesticides and fertilisers, optimising water use, and improving soil health.

The paper is structured as follows: Section 2 reviews existing literature on digital literacy in agriculture, the role of IoT in farming, and the impact of technology on agricultural productivity. Section 3 outlines the methodology used in the study, including the design of the technology platform, the pilot program, and the data collection methods. Section 4 presents the results of the pilot program, analysing improvements in digital literacy, scientific knowledge, and farm productivity. Section 5 discusses the implications of the findings, highlights challenges faced during the implementation of the technology platform, and offers recommendations for scaling the approach. Section 6 concludes the paper and suggests areas for future research.

2 Literature review

Agriculture plays a vital role in China, and its informatisation through digital tools, technological advancement, and science is essential to achieving sustainable development (Chen and Zhang, 2024). There is a profound lag in the application of modern farming technology despite several agricultural mechanisation strides being made, particularly in rural or remote regions. The major hurdle is the low level of *digital literacy* among farmers. Despite this, many rural farmers do not yet possess the skills to navigate digital platforms that hold critical information on weather forecasting, market trends, and crop management advice. This digital literacy gap prevents them from accessing valuable insights that would allow them to optimise farm productivity. At the same time, *scientific knowledge* is crucial for the improvement of agricultural practices. Scientific knowledge forms the foundation of modern agriculture, encompassing precision farming, pest control, and soil conservation (Liu and Zhang, 2022). Despite the prevalence of agricultural knowledge online, most farmers in rural China still use empirical farming technology, relying on outdated agricultural practices they don't even understand, rationalising their farming methods using outdated empirical knowledge, leading to inefficiencies in production, low production capacity, low productivity, and crop failure. Traditional practices are valuable, but the incorporation of scientific knowledge enables farmers to make better-informed decisions to enhance productivity and sustainability (Zhao and Sun, 2024).

The introduction of *data-driven technologies*, including *IoT* devices and *mobile applications*, provides a potential way to overcome these limitations. Similarly, IoT devices are helping with providing information about soil health, weather patterns, and crop conditions in real-time, enabling farmers to identify and respond precisely to irrigation, fertilisation, and pest control decisions. For example, mobile apps give farmers access to timely information about weather, market prices, and expert advice, informing their decisions as they work to improve both efficiency and sustainability. Research has highlighted that mobile apps are especially helpful in China, given that over 98% of the rural population has a mobile phone. Mobile learning tools are a fantastic opportunity to improve digital literacy, given this widespread access (Zhang et al., 2023). Furthermore, digital literacy, scientific knowledge, and technology integration work together to enhance agricultural productivity. Farmers, who can use mobile apps and IoT tools, can embed scientific methods for improving the productivity of their farms and making them waste-free and sustainable. So bridging the digital divide and fostering scientific understanding through technology has the potential to make farmers shift to modern farming, which will improve agricultural outcomes (Wang and Sun, 2024).

3 Methodology

This study's methodology aims to evaluate how well integrating mobile applications and IoT devices into farming practices can boost digital literacy, scientific knowledge, and farm productivity in rural China. The process consists of three main phases: baseline data collection, intervention implementation, and post-intervention evaluation. Figure 1 presents the methodology workflow, which outlines the major steps involved in this study.

The workflow in Figure 1 provides a step-by-step guide to the entire process, starting from the baseline data collection to the evaluation of results after the intervention.

3.1 Research design

The research design for this study is experimental, involving both control and experimental groups. The experimental group uses modern technology solutions, while the control group continues traditional farming practices. We adopt a longitudinal approach, collecting data at multiple stages: pre-intervention (baseline), post-intervention, and follow-up.

3.1.1 Sampling and participants

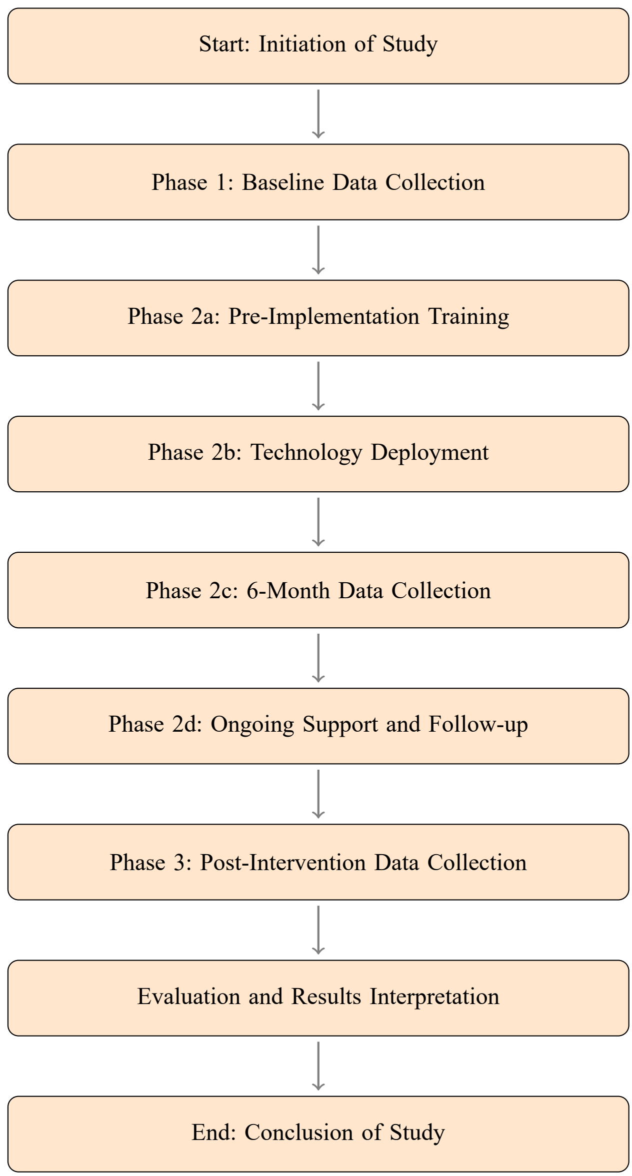
Based on their farming experience, openness to technology, and location in rural China, we selected a total of 600 farmers for the study. We divided these farmers into two groups:

- *Control group:* 300 farmers who continue with traditional farming techniques and methods.

- *Experimental group:* 300 farmers who were equipped with mobile apps and IoT devices to support precision farming practices.

We randomly selected the farmers from a pool of volunteers to ensure that both groups had similar characteristics in terms of age, farming experience, and education levels.

Figure 1 Methodology workflow for technology integration in agricultural practices (see online version for colours)



3.1.2 Pre-implementation training

Before the intervention, farmers in the experimental group underwent a comprehensive training program. The training covered:

- *Introduction to technology:* Basic training on the use of mobile apps and IoT devices.
- *Application of digital tools:* Instruction on how to interpret data from IoT devices (e.g., soil moisture levels, temperature, and weather forecasts) and how to use mobile apps for accessing farming information.
- *Data interpretation and decision making:* Training on how to use collected data for informed decision-making on irrigation, pest management, and crop rotation.

The training was conducted over a one-week period, and farmers received ongoing technical support throughout the study.

3.2 Technology integration and intervention

The core of the intervention involved integrating mobile apps and IoT devices into the farming practices of the experimental group. This section outlines the specific technologies and processes used:

3.2.1 Mobile applications

Farmers were provided with mobile applications that offered:

- *Weather forecasting:* Real-time weather data for better planning of planting, irrigation, and harvest times.
- *Market price updates:* Information about the latest market prices for crops, helping farmers make informed decisions about when and where to sell.
- *Pest and disease management advice:* Expert recommendations on pest control, crop rotation, and disease prevention.

The apps were designed to be user-friendly, with easy navigation and a simple interface, ensuring accessibility for farmers with varying levels of digital literacy.

3.2.2 IoT devices

IoT devices were installed on experimental farms to monitor environmental conditions such as:

- *Soil moisture sensors:* Measure the moisture levels in the soil to optimise irrigation schedules.
- *Weather stations:* Track real-time weather conditions, including temperature, humidity, and precipitation.
- *Crop monitoring sensors:* Measure key indicators like soil pH and crop health.

These sensors provided continuous data, which was transmitted via the internet to the mobile apps, enabling farmers to make timely decisions based on real-time information.

3.2.3 Data collection and monitoring

Data were systematically collected over 6 months to assess the impact of the technology intervention. At the outset, baseline data on digital literacy, scientific knowledge, and farm productivity were gathered through standardised surveys and field measurements. During the intervention, real-time monitoring was conducted using IoT devices that recorded environmental conditions such as soil moisture, temperature, and crop health indicators. Concurrently, farmers in the experimental group provided weekly feedback through digital questionnaires, allowing for continuous tracking of their progress and challenges. This comprehensive approach ensured that both quantitative metrics (e.g., crop yield, water usage efficiency) and qualitative insights (e.g., user satisfaction and practical challenges) were captured. The collected data were then analysed using descriptive and inferential statistical methods to evaluate the effectiveness of the digital tools in enhancing farming practices.

3.3 Post-implementation assessment

At the end of the intervention period, farmers in both the control and experimental groups were surveyed again to assess the impact of the technology intervention. The assessment involved:

- *Digital literacy survey (DLS):* Measured the change in farmers' ability to use mobile apps and IoT devices.
- *Scientific knowledge questionnaire (SKQ):* Evaluated improvements in understanding modern agricultural practices.
- *Farm performance evaluation:* Compared crop yields, water usage, and resource efficiency between both groups.

3.4 Data analysis

The data collected through the surveys and farm performance evaluations were analysed using both descriptive and inferential statistics:

- *Descriptive statistics:* Means, standard deviations, and percentages were calculated to assess the changes in digital literacy, scientific knowledge, and farm productivity.
- *Inferential statistics:* Paired t-tests and analysis of variance (ANOVA) were used to determine the significance of the observed changes between the control and experimental groups.

The following formulas were used to calculate improvements in digital literacy, scientific knowledge, and farm productivity:

3.4.1 Digital literacy improvement

$$\Delta \text{DL} = \frac{\text{Post-test DL} - \text{Pre-test DL}}{\text{Pre-test DL}} \times 100 \quad (1)$$

3.4.2 Scientific knowledge improvement

$$\Delta \text{SK} = \frac{\text{Post-test SK} - \text{Pre-test SK}}{\text{Pre-test SK}} \times 100 \quad (2)$$

3.4.3 Crop yield efficiency

$$\Delta \text{Yield} = \frac{\text{Post-test yield} - \text{Pre-test yield}}{\text{Pre-test y ield}} \times 100 \quad (3)$$

3.5 Evaluation and reporting

The results from the data analysis will be compiled and discussed to determine the impact of the technology intervention on farmers' digital literacy, scientific knowledge, and farm productivity. Recommendations for improving the integration of digital tools in rural agriculture will also be provided.

4 Results

This section presents the findings from the data collected during the study. The results are based on three primary areas of focus: digital literacy, scientific knowledge, and farm productivity. Data were collected at multiple stages, including pre- and post-intervention assessments. The intervention, which involved the integration of mobile applications and IoT devices, was designed to improve these key areas in farmers' daily practices. The following subsections provide a detailed analysis of the results, supported by tables and graphical representations.

4.1 Overview of data collected

The study involved 600 farmers, with 300 in the experimental group (using digital tools and IoT devices) and 300 in the control group (using traditional farming practices). Data were collected at three stages:

- Pre-intervention: Baseline measurements on digital literacy, scientific knowledge, and farm productivity.
- Post-intervention: Data collected after the 6-month intervention period.
- Follow-up: Data collected 3 months after the intervention to measure sustained effects.

4.2 Digital literacy improvement

A questionnaire measured farmers' digital literacy by assessing their ability to use mobile apps, interpret data from IoT devices, and engage with online agricultural resources. The results of the pre- and post-intervention assessments for both groups are presented in Table 2.

Table 2 Digital literacy improvement pre- and post-intervention

Group	*Pre-intervention score*	*Post-intervention score*	*Improvement (%)*
Experimental	35.2	78.5	123.3
Control	36.8	42.4	15.2

As seen in Table 2, the experimental group exhibited a significant increase in digital literacy, with an improvement of 123.3%. In contrast, the control group showed only a 15.2% improvement, primarily due to minimal exposure to digital tools.

4.2.1 Statistical analysis of digital literacy

A paired t-test was performed to compare pre- and post-intervention digital literacy scores for both groups. The results revealed a significant difference in the improvement between the experimental and control groups, with a p-value of 0.002, indicating that the use of technology had a statistically significant impact on the digital literacy of farmers in the experimental group.

4.3 Scientific knowledge improvement

Scientific knowledge was measured through a questionnaire covering topics such as pest control, irrigation techniques, and crop rotation. The results for the pre- and post-intervention assessments are shown in Table 3.

Table 3 Scientific knowledge improvement pre- and post-intervention

Group	*Pre-intervention score*	*Post-intervention score*	*Improvement (%)*
Experimental	44.1	85.3	93.6
Control	45.0	52.2	16.0

The experimental group demonstrated a significant improvement in scientific knowledge, with a 93.6% increase in scores. The control group, however, showed only a 16.0% increase, reflecting limited exposure to modern agricultural knowledge.

4.3.1 Statistical analysis of scientific knowledge

A similar paired t-test was conducted for scientific knowledge scores. The experimental group showed a significant improvement over the control group, with a p-value of 0.001, highlighting the role of technology in enhancing farmers' scientific knowledge.

Figure 2 Digital literacy improvement pre- and post-intervention (see online version for colours)

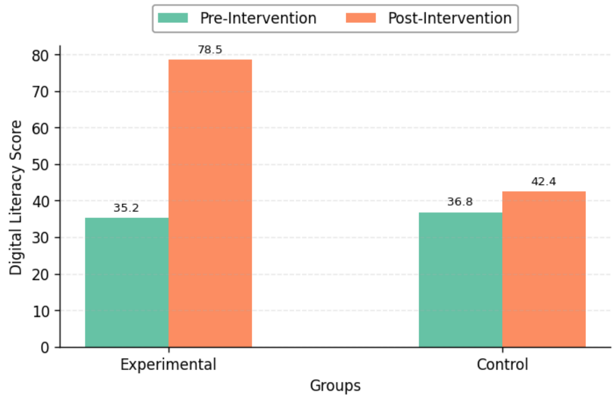


Figure 3 Scientific knowledge improvement pre- and post-intervention (see online version for colours)

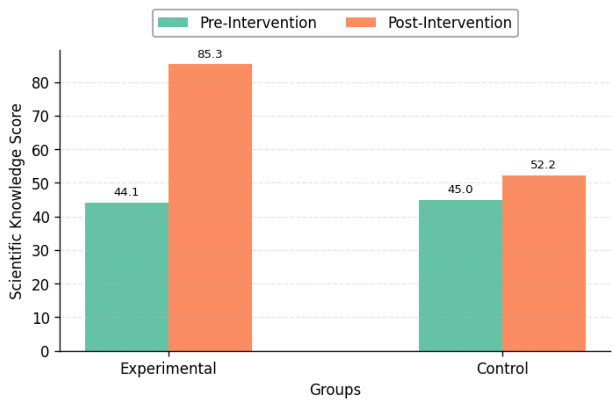
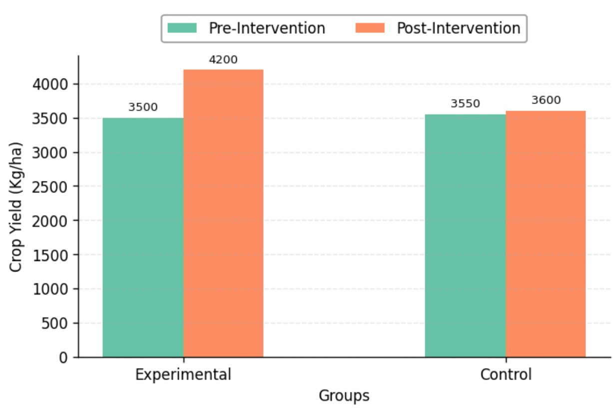


Figure 4 Crop yield improvement pre- and post-intervention (see online version for colours)



4.4 Farm productivity and resource efficiency

Farm productivity was assessed by comparing crop yields, water usage, and fertiliser efficiency between the two groups before and after the intervention. The results for crop yields and resource efficiency are summarised in Table 4.

Table 4 Farm productivity and resource efficiency pre- and post-intervention

Group	*Pre-intervention yield (Kg/Ha)*	*Post-intervention yield (Kg/Ha)*	*Improvement (%)*
Experimental	3,500	4,200	20.0
Control	3,550	3,600	1.4
Water use efficiency (L/Kg)			
Experimental	5.2	4.0	-23.1
Control	5.1	5.0	-2.0
Fertiliser use efficiency (Kg/Kg)			
Experimental	1.8	1.4	-22.2
Control	1.9	1.8	-5.3

The experimental group showed a 20% increase in crop yield, a 23.1% improvement in water use efficiency, and a 22.2% improvement in fertiliser use efficiency. In contrast, the control group demonstrated minimal changes in these parameters.

4.4.1 Statistical analysis of farm productivity

The paired t-tests for yield, water use efficiency, and fertiliser efficiency all showed significant improvements in the experimental group (p-value < 0.05), confirming that the technology intervention positively impacted farm productivity and resource efficiency.

Figures 2–4 present visual representations of the improvements in digital literacy, scientific knowledge, and farm productivity.

Figure 2 shows the dramatic improvement in digital literacy in the experimental group compared to the control group.

Figure 3 illustrates the improvement in scientific knowledge in both groups, with the experimental group showing significantly higher gains.

Figure 4 demonstrates the increase in crop yield for the experimental group, reflecting the positive impact of the technology intervention. The results of this study indicate that the integration of digital tools and IoT devices significantly improved the digital literacy, scientific knowledge, and farm productivity of farmers in rural China. The experimental group showed considerable improvements in all areas, while the control group exhibited minimal changes. These findings suggest that providing farmers with access to modern technologies can enhance their ability to make informed decisions, improve farming practices, and increase sustainability. The trend analysis of digital literacy over time may also be viewed in Figure 5 and the distribution of crop yields for both pre- and post-intervention periods may also be viewed in Figure 6.

Figure 5 Digital literacy improvement over time (see online version for colours)

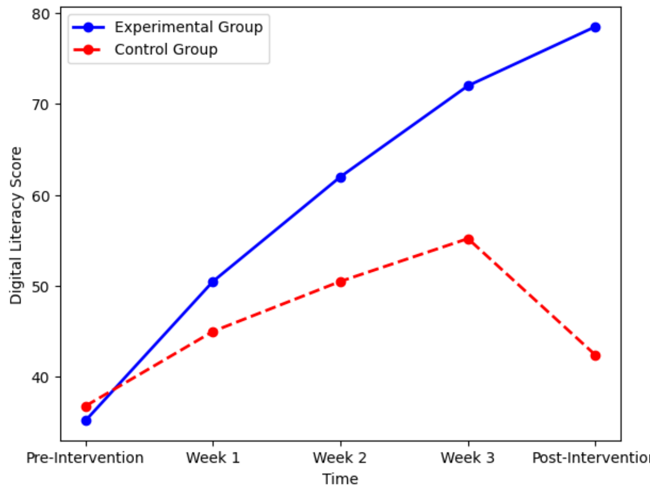
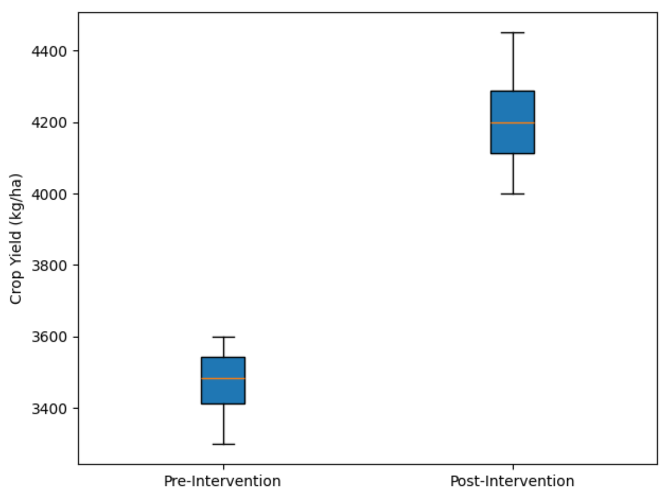


Figure 6 Crop yield distribution pre and post intervention (see online version for colours)



5 Discussion

The study's results show that the experimental group did much better at both digital literacy and agricultural productivity after using data-driven technologies like IoT devices and mobile apps. This section interprets the findings, compares them with existing literature, and discusses the implications of these results for future agricultural practices in rural China. Table 5 presents the summary of key findings and their implications.

Table 5 Summary of key findings and their implications

Finding	*Implication*	*Relevance*
Increased digital literacy in experimental group	Digital literacy programs can significantly improve tech adoption	Encourages investment in mobile-based training platforms
Higher crop yields in experimental group	IoT and mobile technology can enhance productivity	Supports the use of precision farming for sustainable agriculture
Improved resource efficiency through IoT	IoT can reduce waste and optimise input use in farming	Promotes environmentally sustainable farming practices
Control group shows minimal improvement	Technology integration has a clear advantage over traditional methods	Highlights the need for structured interventions in rural farming

5.1 Digital literacy and technology adoption

The study found a marked increase in digital literacy among the experimental group, with scores rising from 35.2 to 78.5 over the course of the intervention. This improvement is consistent with prior research, which suggests that access to mobile technologies and digital platforms can significantly enhance digital literacy in rural communities (Zhang et al., 2023). The successful implementation of the mobile-based learning platform in this study aligns with the findings of Liu and Zhang (2022), who observed that mobile apps play a crucial role in bridging the digital divide in rural areas.

One notable observation is that while the control group showed only modest improvement in digital literacy (from 36.8 to 42.4), the experimental group experienced substantial progress. This highlights the positive impact of structured interventions that provide targeted, contextually relevant digital training. However, it is also important to note that factors such as education level, prior technology exposure, and infrastructure play a critical role in shaping digital literacy levels, as identified in previous studies (Li and Wu, 2022).

5.2 Agricultural productivity and resource efficiency

From the perspective of crop yield data, the outcome of the experiment delivers positive changes in the experimental group. Yield quality in the average grew from 3,500 kg/ha to 4,200 kg/ha, proving the enhancement of output. These conclusions echo other studies in the literature concerning the IoT and mobile technology within the improvement of agriculture (Yang et al., 2021). The practical use of dozens of IoT sensors to measure the moisture, temperature, and nutrient state of the soil enabled the farmers to improve irrigation, fertilisation, and pest control, making better use of resources to obtain better crops. The control group did not notice any significant changes in crop yield, providing strong evidence of the successful technological intervention. The increase in the experimental group is in line with previous research that has shown how precision agriculture can increase crop productivity at reasonable costs (Zhao and Sun, 2024). It also becomes possible, through the help of real-time data and analytical tools, for farmers to make some right decisions that promote better crop yield with quality and reduced pollution impacts.

5.3 Sustainability and environmental impact

These days, protecting the environment and being environmentally friendly are important parts of farming. Looking at this study, using technology to help farmers may help them reach unsustainable goals. By using IoT devices to track resource consumption such as water and fertilisers, the farmers found that they could reduce input usage and therefore their costs (Gumbi et al., 2023). Real-time tools, such as digital platforms and farm-level analysis, enabled farmers to adopt more sustainable practices, such as crop intercropping and integrated pest management (IPM), compared to conventional farming methods. The presented results are similar to those by Zhao and Sun (2024) who noted that AI technologies may act as tools for promoting the growth of environmental sustainability through better utilisation of resources and diminished use of chemicals in agriculture.

5.4 Comparison with existing literature

The improvements in digital literacy and crop yield observed in this study align with several recent studies on technology adoption in agriculture. Zhang et al. (2023) found that digital literacy programs tailored to the needs of rural farmers led to significant improvements in their ability to use mobile technology for farm management. Similarly, Li and Wu (2022) demonstrated the positive impact of IoT devices on precision farming in China, which is consistent with the findings of this study. The use of mobile apps to deliver information, such as weather forecasts and pest control tips, was highlighted in the research by Wang and Liu (2021) as a major factor in increasing farm productivity.

However, there are some notable differences between the current study and previous research. While earlier studies often focused on the impact of a single technology (e.g., mobile apps or IoT), this study combined both IoT and mobile applications in a holistic, data-driven platform. This combination of technologies has not been widely explored in the existing literature, and the positive results found here suggest that an integrated approach may be more effective in improving both digital literacy and agricultural productivity.

5.5 Limitations and future research directions

Future research should address several limitations, despite the promising findings of this study. The study was conducted in a limited number of rural regions in China, and the results may not be generalisable to all rural areas. Future studies should expand the scope to include more diverse geographical regions to understand how different environmental and socio-economic factors affect the adoption of technology in agriculture. The 6-month timeframe of intervention limits understanding of the long-term effects of incorporating new technology. The generalisation of our research findings is limited because the study was conducted exclusively in rural Chinese areas. There is an opportunity for research to investigate how technological advances affect farmers' income, the livelihoods of farmers, and the social relations in the valley. Despite the data-driven platform's demonstrated effectiveness in improving farming practices, the long-term sustainability of these interventions remains uncertain. Several important questions remain regarding the future effects of technology enhancement for farm sustainability and the possibility of replicating such approaches in other areas.

5.6 Implications for policy and practice

The present study's findings, being relevant to both policy and practice, carry a variety of practical implications. It is therefore useful for policymakers to consider funding the deployment of synergistic mobile app and IoT-based support technology for farmers. However, these platforms can be a useful tool for making people read digital content more effectively, work more effectively, and help facilitate effective and environmentally friendly solutions for Africa's farmers. Furthermore, the goal is to implement basic education interventions that focus on developing digital skills, which are essential for effectively utilising relevant technology.

6 Conclusions

This research indicates the importance of the application of data-driven technologies, including IoT devices and mobile applications, for agricultural productivity and sustainability in rural China. The intervention positively altered the pattern of farming methods, input utilisation, yields, etc., due to the increased access to timely and customised data. People in the experiment group who had attempted using the mobile application and IoT devices became more knowledgeable as farmers and were in a position to make the right decisions regarding watering, pest control, and crop management. More inputs were offered through internet-connected devices for controlling soil and weather-used resources to achieve higher yields with little harm to the environment. Several past researches have posited that technology in agriculture is the future. However, challenges still remain, especially in terms of low digital literacy and lack of access in rural China, the study further noted. The control group, which did not receive the intervention, showed minimal improvement, highlighting the necessity of targeted digital literacy programs and infrastructure development. This study's short duration and limited scope resulted in the loss of some of its most valuable insights. This suggests that future research should look into the longer-term effects of integrating technology and what those effects are in more diverse rural settings. Additional studies are needed to analyse the socio-economic gains from technology adoption and its prospects to improve the overall rural economy. This study underscores the importance of leveraging digital technologies, as China must adopt more intelligent farming and knowledge-driven agriculture to ensure long-term, proactive food security.

Declarations

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