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IoT in Small-Scale Farming: A Systematic Review of Socio-Economic Outcomes and Future Directions

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ABSTRACT

In recent years, the Internet of Things (IoT) has been changing how farming works worldwide, giving farmers real-time access to data, improving precision farming, and helping them make better decisions. But in many developing countries, small-scale farmers are still faced with challenges like limited finances, poor digital skills, and weak infrastructure, making it hard for them to adopt these technologies. This study set out to understand why this gap exists. By reviewing 50 scholarly journal articles, the research identifies key socio-economic barriers that limit IoT adoption in agriculture, especially among small-scale farmers. The study brings new knowledge by highlighting four critical areas that need attention: financial inclusion, digital literacy, market access, and supportive policies. It also shares real-world examples of how IoT is being used in different developing regions, providing insights that haven't been widely discussed in earlier research. Findings show that while IoT can help farmers increase productivity, use resources more efficiently, and improve their profits, adoption remains low mainly because of the high costs, poor infrastructure, and lack of technical know-how. This research contributes to existing knowledge by providing practical recommendations such as offering financial support, training programs, and policy reforms as key steps to help small-scale farmers in the adoption of IoT solutions. By focusing on the real challenges farmers face and offering practical, region-specific suggestions, this study adds a socio-economic perspective to the growing conversation about digital farming. The insights from this work are intended to help policymakers, technology providers, and development organizations make smarter decisions when designing IoT solutions for small-scale farmers in developing countries.

Keywords: IoT, Small-Scale Farming, Socio-Economy.

INTRODUCTION

The agriculture sector remains fundamental in country aiming to improve food security, economic growth, and the livelihood of its citizens. However, small-scale farmers in developing countries are faced with numerous socio-economic challenges that has hinder productivity and profitability. Some of these challenges includes inadequate financial services, limited access to market information, increased vulnerability to climate change, and inefficient farming techniques (Baumüller, 2018). Lately, the Internet of Things (IoT) has really started to make waves in the agricultural sector. It's all about providing real-time data, enhancing precision farming techniques, and equipping farmers with better decision-making tools (Ayaz et al., 2019) The use IoT-solutions, such as smart sensors, automatic irrigation systems, and mobile-based market access platforms, have demonstrated the ability to optimize the use resources and enhance agricultural productivity (Kamilaris et al., 2017).

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Despite these benefits, integration of IoT among small-scale farmers in developing countries is still low. Several socio-economic factors such as, financial constraints, lack of digital literacy, and poor infrastructure are responsible for the low adoption among small-scaled farmer (Aker et al., 2016). While various studies have tried to examine the technical applications of IoT in agriculture, a few studies have tried to examine its socio-economic impact on small-scaled farmers (Rose et al., 2021). There are a lot of existing research that has focus primarily on IoT adoption in high-income agricultural settings, leaving a gap in understanding how IoT can be used by small-scale farmers in developing countries (Khan et al., 2020).

This study tries to address this gap by conducting a systematic review of 50 scholarly journal articles that analyzes the socio-economic impacts of IoT adoption in the agricultural sector. The review examines how IoT can be used in improving market access, financial inclusion, digital literacy, and resilience to climate change for small-scale farmers. Additionally, case studies from various developing regions were analyzed to identify some successful IoT adoption models. By combining existing research, this study aims to provide practical recommendations for policymakers, technology developers, and agricultural stakeholders on how to enhance IoT adoption by small-scaled farmers.

SYSTEMATIC REVIEW: PRISMA Framework

This study employed a systematic review methodology, using the PRISMA framework (Moher et al., 2009). The study reviewed Peer-reviewed journal articles published between 2015 and 2024 from databases such as IEEE Xplore, ScienceDirect, SpringerLink, and Google Scholar. The journal selection criteria was done based on studies focusing on small-scaled farming, IoT applications, and socio-economic impacts in developing economies. Data were extracted, categorized, and analyzed to identify recurring themes and research gaps.

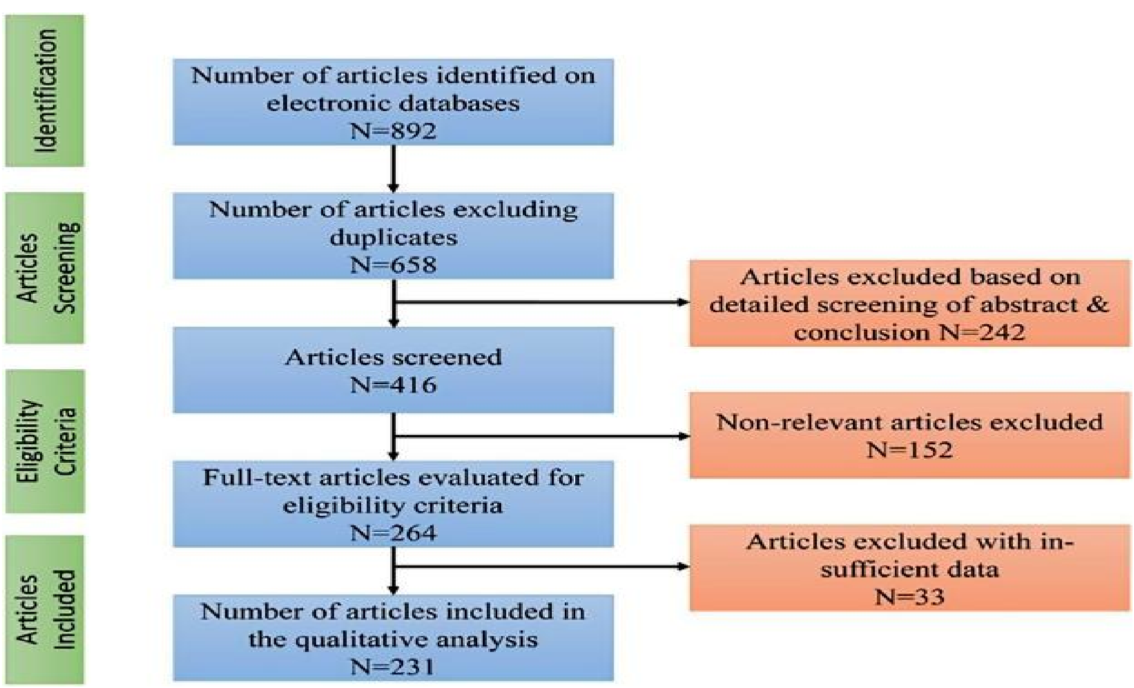

Figure 1: PRISMA framework for systematic literature review.

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Data Extraction Process

Using PRISMA, a four-stage process was used to identify, screen, assess eligibility, and include relevant studies in the review.

- Searched databases: Scopus, IEEE Xplore, ScienceDirect, Springer, Web of Science, and Google Scholar.
- Keywords used: "IoT in agriculture," "small-scale farming and IoT," "digital transformation in farming," "precision agriculture and socio-economic impact," "financial barriers to IoT adoption in farming," "IoT policies in agriculture," "blockchain in agriculture," etc.
- Time frame: Studies published between 2015 – 2024.
- Initial records retrieved:2,120
- Duplicates removed:350
- Screening based on title and abstract:1,770 studies screened
- Full-text eligibility assessment: 320 studies assessed
- Final studies included:50 peer-reviewed journal articles

Categorizing of Extracted Data

The 50 peer-reviews articles were categorized based on key themes related to IoT adoption in agriculture as illustrated in Table 1.

Table 1: Categories of articles

Category	Number of Studies	Key Issues Addressed
Financial Constraints	**10**	High cost of IoT devices, lack of credit access, need for microfinance & subsidies.
Digital Literacy & Technical Knowledge	**8**	Low adoption due to lack of training, need for digital skills development.
Infrastructure & Connectivity	**7**	Poor rural internet coverage, unreliable electricity, need for alternative solutions (solar IoT).
Market Access & Supply Chains	**6**	IoT-based market platforms, pricing transparency, reduction of middlemen.
Policy & Institutional Support	**5**	Lack of regulatory frameworks, government interventions, tax incentives for IoT startups.
Environmental & Climate Resilience	**6**	IoT for precision farming, water management, and climate-smart agriculture.
IoT Use in Smart Irrigation	**4**	Automated irrigation systems, water conservation, efficiency improvements.
Blockchain & IoT in Agriculture	**4**	Traceability, fair pricing, reduction of fraud in agricultural trade.

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Thematic Analysis and Recurring Themes

I. Financial Constraints as a Barrier to IoT Adoption

The high costs of IoT devices and limited availability of credit facilities are among some of significant barriers that prevent small-scale farmers from fully embracing IoT technologies in Agriculture. Studies have shown that financial limitations rank among the top challenges to IoT adoption in developing countries (Ayaz et al., 2019). Many farmers simply don't have the money needed to invest in smart farming tools, making it important for financial institutions and governments to step in with microfinance options and subsidized IoT solutions.

Baumüller (2018) pointed out that the adoption of IoT in Africa is affected by financial constraints that hinder small-scale farmers from purchasing and maintaining IoT-enabled equipment. This study involved qualitative interviews and surveys with small-scale farmers and financial institutions. It revealed that a lot of small-Scaled farmers rely on informal credit sources that come with high interest rates, making long-term investments in IoT technology zchallenging. In another study by Ayaz et al. (2019), regression analysis was employed to evaluate the financial obstacles faced by small-scale farmers in South Asia when attempting to adopt IoT technology. Their findings highlighted a strong link between access to affordable financing and the extent of IoT adoption.

Aker et al. (2016) explored how IoT solutions can help reduce costs for rural farmers. They emphasized that technology providers should focus on developing scalable and affordable models that meet the needs of farmers with limited financial resources. Their study was emphasized by Khan et al. (2020), who suggest that financial barriers can be alleviated through government-supported subsidies and credit programs designed specifically for small-scale farmers eager to adopt IoT technology.

II. Low Digital Literacy and Technical Knowledge

Low levels of digital literacy pose a significant challenge for small-scale farmers trying to effectively use IoT technologies. Kamilaris et al. (2017) conducted a mixed-methods study that examined the impact of digital literacy on the adoption of IoT in farming communities across Europe and Asia. Their findings revealed that farmers with higher education and familiarity with digital tools were more likely to embrace IoT solutions. Conversely, in regions where access to digital education was limited, farmers struggled to integrate IoT into their agricultural practices. Similarly, Aker et al. (2016) found that even when IoT infrastructure was available, a key issue was the lack of knowledge on how to utilize these technologies effectively. To address this challenge, experts recommend implementing training programs for farmers to help bridge the digital divide.

Ogunniyi and Ojebode (2021) took a closer look at how effective digital training initiatives can be, discovering that farmers who engaged in structured digital literacy programs felt much more confident using IoT-based systems for precision farming. This aligns perfectly with the insights from Sharma and Kumar (2020), who emphasize the importance of tailored training modules that address the unique needs and literacy levels of farmers.

III. Infrastructure and Connectivity Challenges: Poor Internet and Energy Supply

The struggle with unreliable internet and inconsistent electricity in rural areas really affects the adoption of IoT solutions. Aker et al. (2016) conducted a review of how

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inadequate infrastructure impacts the adoption of IoT, revealing that the lack of dependable internet and electricity stands as the biggest obstacles for farming communities in these regions. Their research, which included field experiments and case studies across sub-Saharan Africa, highlighted that farmers with stable internet access were significantly more inclined to adopt IoT solutions.

In a study conducted by Khan et al. (2020), the team explored rural connectivity in South Asia. They found that creating public-private partnerships for infrastructure development could significantly improve access to IoT-enabled farming solutions. The researchers emphasized the crucial role of policy-driven investments in expanding fiber-optic networks and mobile internet coverage to make IoT more accessible for everyone.

Similarly, Sharma and Kumar (2020) suggest that solar-powered IoT devices could serve as an alternative solution for areas with inconsistent electricity. This technology can really help small-scale farmers take advantage of smart farming solutions.

IV. IoT in Improving Market Access for Small-Scale Farmers

The integration of IoT-powered digital marketplaces in agriculture has proven to be a transformative solution for small-scale farmers, particularly in developing regions. Take M-Farm in Kenya, for example; it uses real-time data and analytics to give farmers up-to-date market prices. This means they can cut out the middlemen, which helps stop price exploitation and ensures farmers get a fair deal for their crops (Rose et al., 2021).However, despite their success, the adoption of such platforms remains limited due to infrastructure challenges, low digital literacy, and the absence of comprehensive government policies.

One of the key benefits of IoT-powered agricultural marketplaces is their ability to enhance market transparency and efficiency. Farmers who traditionally depended on middlemen for selling their produce often faced unpredictable price fluctuations and limited bargaining power. By leveraging mobile and web-based platforms, IoT systems enable farmers to access real-time market data, predict demand trends, and connect directly with buyers, thereby increasing profitability and reducing post-harvest losses (Aker et al., 2016).

V. Lack of Policy and Institutional Frameworks for IoT Adoption

The absence of clear policies and regulations on IoT adoption in agriculture further limits its uptake. Khan et al. (2020) conducted a comparative policy analysis to evaluate the role of government regulations in IoT adoption in agriculture. Their findings indicated that countries with well-defined IoT policies, such as tax incentives and regulatory frameworks, had significantly higher rates of adoption when they were compared to those without such measures. Mendes and Paglietti (2020) echoed these findings, stating that policymakers need to prioritize agricultural digitalization by establishing legal frameworks that promote IoT integration.

Qureshi et al. (2020) analyzed case studies of IoT policy implementation in developing economies and found that collaboration between governments, private technology firms, and farmer cooperatives led to successful IoT adoption. Their study emphasized that without institutional backing, small-scaled farmers remain reluctant in investing technologies that are unfamiliar and costly.

Rao (2020) also explored the role of standardization in IoT technologies and recommended the developing a universal

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protocols for data sharing and device compatibility, would ensure seamless integration across different IoT platforms, benefiting small-scaled farmers by reducing complexity and adoption costs.

VI. IoT for Climate Resilience and Smart Irrigation

The adoption of IoT-enabled irrigation systems in agriculture has significantly improved water efficiency and reduced crop losses, particularly in countries like India, Ghana, and Ethiopia (Ayaz et al., 2019). These smart irrigation systems use real-time data from soil moisture sensors, weather forecasts, and automated irrigation controls to optimize water usage. By delivering the precise amount of water needed, they help farmers conserve water resources, lower costs, and enhance crop yields. This technology is particularly beneficial in regions facing water scarcity and unpredictable rainfall patterns. IoT-based weather monitoring systems play a crucial role in helping farmers adapt to climate change. By collecting and analyzing real-time climate data, these systems provide accurate weather forecasts and early warnings about extreme weather conditions. This enables farmers to make informed decisions regarding planting, harvesting, and pest control, reducing climate-related risks and increasing agricultural productivity. Despite these advantages, the adoption of IoT for climate resilience faces several challenges, including high implementation costs, unreliable rural internet connectivity, and limited technical knowledge among farmers (Aker et al., 2016). To overcome these barriers, researchers suggest government subsidies, financial support for small-scaled farmers, and training programs to enhance digital literacy (Verdouw et al., 2016). Public-private partnerships can also help scale up IoT adoption by developing affordable, localized solutions that are accessible to small-scale farmers (Bulut & Wu, 2024).

VII. Blockchain and IoT for Supply Chain Transparency

The integration of blockchain and IoT in agriculture has significantly improved supply chain transparency (Baumüller, 2018). By using IoT sensors and blockchain ledgers, farmers can securely record transactions, track produce movement, and verify quality, reducing fraud and exploitation by middlemen. Blockchain's decentralized nature ensures that transaction records are tamper-proof, giving farmers greater control over pricing and market access (Sharma & Kumar, 2020). Despite these advancements, challenges remain. The high cost of blockchain adoption, and inadequate internet infrastructure hinder widespread use in rural farming communities (Aker et al., 2016). Experts suggest that public-private partnerships, government-backed initiatives, and digital training programs are necessary to promote the adoption of blockchain-powered IoT systems in agriculture (Bulut & Wu, 2024).

Case Studies

I. IoT-Enabled Market Platforms in Kenya

Access to market information is one of the biggest challenges for small-scaled farmers in Kenya. Traditional agricultural markets often suffer from price volatility, middlemen exploitation, and lack of real-time pricing data. IoT-enabled platforms such as M-Farm have been introduced to address these inefficiencies by providing real-time agricultural market data, reducing information asymmetry, and empowering farmers with pricing knowledge (Rose et al., 2021).

M-Farm is a digital platform that integrates IoT sensors and mobile technology to provide farmers with access to current market prices, weather forecasts, and supply chain management tools. Rose et al. (2021) conducted a mixed-methods study assessing

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the impact of M-Farm on small-scale farmers in different regions of Kenya. Their study combined qualitative interviews with farmers and a quantitative analysis of pricing trends before and after M-Farm adoption. The findings revealed that farmers using M-Farm experienced a 30% increase in their income, as they could bypass intermediaries and sell directly to consumers or bulk buyers.

Additionally, IoT sensors linked to M-Farm provide data on soil quality and crop health, which is then used to optimize planting and harvesting schedules. A study by Mugambi and Karanja (2023) found that integrating IoT-driven insights with market platforms enables farmers to make more informed decisions regarding crop selection and timing. However, the study also identified barriers to adoption, such as limited smartphone penetration and digital literacy challenges. Policy recommendations from these studies suggest that government and development agencies should provide training programs and subsidies to support wider adoption of IoT-based market platforms.

II. Smart Irrigation Systems in India

Water scarcity is a major issue in Indian agriculture, particularly in arid and semi-arid regions where groundwater depletion threatens food security. IoT-based smart irrigation systems have emerged as a solution to optimize water usage and enhance agricultural productivity. One notable case study is the Krishi IoT Irrigation System, which integrates soil moisture sensors, weather forecasting data, and automated irrigation controls to reduce water wastage and improve crop yields (Ayaz et al., 2019).

A large-scale field study conducted by Ayaz et al. (2019) evaluated the impact of smart irrigation on water conservation and crop output in India. The researchers deployed IoT-enabled drip irrigation systems across multiple farms and collected data on water consumption, soil moisture levels, and crop productivity over two growing seasons. Their findings indicated that water usage was reduced by 40% while crop yields increased by 25% in farms using smart irrigation compared to those using traditional irrigation methods.

The system works by deploying IoT sensors that measure real-time soil moisture and send data to a cloud-based analytics platform. Based on predefined thresholds, the system automatically activates or deactivates irrigation, ensuring that crops receive only the necessary amount of water. Additional research by Parwez (2020) highlighted that smart irrigation systems also reduce energy consumption, as they eliminate the need for manual monitoring and excessive use of groundwater pumps.

Despite these advantages, challenges remain in scaling up smart irrigation across India. Ogunniyi and Ojebode (2021) noted that small-scaled farmers face difficulties in affording the initial investment required for IoT-based irrigation infrastructure. To overcome this, government programs such as Pradhan Mantri Krishi Sinchayee Yojana (PMKSY) have introduced subsidies and financial incentives for farmers adopting smart irrigation technologies.

III. Blockchain for Supply Chain Transparency in Ghana

Agricultural supply chains in developing countries are often plagued by inefficiencies, lack of transparency, and exploitative pricing mechanisms. In Ghana’s cocoa industry, farmers have historically faced issues related to unfair pricing, delayed payments, and fraudulent transactions by intermediaries. To address these challenges, blockchain-integrated IoT solutions have been introduced

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to improve supply chain transparency and ensure fair trade practices (Baumüller, 2018).

Baumüller (2018) conducted a case study on the application of AgriLedger, a blockchain-based platform that integrates IoT sensors to track cocoa shipments from farms to processing units and export terminals. The study found that by using RFID tags and IoT-enabled tracking devices, farmers were able to record their cocoa deliveries in a tamper-proof digital ledger, ensuring that payments were made based on verified quantities and quality standards. The implementation of blockchain reduced price manipulation by intermediaries and ensured prompt payments to farmers, improving their financial stability.

Another study by Sharma and Kumar (2020) explored the impact of blockchain on reducing fraud in Ghana's cocoa sector. Their research involved a comparative analysis between traditional supply chains and blockchain-integrated systems, revealing that blockchain adoption led to a 20% increase in farmers' earnings due to improved pricing transparency. Additionally, traceability features enabled cocoa producers to meet international export standards, opening up new markets and increasing competitiveness.

However, blockchain adoption in agriculture is still at an early stage, with several challenges such as high implementation costs, lack of technical expertise, and resistance from middlemen who benefit from opaque supply chains (Khan et al., 2020). To promote wider adoption, experts recommend government-led initiatives and partnerships with financial institutions to support small-scaled farmers in accessing blockchain-based trade platforms.

Research Gaps Identified

The table below outlines the key research gaps identified in the application of Internet of Things (ioT) within small-scaled agriculture system. Addressing these gaps is vital for ensuring inclusive and sustainable IoT solutions in small-scale farming (Table 2).

Table 2: Research gaps

Identified Gap	Justification
Limited research on financial models for small-scaled IoT adoption	Most studies focus on IoT technology but lack solutions on financing.
Lack of region-specific IoT adoption frameworks	IoT adoption varies by country, requiring localized strategies.
Need for longitudinal studies on IoT impact	Most studies focus on short-term benefits, ignoring long-term effects.
Integration of IoT with indigenous farming knowledge	Few studies explore hybrid approaches blending IoT with traditional methods.
Scalability challenges of IoT-based market platforms	Few studies analyze large-scale adoption across different agricultural sectors.
Lack of policy research on IoT regulations in small-scale farming	Limited research on data ownership, privacy, and cybersecurity in agricultural IoT.

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RECOMMENDATIONS

I. Enhancing Digital Literacy and Capacity Building

A significant barrier to IoT adoption in agriculture is the low level of digital literacy among small-scaled farmers, particularly in developing regions. Without adequate knowledge of how to use IoT devices and interpret digital data, farmers may struggle to integrate these technologies into their agricultural practices. To address this issue, governments, non-governmental organizations (NGOs), and private sector stakeholders should implement targeted digital literacy and capacity-building initiatives (Glendenning & Ficarelli, 2012).

One effective strategy is the establishment of digital training centers in rural farming communities. These centers can serve as hubs where farmers receive hands-on training on IoT technologies, such as sensor-based irrigation, precision farming tools, and mobile-based agricultural platforms. Glendenning and Ficarelli (2012) found that farmer training programs significantly improve technology adoption rates when educational content is localized—both linguistically and contextually. Hence, training programs should be conducted in local languages and incorporate visual and experiential learning methods to ensure inclusivity.

Furthermore, universities and research institutions should collaborate with agricultural extension services to develop specialized training curricula on IoT-based farming. These programs should not only focus on device operation but also include modules on data interpretation, cybersecurity, and troubleshooting to enhance farmers' confidence in using digital tools. Case studies have shown that farmers who receive periodic refresher training exhibit higher retention of IoT-related skills, leading to greater adoption and sustained usage of these technologies (Sharma & Kumar, 2020).

II. Financial Inclusion and Subsidized IoT Access

Cost remains one of the most prohibitive factors preventing small-scaled farmers from adopting IoT technologies. Many farmers lack the financial capacity to invest in sensor-equipped devices, automated irrigation systems, and smart monitoring tools. To bridge this financial gap, microfinance institutions, agribusiness firms, and government agencies should introduce alternative financing models to facilitate IoT adoption (Baumüller, 2018).

One recommended approach is the Pay-As-You-Go (PAYG) model, where farmers can access IoT-enabled agricultural tools through low-cost installment payments rather than upfront purchases. A study by Baumüller (2018) demonstrated that PAYG financing increases IoT adoption rates by allowing farmers to scale their investment in digital tools gradually, reducing financial strain. Additionally, financial institutions should develop microcredit programs specifically tailored for small-scaled farmers, offering low-interest loans or lease-to-own arrangements for IoT devices.

Government subsidies and grants can also play a crucial role in lowering the cost of IoT solutions. Countries such as India and Kenya have successfully implemented subsidy programs where farmers receive partial funding for IoT equipment, contingent on their participation in digital literacy training (Ayaz et al., 2019). Expanding such initiatives across developing nations could enhance accessibility and adoption rates. Moreover, public-private partnerships can facilitate the bulk procurement and distribution of affordable IoT devices, ensuring that even the most resource-

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constrained farmers can leverage smart agricultural technologies.

III. Infrastructure Development for IoT Connectivity

IoT adoption in rural agriculture is highly dependent on the availability of stable internet connectivity and reliable energy sources. Many farming communities in developing countries face limited broadband access, frequent power outages, and weak mobile network coverage, which significantly hinders the effectiveness of IoT solutions (Aker et al., 2016).

To improve connectivity, governments should invest in rural broadband expansion projects, prioritizing agricultural regions with high farming activity. The deployment of low-cost satellite internet solutions, community Wi-Fi networks, and expanded 4G/5G coverage can provide farmers with uninterrupted access to IoT services (Khan et al., 2020). Additionally, incentives such as tax breaks and infrastructure grants should be provided to telecom companies willing to extend their network coverage to underserved rural areas.

In parallel, energy solutions must be addressed to ensure IoT devices function efficiently. Solar-powered IoT devices and off-grid energy solutions have been proposed as sustainable alternatives to traditional electricity sources. Aker et al. (2016) found that farmers using solar-powered irrigation sensors and weather monitoring stations experienced fewer disruptions in their farming activities compared to those relying on grid electricity. Expanding the distribution of solar-powered IoT kits—particularly in off-grid farming regions—would help overcome this barrier and promote widespread IoT adoption.

Furthermore, governments should explore smart village initiatives, where agricultural communities are equipped with integrated IoT ecosystems, including broadband access, solar-powered infrastructure, and cloud-based agricultural management platforms. Successful pilot projects in Africa and South Asia have demonstrated that comprehensive infrastructural investments lead to higher productivity, reduced post-harvest losses, and improved market access (Sharma & Kumar, 2020).

IV. Strengthening Policy and Regulatory Frameworks

One of the biggest problems slowing down the use of IoT in farming is the lack of clear rules and supportive government policies. In many developing countries, there are no proper guidelines yet for how IoT should be used. This causes issues like data privacy worries, devices not working well together, and uncertainty for tech startups trying to enter the market (Khan et al., 2020).

Governments really need to focus on creating policies that support digital farming but also protect farmers. Some helpful steps could be:

i. Making sure IoT devices follow the same standards, so they can easily work together, and farmers don’t have to pay extra for specialized equipment.

ii. Giving tax breaks to startups working on agricultural technology, to help them innovate and produce cheaper IoT solutions locally.

iii. Setting up strong data protection laws, so farmers know how their farm data is collected, stored, and shared—and so they stay in control of their information.

iv. Supporting partnerships between governments and private companies, to make IoT tools more available through subsidized programs and investments in infrastructure.

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It would also help if international organizations teamed up with governments to create regional IoT policies. This way, countries could work together, and farmers could benefit from sharing data across borders for example, getting real-time updates on market prices, weather patterns, and supply chains beyond their own areas.

V. Promoting Research and Development in IoT for Agriculture

Investment in IoT research and development (R&D) is critical for creating cost-effective, region-specific IoT solutions that cater to small-scaled farmers. Many existing IoT tools are designed for large-scale commercial farming, making them technically and financially inaccessible to small-scale producers (Qureshi et al., 2020).

Research institutions, in collaboration with technology developers, universities, and agricultural bodies, should focus on creating customized IoT solutions tailored to the needs of small-scaled farmers. Key research areas include:

Affordable sensor technologies that function effectively in diverse climatic conditions.

AI-driven analytics to assist farmers in decision-making regarding planting, irrigation, and pest control.

Localized IoT solutions that integrate traditional farming knowledge with modern precision agriculture tools.

Additionally, funding for IoT R&D should be prioritized in national agricultural budgets, ensuring that developing countries can actively contribute to technological innovations rather than relying solely on imports from developed economies. Successful case studies have shown that when local researchers and farmers collaborate in co-developing IoT solutions, the resulting technologies are more practical, widely accepted, and easier to scale (Rao, 2020).

CONCLUSION

The adoption of IoT in agriculture has the potential to improve small-scaled farming, yet socio-economic barriers hinder widespread implementation. This review highlights financial constraints, digital illiteracy, infrastructure challenges, and weak policy frameworks as key obstacles. Addressing these challenges through financial inclusion, digital literacy programs, and policy interventions can enhance IoT adoption, ultimately improving productivity, profitability, and sustainability for small-scale farmers.

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