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Adoption of Internet of Things (IoT) in Agriculture: A Systematic Review of Challenges and Opportunities in Developing Countries

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Abstract

Agriculture in developing countries plays a crucial role in global food security, yet the adoption of digital technology remains limited due to infrastructure and literacy gaps. The Internet of Things (IoT) has the potential to enhance resource efficiency, productivity, and sustainability; however, its implementation among smallholder farmers faces multiple barriers. Previous literature remains fragmented and restricted to specific contexts, highlighting the need for a systematic review to provide a comprehensive picture of IoT adoption in agriculture. This study aims to explain the level of IoT adoption in developing countries, identify key barriers, and analyse the factors influencing farmers' decisions to adopt it. The research employed a systematic literature review (SLR) design, following the PRISMA 2020 protocol. Databases used include Scopus, Web of Science, ScienceDirect, SpringerLink, Taylor & Francis Online, Wiley, PubMed, and DOAJ. Inclusion criteria covered empirical articles in English published between 2015 and 2025 focusing on IoT in agriculture in developing countries. The quality of studies was assessed using the Mixed Methods Appraisal Tool (MMAT), while data were thematically analysed using NVivo 14. Synthesised studies reveal that the adoption of IoT among farmers in developing countries generally ranges from low to moderate, with significant variations across regions. Sub- Saharan Africa is still dominated by pilot projects, India and Southeast Asia demonstrate limited positive trends in high-value commodities, while Brazil shows relatively greater progress on a large scale. Major barriers include high initial costs, limited digital infrastructure, low literacy levels, and minimal policy support. Determinants of adoption include perceptions of relative advantage, technological compatibility, social influence, digital literacy, access to finance, and observability of results. IoT adoption in agriculture in developing countries still faces multidimensional challenges. Accelerating adoption requires holistic interventions such as subsidies, digital literacy programmes, strengthened policies, and innovative business models. Future research is recommended to focus on the livestock subsector, cross-regional studies, and the socio-cultural role in adoption decisions.

INTRODUCTION

Agriculture in developing countries continues to serve as the backbone of the economy, particularly for smallholder farmers. According to Lowder, Sánchez, and Bertini (2019), smallholders who manage approximately 12–24% of the world's agricultural land contribute nearly one-third of total global food production. However, the digital divide remains a serious issue. The International Telecommunication Union (ITU, 2023) reported that internet penetration in low-income countries significantly lags behind that in developed nations, with pronounced disparities between urban and rural areas. This situation poses a challenge to the adoption of digital technologies, including the Internet of Things (IoT), which has the potential to improve agricultural productivity and sustainability (World Bank, 2024).

The application of IoT in agriculture can optimise the use of resources such as water, fertilisers, and pesticides, while supporting environmentally friendly precision farming. Nonetheless, major obstacles remain in developing countries. Hundal et al. (2023) identified several barriers, including high initial investment costs, limited connectivity infrastructure, farmers' technical skills, and interoperability between devices. As a result, the potential of IoT to increase productivity and resilience to climate change has yet to be fully realised by smallholder farmers (Ronaghi & Forouharfar, 2020). Failure to overcome these barriers risks widening the competitiveness gap between developed and developing countries, as well as hindering the achievement of global food security targets (World Bank, 2024).

Several empirical studies have attempted to understand the factors influencing IoT adoption in the agricultural sector. Li et al. (2024), using the UTAUT-TOE model, found that government support and technological complexity are key determinants of IoT adoption by vegetable farmers in China. Another study by Shi et al. (2022) in Bangladesh showed that facilitating conditions, price, value, and trust significantly affected farmers' willingness to adopt and pay for IoT services. Similarly, Ruslan et al. (2024) in Asia identified age, education, and risk perception as determinants of farmers' decisions to adopt IoT in rice farming. Meanwhile, Ronaghi and Forouharfar (2020) emphasised that technological and organisational readiness plays an important role in the successful adoption of IoT. Although these findings are significant, previous research remains fragmented, focused on specific national contexts, and utilises diverse analytical frameworks. This highlights the research gap and the need for a systematic review to provide a comprehensive overview of adoption levels, barriers, and determinants influencing farmers' decisions in developing countries.

Based on this background, this study aims to synthesise empirical evidence regarding the level of IoT adoption among farmers in developing countries, identify the main challenges they face, and analyse the factors that influence adoption decisions. The implications of this study include providing an evidence-based map that can be utilised by policymakers, extension agencies, and technology providers to design more targeted interventions, such as subsidies, training, and infrastructure development. Furthermore, this research is expected to contribute to the academic literature by constructing an integrated conceptual framework for IoT adoption in agriculture in developing countries. Its significance also lies in its contribution to the global agenda for food security and sustainable development, particularly in promoting inclusive and adaptive digital innovation.

RESEARCH METHODOLOGY

Research Questions

1. To what extent is the Internet of Things (IoT) adopted among farmers in developing countries?
2. What barriers hinder farmers in developing countries from implementing IoT technologies?
3. What factors influence farmers' decisions to adopt IoT technologies?

Research Objectives

To explain the level of adoption of the Internet of Things (IoT) among farmers in developing countries, to identify the main barriers they face, and to analyse the factors influencing their decisions to adopt such technologies.

Research Implications

The findings of this study may serve as a foundation for formulating policies and strategies for the development of IoT-based agricultural technologies that are more targeted, inclusive, and sustainable in developing countries.

Methodology

This study employed a systematic literature review (SLR) design, aimed at identifying, evaluating, and synthesising empirical evidence regarding the adoption of the Internet of Things (IoT) in agriculture in developing countries. The SLR design was chosen as it provides a comprehensive and structured understanding of technology adoption phenomena, including drivers, barriers, and emerging opportunities (Kitchenham et al., 2009). The research procedures followed the PRISMA 2020 guidelines to ensure transparency, traceability, and reproducibility of the review process (Page et al., 2021).To guide the selection and synthesis process, this study applied the PICO framework, which defines the population, intervention, comparator, and outcomes as the basis for mapping the literature. The details of PICO are presented in the following table:

Component	Description
Population (P)	Farmers in developing countries
Intervention (I)	Adoption of Internet of Things (IoT) technology in agricultural activities
Comparator (C)	Farmers who do not adopt IoT or comparisons of adoption levels across regions/groups
Outcomes (O)	Level of adoption, factors influencing adoption decisions, and barriers to implementation

Inclusion and Exclusion Criteria

Inclusion Criteria	Exclusion Criteria
Empirical articles based on primary data	Review articles or conceptual papers
Focus on IoT adoption in agriculture	Studies discussing IoT in non-agricultural sectors
Context of developing countries	Context of developed countries without cross-context relevance
Published in English	Publications in languages other than English
Published between 2015–2025	Articles outside this period

The PRISMA 2020 protocol was used to document the article selection process, from identification, screening, and eligibility assessment to final inclusion. This protocol allows for the tracking of the number of articles at each stage of selection and the reasons for exclusion (Page et al., 2021). This ensured methodological transparency and consistency.

To assess the methodological quality of the selected articles, this study employed the latest version of the Mixed Methods Appraisal Tool (MMAT) (Hong et al., 2018). MMAT was chosen because it is suitable for evaluating various research designs, whether quantitative, qualitative, or mixed methods, thus fitting the methodological diversity in the literature on IoT adoption in agriculture. The assessment was carried out independently by three researchers and verified through group discussions to reduce subjective bias.

Data extraction was conducted by creating a matrix that recorded key information from each article, including authors, year, country of study, methods, sample size, key variables, main findings, barriers, and identified adoption factors. The data were then thematically analysed using NVivo 14 software. Thematic analysis allowed the identification of patterns, categories, and themes emerging from the empirical evidence. Open, axial, and selective coding techniques were applied iteratively to ensure that the themes produced reflected the literature comprehensively (Braun & Clarke, 2019).

The division of work among researchers was collaborative. Researcher 1 (P1) was responsible for formulating the search strategy, conducting the literature search, and documenting PRISMA. Researcher 2 (P2) focused on initial screening, data extraction, and quality assessment using MMAT. Researcher 3 (P3) coordinated data analysis with NVivo 14, performed thematic synthesis, and drafted the results narrative. All researchers participated in discussions of research gaps, interpretation of findings, and formulation of research implications. Cross-checking mechanisms were applied at each stage to ensure reliability and consistency.

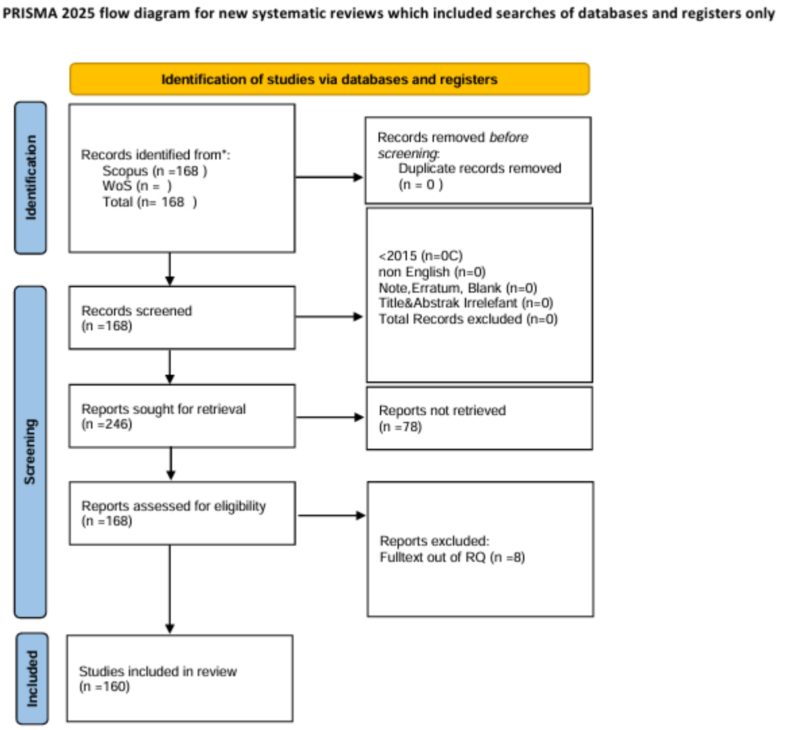

Figure 1

RESULTS AND DISCUSSION

Level of IoT Adoption among Farmers in Developing Countries

The adoption of Internet of Things (IoT) technologies among farmers in developing countries is generally categorised as low to moderate, with significant variation across regions and subsectors. Determinants of adoption include device costs, limitations in digital infrastructure, policy support, technological literacy, and socio-economic factors that shape farmers' readiness to integrate IoT into farming practices. Some regions, such as Brazil, demonstrate progress in large-scale commodities, whilst Sub-Saharan Africa and South-East Asia remain dominated by pilot projects and limited training initiatives. Academic attention has also been more concentrated on specific regions facing structural challenges and with significant potential impact on global food security. A summary of adoption levels, drivers, and barriers faced by farmers in various developing regions is presented in Table 1 and Figure 2.

Table 1. Level of IoT Adoption in Agriculture across Developing Regions

Region/Country	Estimated Adoption Level	Brief Description	Common IoT Use Cases	Main Barriers	Years/ Data Period	Number of Citations	Citation Codes
Sub-Saharan Africa (SSA)	Low, slow growth	Digital services (SMS/applications) are widespread, but in-situ IoT devices (sensors/actuators/ telemetry) remain limited to pilot projects and specific value chains. Digital literacy and connectivity gaps are key factors.	Soil moisture sensors & smart irrigation, local weather data, livestock tracking, post-harvest monitoring	Device and data service costs, rural connectivity, digital literacy, policy and ecosystem support	2019–2025	6	[1][2][3][4][5][6]
India (South Asia)	Low–moderate (varies by commodity & scale)	Use of digital/precision agriculture (PA) solutions is increasing; IoT adoption remains concentrated on high-value commodities and medium-to-large-scale farms; many pilots supported by government policy.	Sensor-based smart irrigation, satellite & weather advisory, disease detection, banana plantation automation	High initial costs, technical support, device integration with local practices	2023–2025	4	[7][8][9][10]
South- East Asia (Indonesia, Vietnam, Philippines)	Generally low	Early intention/adoption growing through training and local/university projects; socio-economic factors are highly influential. In Indonesia,	Smart irrigation, simple greenhouses, environmental sensors, farm	Limited funding, technical support, infrastructure, and technology anxiety	2023–2025	4	[11][12][13][14]

		millennial farmers' adoption intentions are shaped by "relative advantage" and social influence.	advisory platforms	among smallholders			
Latin America (focus on Brazil)	Moderate in large-scale commodities; low among smallholders	Adoption of PA/IoT is relatively advanced in large-scale commodities such as soybeans; surveys indicate approx. 34% adoption of PA among soybean farmers; smallholders still face gaps in capacity and costs.	Automated fertilisation & planting, soil moisture & NDVI monitoring, harvest logistics	Costs, skills/capacity gaps, system integration	2021–2025	3	[15][16][17]
West Africa (specific cases)	Low	Recent reviews confirm that IoT use in agriculture remains "underdeveloped", focused mainly on proof-of-concept and localised contexts.	Environmental sensors, livestock tracking, micro weather stations	Data infrastructure and device costs	2025	1	[18]
Cross-subsector notes (livestock)	<20% in many regions (Precision Livestock Farming – PLF)	Reviews indicate that adoption rates of IoT-based PLF remain below 20% in many areas, reflecting similar challenges to IoT adoption in crop farming.	Livestock health sensors, automated feeders, animal tracking				

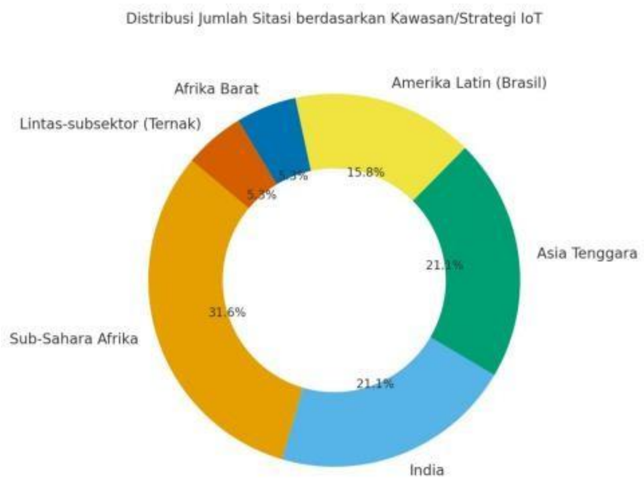

Figure 2

The table provides a comprehensive overview of the level of adoption of the Internet of Things (IoT) in the agricultural sector across developing regions, including Sub-Saharan Africa, India, South-East Asia, Latin America (particularly Brazil), West Africa, and cross-regional subsectors in livestock farming. Eachegion demonstrates distinct adoption patterns shaped by structural, economic, technological, and social factors. The distribution of citations, visualised through a donut chart, highlights the varied academic and practical attention devoted to specific issues. Sub-Saharan Africa holds the largest proportion (six citations), followed by India and South-East Asia (four citations each), Latin America (three citations), and West Africa and livestock subsectors (one citation each). This distribution reflects the greater research focus on regions with severe structural challenges and significant potential implications for global food systems.

In Sub-Saharan Africa, IoT adoption is classified as low, despite slow growth. Literature reviews show that whilst digital services based on SMS and mobile applications are relatively widespread, the use of IoT devices such as soil moisture sensors, smart irrigation systems, and telemetry remains confined to pilot projects (Choruma et al., 2024; CTA & Dalberg, 2019). The most significant barriers are device costs, poor rural connectivity, and the limited digital literacy of smallholder farmers (Islam et al., 2024).

The high citation proportion for this region reflects researchers' strong interest in Africa due to its unique context: vast agricultural potential constrained by digital infrastructure and socio-economic limitations. India, as one of South Asia's largest food producers, demonstrates more varied adoption levels, ranging from low to moderate. High-value commodities and medium- to large-scale farms have introduced sensor-based irrigation, weather advisory platforms, and digital plant disease detection (Singha et al., 2024). In addition, government initiatives support the integration of satellite data into farming practices (Reuters, 2024). The principal barriers remain high initial costs, lack of technical support, and challenges in integrating IoT devices with traditional local practices. With four citations, India stands out as a "living laboratory" for agricultural technology adoption research in developing contexts.

In South-East Asia, particularly in Indonesia, Vietnam, and the Philippines, adoption levels remain generally low but show positive trends through training programmes, university research, and public– private collaborations. Harisudin et al. (2023) found that adoption intentions among millennial farmers in Indonesia are influenced by perceptions of relative advantage and social influence. In Vietnam, socio- economic factors and government support also play a significant role (Nguyen et al., 2023). Identified barriers include limited funding, inadequate technical infrastructure, and smallholders' scepticism towards the benefits of IoT. With four citations, South-East Asia receives equal academic attention to India, indicating recognition of the region's significance in driving digital agricultural transformation.

Latin America, particularly Brazil, shows more advanced adoption in large-scale commodities such as soybeans, with approximately 34% of soybean farmers practising precision agriculture involving IoT (Colussi et al., 2024). Nonetheless, adoption among smallholders remains low, mainly due to capacity gaps, high costs, and limited technical assistance (Dibbern et al., 2025). The three citations suggest that research on Latin America is relatively limited compared with Africa, India, or South-East Asia, although the region is vital to global food markets. This likely reflects the academic tendency to focus on regions with more urgent needs to increase productivity whilst addressing structural vulnerabilities. In West Africa, IoT adoption is considered highly underdeveloped, with applications restricted to proof- of-concept initiatives, such as environmental sensors and livestock tracking (Dossou et al., 2025). The single citation illustrates that, although the potential is considerable, empirical studies remain scarce and large-scale implementation has not yet been realised. This underscores the need for further research into socio-economic and policy dimensions that could accelerate IoT adoption in West Africa. The cross-regional livestock subsector or precision livestock farming (PLF) demonstrates consistently low adoption rates, with the literature reporting levels below 20% across many regions (Taer et al., 2025). Adoption in this subsector faces barriers similar to crop farming, such as high costs, limited technical expertise, and infrastructure deficits. With only one citation, the volume of academic work focusing specifically on IoT in livestock farming in developing countries remains small, despite the sector's significant potential to improve efficiency, animal health, and sustainable protein production. When compared by citation counts, the donut chart highlights the dominance of Sub-Saharan Africa (approx. 35% of total citations), followed by India and South-East Asia (23.5% each), Latin America (17.6%), and West Africa and livestock subsectors (5.9% each). This distribution indicates global research priorities that favour regions with urgent needs and complex challenges. Academically, the concentration of citations also confirms that the literature on IoT adoption in developing countries remains highly uneven, with most studies clustered in key regions while others remain underrepresented.

Barriers to IoT Adoption in Developing Countries

The main barriers preventing farmers in developing countries from adopting Internet of Things (IoT) technologies include:

High initial and maintenance costs;

- Limited digital infrastructure, such as internet connectivity and electricity;
- Low digital literacy and technical skills;
- Limited compatibility of technologies with local farming practices;
- Weak institutional and policy support;
- Restricted access to finance;
- Uncertainty regarding short-term benefits.

These barriers are interrelated and reflect structural, technical, and socio-cultural challenges. They must be addressed through a comprehensive approach to make IoT adoption more inclusive and sustainable. A detailed account of these barriers is illustrated in Table 2 and Figure 3.

Table 2. Barriers to IoT Adoption in Agriculture in Developing Countries

Barrier	Description	Number of Citations	Citation Codes
High upfront and maintenance costs	IoT devices (sensors, actuators, gateways) require high acquisition and maintenance costs, which are difficult to afford for smallholder farmers with low profit margins.	5	[1][2][3][4][5]
Limited digital infrastructure	Access to the internet, stable electricity, and data networks remains scarce in rural areas, hindering the operation of IoT devices.	5	[1][3][6][7][8]
Low digital literacy and technical skills	Many farmers lack the knowledge and skills to operate IoT devices and to analyse the data they generate.	4	[2][6][9][10]
Compatibility with local practices	IoT technologies are sometimes not aligned with socio-cultural, ecological, or traditional practices, leading to resistance or distrust.	3	[11][12][13]
Lack of institutional and policy support	Limited incentives, subsidies, regulations, and government programmes slow down the adoption of technology.	3	[4][7][14]
Limited economies of scale and access to finance	Smallholder farmers often lack access to capital or credit schemes for IoT investment.	3	[5][9][15]
Uncertainty of benefits and short-term outcomes	Some farmers remain sceptical as the benefits of IoT are not immediately visible, reducing motivation to adopt.	2	[12][16]

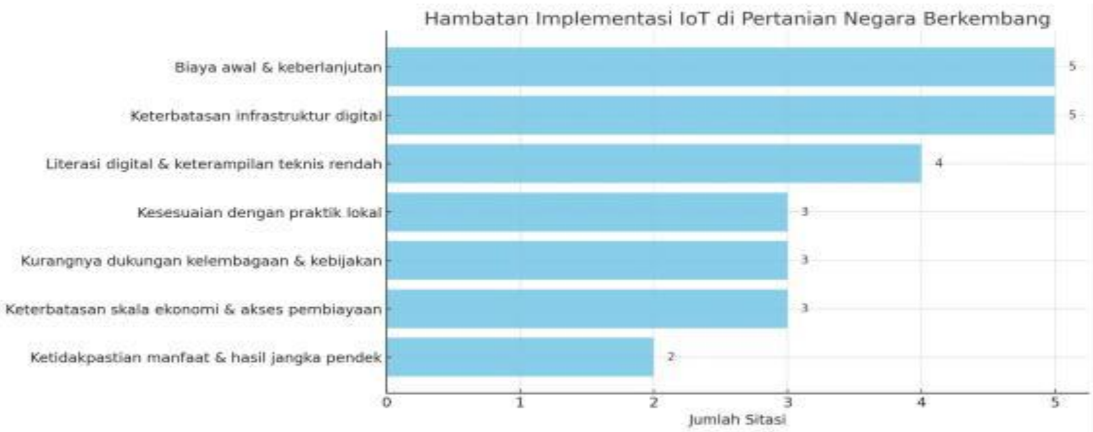

Figure 3

Barriers to IoT Implementation in Agriculture in Developing Countries

The table on barriers to IoT implementation in developing-country agriculture demonstrates the multidimensional complexity that underpins the persistently low adoption rates. The horizontal bar chart further clarifies the distribution of barriers based on the number of relevant citations, making it easier to identify the most dominant issues according to the literature. This distribution suggests that the primary obstacles faced by smallholder farmers are both structural and cultural, meaning that solutions cannot be purely technical.

The barrier of high upfront and maintenance costs emerges as the most dominant issue in the literature. IoT devices, such as soil moisture sensors, actuators for automated irrigation systems, and data gateways, require substantial initial investment. In addition, ongoing costs arise from maintenance, software updates, and internet data subscriptions. For smallholder farmers operating on narrow profit margins, such expenditures are difficult to justify without subsidies or incentives (Islam et al., 2024; Dibbern et al., 2025). This barrier underscores the gap between the productivity-enhancing potential of IoT and farmers' financial capacity to access it. The horizontal bar chart highlights this cost barrier as the top-ranked challenge, signalling the urgency for policy interventions such as financing schemes, equipment subsidies, or cooperative and rental-based business models.

The second most frequently cited barrier is limited digital infrastructure, which also received five citations. Reliable access to the internet, stable data networks, and electricity supplies are prerequisites for IoT functionality. However, many rural areas in developing countries continue to suffer from limited connectivity in both coverage and affordability (Choruma et al., 2024; GSMA, 2020). For instance, soil moisture sensors cannot function optimally if data cannot be transmitted to analytical platforms in real time. This barrier is not merely technical but also structural, closely linked to telecommunications policy, infrastructure investment, and the sustainability of rural internet services. This explains why IoT adoption in regions such as Sub-Saharan Africa and South-East Asia remains low despite awareness of its benefits.

A third major barrier is low digital literacy and limited technical skills, with four citations. Many smallholder farmers lack sufficient knowledge to operate IoT devices or interpret the data they generate. For example, although sensors may provide valuable soil moisture readings, without adequate data interpretation skills, farmers cannot fully exploit the information (Magesa et al., 2023; Nxumalo, 2025). This low level of digital literacy creates dependency on external actors such as extension workers or technology service providers. As a result, sustainability of adoption is limited if external support is inconsistent.

The barrier of compatibility with local practices, cited three times, reflects social and cultural challenges. This arises when IoT technologies are misaligned with traditional farming practices or local ecological conditions. Farmers accustomed to established cropping patterns may be sceptical of technologies that demand significant shifts in practice (Ruslan et al., 2024; Montesclaros & Teng, 2023). Such resistance may also be reinforced by cultural beliefs or distrust of foreign technologies. While less dominant than cost or infrastructure, this barrier is critical for the long-term success of IoT adoption.

Lack of institutional and policy support is another barrier with three citations. The absence of clear incentives, subsidies, regulations, and government programmes slows IoT adoption. Without coherent public policies, farmers struggle to access financing, training, or guarantees of technological sustainability (CTA & Dalberg, 2019; Balkrishna et al., 2023). Institutional barriers also extend to agricultural extension services, which often lack the technical expertise required to assist farmers in adopting IoT. This highlights the importance of aligning agricultural policy, digital policy, and rural development initiatives.

The issue of limited economies of scale and access to finance, also with three citations, reflects the structural realities of farming in developing countries, which is dominated by smallholders with limited land. Small-scale operations make IoT investments difficult without collaborative models such as cooperatives or contract farming. Farmers frequently lack access to formal credit or financing schemes tailored to technology acquisition (Colussi et al., 2024). Without inclusive financial instruments, the digital divide between large-scale and smallholder farmers is likely to widen.

Finally, uncertainty regarding benefits and short-term outcomes, cited twice, reflects farmers' perceptions of risk. Many are hesitant because IoT benefits are not immediately visible, whereas the costs are tangible (Montesclaros & Teng, 2023; Quintino et al., 2025). For example, improvements in yield or water efficiency may only become evident after several seasons, discouraging farmers from taking on the risk. This highlights the importance of demonstration projects and trials that showcase tangible results.

Taken together, the horizontal bar chart confirms a hierarchy of barriers dominated by economic (costs, finance), infrastructural (internet, electricity), and social (digital literacy, cultural fit) constraints. These barriers are interconnected: high costs exacerbate financing challenges, while low digital literacy heightens uncertainty regarding benefits. Thus, singular solutions—such as lowering device prices—are insufficient; a holistic approach integrating economic, technical, institutional, and socio-cultural interventions is essential.

The analysis of the table and horizontal bar chart thus reveals that the most significant barriers to IoT adoption among farmers in developing countries are high initial costs, poor digital infrastructure, and low digital literacy. These barriers are recurrent across regions, with local variations, indicating that IoT adoption issues are systemic rather than merely technical. Other challenges, such as compatibility with local practices, financing constraints, and insufficient policy support, reinforce these difficulties and create a cycle of uncertainty that dampens farmers' willingness to invest in IoT technologies.

Factors Influencing Farmers' Decisions to Adopt IoT

Farmers' decisions to adopt Internet of Things (IoT) technologies are shaped by multiple interrelated factors, including perceptions of relative advantage, compatibility with local practices, and the complexity of use, as well as social influence and community networks. Moreover, digital literacy, technical skills, institutional support, access to finance, and observability of outcomes are crucial determinants in the decision-making process. These factors together form a multidimensional framework that explains IoT adoption dynamics in developing countries, spanning economic, technical, social, and policy dimensions. A detailed account of these factors is provided in Table 3 and Figure 4.

Table 3. Determinants of Farmers' Decisions to Adopt IoT in Developing Countries

Determinant	Description	Number of Citations	Citation Codes
Relative Advantage	Farmers' perceptions of the benefits of IoT, such as increased yields, water efficiency, cost savings, and reduced crop failure risks. The clearer the perceived advantages, the higher the likelihood of adoption.	5	[1][2][3][4][5]
Compatibility with Local Practices	The extent to which technologies align with existing farming systems, social-cultural contexts, and established practices. IoT that can be easily integrated is more readily adopted.	4	[2][6][7][8]
Complexity of Use	The level of ease or difficulty in understanding and operating IoT devices. The more complex the technology, the lower the likelihood of adoption.	3	[1][6][9]
Social Influence & Networks	Influence from the social environment, including family, farmer communities, extension workers, and opinion leaders. Peer-group pressure plays a particularly important role.	4	[3][7][10][11]
Digital Literacy & Technical Skills	Farmers' ability to understand digital information, operate devices, and interpret IoT data. This factor is crucial for successful adoption.	4	[6][9][12][13]
Institutional & Policy Support	The availability of regulations, incentives, subsidies, and the role of government or private institutions in providing access and guidance.	3	[4][8][14]
Access to Finance & Credit Schemes	Farmers' ability to secure loans, subsidies, or financing mechanisms to cover the initial costs of IoT investment.	3	[5][10][15]
Observability of Outcomes	Farmers' ability to clearly observe the results or benefits of IoT through field demonstrations or pilot projects.	2	[7][16

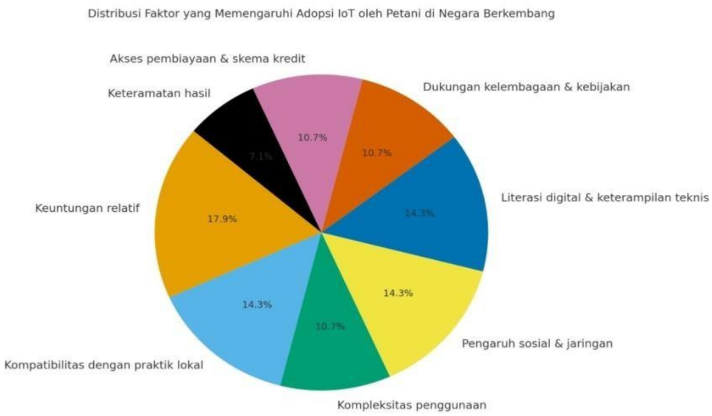

Figure 4

Factors Influencing Farmers’ Adoption of IoT

The table presenting the factors influencing IoT adoption by farmers in developing countries provides a comprehensive overview of the social, economic, and technical dynamics shaping adoption decisions. The pie chart illustrates the proportion of citations per factor, reflecting the focus of academic literature on specific dimensions. The first dominant factor is relative advantage. According to Rogers (2003), relative advantage is one of the most important attributes determining the speed of innovation diffusion. In agriculture, farmers are more motivated to adopt IoT when they perceive tangible benefits such as increased productivity, water efficiency, cost savings, or reduced crop failure risks. Islam et al. (2024) confirmed that perceptions of direct benefits are the primary drivers of adoption intention. Similarly, Harisudin et al. (2023) found that millennial farmers in Indonesia are more likely to adopt technologies when they believe these confer competitive advantages. The large proportion of citations for this factor indicates that economic and practical benefits remain central in decision-making.

The second factor is compatibility with local practices, referring to the extent to which technologies align with farmers’ values, traditions, experiences, and needs. IoT is more readily adopted when it does not require radical shifts in traditional practices. For instance, soil moisture sensors designed to complement local irrigation practices are more acceptable than fully automated systems demanding major changes. Choruma et al. (2024) note that low compatibility often results in resistance, particularly in rural communities with entrenched agricultural traditions. Similarly, Montesclaros and Teng (2023) emphasised that integration is more effective when adjusted to socio-cultural contexts. The four citations for this factor underscore the need to consider cultural adaptation in adoption strategies.

Social influence and networks are also significant, with four citations. Farmers’ decisions are often shaped not individually, but collectively, through communities, extension agents, opinion leaders, and family. Harisudin et al. (2023) observed that peer and farmer-group influence is critical in shaping young farmers’ intention to use IoT. Colussi et al. (2024) in Brazil highlighted the role of communication networks in accelerating precision agriculture adoption. This indicates that social diffusion mechanisms are vital for scaling adoption.

Digital literacy and technical skills represent another major factor (four citations). This encompasses the ability to read, interpret, and use data produced by IoT devices. Without adequate literacy, farmers struggle to operate sensors or incorporate data into farming practices (Magesa et al., 2023). Nxumalo (2025) also stressed that digital skills limitations represent systemic barriers in many developing countries. The attention paid to this factor underscores the need for education and technical training programmes to accompany IoT adoption.

Other factors include:

- Complexity of use (3 citations): The more complex the technology, the slower its adoption (Rogers, 2003). Farmers are less likely to adopt technologies they perceive as overly complicated (Islam et al., 2024).
- Institutional and policy support (3 citations): Adoption is closely tied to state or institutional involvement, including incentives, regulations, and subsidies (CTA & Dalberg, 2019; Balkrishna et al., 2023).

- Access to finance and credit (3 citations): Limited financial access hinders adoption, even when relative advantage is recognised (Dibbern et al., 2025; Colussi et al., 2024).
- Observability of outcomes (2 citations): Although least cited, this factor is crucial during early diffusion. Farmers are more likely to adopt when they can directly observe benefits through field demonstrations (Singha et al., 2024; Montesclaros & Teng, 2023).

Overall, the pie chart suggests a relatively balanced distribution of determinants, with relative advantage, compatibility, social influence, and digital literacy emerging as the most important. Adoption of IoT is therefore shaped by a complex interplay of economic, social, cultural, technical, and institutional factors, and cannot be explained from a single perspective.

Findings and Thematic Synthesis

The systematic review indicates that IoT adoption among farmers in developing countries is generally low to moderate, with significant regional variation. Sub-Saharan Africa remains at the lowest adoption level, dominated by pilot projects and SMS/app-based services. India and South-East Asia show more dynamic trends, though adoption remains concentrated in high-value commodities and larger farms. Latin America, particularly Brazil, is more advanced in large-scale crops such as soybeans but still faces gaps between large- and small-scale farmers. West Africa and the livestock subsector reveal very limited adoption.

Thematically, the main barriers include high costs, weak digital infrastructure, low digital literacy, and insufficient institutional support. Determinants of adoption are multidimensional, encompassing relative advantage, compatibility, complexity, social influence, literacy, finance, and observability. These findings are consistent with Rogers' (2003) innovation diffusion theory and socio-technical systems perspectives, both of which emphasise the interplay of technical, social, economic, and institutional factors.

This review aligns with prior studies highlighting the digital divide between developed and developing countries (Ronaghi & Forouharfar, 2020). Earlier work emphasised device costs as a key barrier (Hundal et al., 2023), consistent with this study's findings. Li et al. (2024) further highlighted the importance of government support, reinforced here with evidence from India and South-East Asia. However, this review contributes new insights by stressing social influence and cultural dimensions, often underexplored in previous literature, as equally significant alongside technical and economic factors.

Contributions and Implications

The study extends theoretical understanding by showing that while Rogers' (2003) diffusion framework remains relevant, it requires enrichment through socio-economic and institutional dimensions. It also reinforces socio-technical systems perspectives, which view adoption as shaped not only by technology but also by public policy, infrastructure, and institutional ecosystems.

From a practical perspective:

- Technology providers must design devices that are affordable, simple, and compatible with local practices, supported by cooperative or rental-based business models.
  - Extension services should prioritise digital literacy training and long-term technical support.
- Private sector actors can build sustainable IoT ecosystems by integrating sensors, data analytics, and advisory platforms.
- Policy makers must provide subsidies, expand rural infrastructure, and implement supportive regulations.

CONCLUSIONS AND SUGGESTIONS

This study concludes that IoT adoption among farmers in developing countries remains low to moderate, hindered by structural, technical, and socio-cultural barriers. The most critical obstacles are high costs, poor infrastructure, low digital literacy, and weak policy support. Determinants of adoption are multidimensional, encompassing relative advantage, compatibility, social influence, literacy, and financial access. The key contribution lies in highlighting the importance of social and institutional dimensions in addition to technical and economic factors. Practically, the findings call for holistic interventions combining affordable technology design, farmer training, supportive financing models, and integrative policy frameworks.

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