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Implementation of the Internet of Things (IoT) in the Sustainable Agricultural Products Sales System

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ABSTRACT

The rapid development of the Internet of Things (IoT) has created new opportunities for transforming agricultural systems toward sustainability, particularly in agricultural product sales systems. This study aims to explore the implementation of IoT in sustainable agricultural product sales systems in Indonesia and to understand its economic, environmental, and social implications. Using a qualitative research approach, data were collected through in-depth interviews with five key informants representing farmers, agribusiness actors, technology providers, and supporting institutions involved in IoT-based agricultural practices. The findings reveal that IoT implementation supports real-time monitoring of product quality, inventory management, traceability, and sales coordination, which contribute to improved market transparency and efficiency. Economically, IoT helps reduce post-harvest losses, strengthens bargaining positions, and stabilizes income. Environmentally, it supports waste reduction and promotes environmentally responsible sales practices. Socially, IoT enhances trust and collaboration among stakeholders, although challenges related to digital literacy, infrastructure limitations, and investment costs remain significant. Overall, this study demonstrates that IoT has strong potential to support sustainable agricultural product sales systems in Indonesia, provided that its implementation is accompanied by institutional support, capacity building, and inclusive governance mechanisms.

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1. Introduction

The agricultural sector plays a strategic role in Indonesia's economic structure, not only as a source of food security but also as a major contributor to employment and rural livelihoods. Alongside its economic importance, agriculture in Indonesia faces persistent challenges related to productivity, market access, price volatility, post-harvest losses, and environmental sustainability [1]. Traditional agricultural product sales systems are often characterized by long distribution chains, limited transparency, information asymmetry between farmers and buyers, and weak bargaining positions for small-scale producers [2]. These conditions hinder the realization of a

sustainable agricultural system that is economically viable, socially inclusive, and environmentally responsible [3].

In recent years, digital transformation has emerged as a key driver in addressing structural problems within agricultural value chains. One of the most prominent technological innovations influencing this transformation is the Internet of Things (IoT) [4]. IoT refers to the integration of sensors, devices, and digital platforms that enable real-time data collection, monitoring, and communication across interconnected systems. In the agricultural context, IoT has been widely applied in areas such as precision farming, soil and climate monitoring, irrigation management, and crop health surveillance [5]. However, beyond production activities, IoT also holds significant potential in reshaping agricultural product sales systems by improving traceability, transparency, and efficiency from farm to market [6].

The concept of sustainability in agricultural sales systems emphasizes not only economic outcomes, such as income stability and market expansion, but also environmental stewardship and social equity [7]. Sustainable sales systems aim to reduce waste, optimize resource use, ensure fair pricing mechanisms, and strengthen trust among stakeholders, including farmers, distributors, retailers, and consumers [8]. In Indonesia, where smallholder farmers dominate the agricultural landscape, the integration of IoT into sales systems offers an opportunity to bridge information gaps, shorten supply chains, and enhance farmers' access to markets and consumers [9].

Despite the growing discourse on digital agriculture, empirical research examining the implementation of IoT within agricultural product sales systems—particularly from a sustainability perspective—remains limited in the Indonesian context [10]. Existing studies largely focus on technical efficiency and productivity improvements, while comparatively little attention has been given to how IoT adoption reshapes sales mechanisms, stakeholder interactions, and sustainable value creation [11]. Furthermore, the successful integration of IoT in agriculture extends beyond technological readiness, as it is strongly influenced by institutional support, digital literacy, infrastructure availability, and the preparedness of actors within the agricultural ecosystem. Addressing these gaps, this study employs a qualitative approach to explore the implementation of IoT in sustainable agricultural product sales systems in Indonesia by engaging directly with key informants involved in IoT-based agricultural practices. Through this approach, the research seeks to generate in-depth insights into how IoT technologies are applied in sales processes, the sustainability-related benefits perceived by stakeholders, and the challenges encountered during implementation. By doing so, this study contributes qualitative empirical evidence to the literature on IoT-enabled sustainable agriculture in a developing country context and provides practical implications for policymakers, agribusiness actors, and technology providers in formulating context-sensitive strategies that support inclusive and sustainable digital transformation in Indonesian agriculture.

2. Literature Review

2.1 Internet of Things (IoT) in Agriculture

The Internet of Things (IoT) refers to a network of interconnected physical devices equipped with sensors, software, and connectivity that enable the real-time collection, exchange, and analysis of data, and it has become a central component of digital agriculture supporting data-driven decision-making across agricultural value chains [5]. In the agricultural sector, previous studies indicate that IoT applications are widely used in areas such as soil moisture sensing, weather monitoring, livestock tracking, smart irrigation, and crop health monitoring, allowing

farmers and agribusiness actors to enhance operational efficiency, reduce uncertainty, and optimize resource utilization [12]. Beyond production-focused applications, recent literature also highlights the growing role of IoT in post-harvest handling, logistics, and market integration, where IoT-enabled systems facilitate continuous monitoring of product quality, storage conditions, and transportation processes to preserve value and minimize losses [13]. In developing country contexts such as Indonesia, characterized by fragmented agricultural supply chains, IoT adoption holds significant potential to improve coordination among actors and enable access to timely and accurate information; however, existing studies also emphasize that the effectiveness of IoT implementation is strongly shaped by contextual factors, including infrastructure availability, technology affordability, and users' digital capabilities.

2.2 *Sustainable Agricultural Product Sales Systems*

Sustainable agricultural product sales systems are founded on the principles of sustainability, encompassing economic viability, environmental responsibility, and social inclusiveness [14]. From an economic perspective, such systems aim to ensure fair pricing, stable income for farmers, and efficient access to markets, while environmentally they emphasize waste reduction, efficient use of natural resources, and lower carbon footprints throughout distribution processes. Socially, sustainability in agricultural sales systems is reflected in equitable stakeholder participation, transparency, and trust-building between producers and consumers [15]. However, the literature indicates that traditional agricultural sales systems in developing economies often fall short of these sustainability objectives due to lengthy distribution chains, the dominance of intermediaries, and limited product traceability, which frequently lead to price distortions, weakened farmer bargaining power, and consumer concerns regarding product quality and origin [7]. As a result, scholars highlight the need for innovation in agricultural sales systems, particularly through the adoption of digital technologies, to address these structural challenges. In this context, digital platforms, traceability mechanisms, and data-driven sales systems are increasingly viewed as transformative tools capable of enhancing market transparency and efficiency, with IoT playing a critical role by supplying reliable, real-time data that can be integrated into digital sales platforms, certification processes, and market information systems to support sustainable agricultural markets.

2.3 *IoT and Sales System Transformation*

The integration of IoT into agricultural sales systems drives structural changes in how agricultural products are marketed, distributed, and valued by enabling greater transparency, efficiency, and data-driven decision-making [16]. Existing studies indicate that IoT-enabled traceability systems allow stakeholders to monitor products from production to consumption, thereby strengthening transparency and accountability, which are increasingly demanded in sustainability-oriented markets where consumers seek information on production methods, environmental

impacts, and product authenticity [17]. In addition, IoT facilitates data-driven sales strategies through real-time data collection that supports demand forecasting, inventory management, and dynamic pricing, helping to reduce overproduction and better align supply with market demand [18]. For farmers, access to timely market and quality information can enhance bargaining power and reduce dependence on intermediaries. However, the literature also highlights persistent challenges in integrating IoT into agricultural sales systems, including data interoperability constraints, high initial investment costs, cybersecurity risks, and resistance to change among traditional market actors. Consequently, the successful transformation of agricultural sales systems through IoT requires not only technological readiness but also strong institutional support, coherent policy frameworks, and effective collaboration among stakeholders across the agricultural ecosystem.

2.4 Sustainability Implications of IoT Adoption

From a sustainability perspective, the adoption of IoT in agriculture is frequently associated with positive environmental and economic outcomes, as empirical studies indicate that IoT-enabled monitoring can reduce resource waste, optimize logistics routes, and minimize post-harvest losses, thereby supporting environmental sustainability, while improved operational efficiency and enhanced market transparency contribute to greater profitability and income stability for agricultural producers [19]. However, the implications of IoT adoption for social sustainability remain subject to debate in the literature, as although IoT has the potential to empower farmers through improved access to information and markets, unequal access to technology may intensify digital divides between large-scale agribusinesses and smallholder farmers. Consequently, scholars underscore the need for inclusive IoT implementation strategies that prioritize capacity building, affordability, and sensitivity to local contexts to ensure that digital transformation in agriculture promotes equitable and broad-based sustainable development [20].

2.5 Research Gap and Conceptual Positioning

Although the existing literature offers valuable insights into IoT applications in agriculture and their sustainability implications, several critical gaps remain, as most studies continue to emphasize production efficiency while giving limited attention to agricultural product sales systems as integrated and sustainability-oriented processes. In addition, empirical research on the implementation of IoT in agricultural sales systems within the Indonesian context remains scarce, particularly qualitative studies that capture stakeholder experiences, perceptions, and contextual realities. Moreover, the interplay between technological innovation, sustainability objectives, and socio-institutional factors in shaping agricultural sales systems has not been adequately explored. Addressing these gaps, this study examines the implementation of IoT in sustainable agricultural product sales systems in Indonesia by emphasizing stakeholder perspectives, contextual challenges, and sustainability outcomes. In doing so, the research positions itself at the

intersection of digital agriculture, sustainable sales systems, and qualitative inquiry, contributing a more holistic understanding of IoT-driven transformation in agriculture.

3. Research Methods

3.1 Research Design and Approach

This study employed a qualitative research design to explore the implementation of the Internet of Things (IoT) in sustainable agricultural product sales systems in Indonesia, as a qualitative approach is well suited to capturing in-depth insights into processes, experiences, perceptions, and contextual factors surrounding IoT adoption rather than measuring causal relationships or testing hypotheses. Using an exploratory and descriptive orientation, the research enables a comprehensive examination of how IoT technologies are applied within agricultural sales systems, the sustainability-related benefits perceived by stakeholders, and the challenges encountered during implementation, thereby reflecting the complex interactions between technology, sustainability, and agricultural sales practices in real-world contexts.

3.2 Informant Selection

The study involved five key informants selected through purposive sampling to ensure that participants possessed relevant knowledge, experience, and direct involvement in IoT-based agricultural practices and sales activities. The informants represented diverse stakeholder groups within the agricultural sales ecosystem, including smallholder farmers, agribusiness or distributor representatives, technology providers, and institutional or organizational actors supporting digital agriculture initiatives. Informant selection was guided by criteria such as active involvement in IoT-supported agricultural production or sales systems, practical experience in using digital tools for monitoring, traceability, or sales activities, and willingness to share insights regarding the sustainability impacts and implementation challenges of IoT. The number of informants was deemed sufficient to achieve data saturation, as recurring themes and consistent patterns emerged throughout the interview process.

3.3 Data Collection Techniques

Primary data were collected through in-depth, semi-structured interviews, a method that enabled the researcher to address predefined topics while retaining flexibility to explore emerging issues in greater depth. An interview guide was developed to capture key themes, including the role of IoT in agricultural sales processes, perceived economic, environmental, and social sustainability benefits, changes in market access and transparency, and barriers to implementation. Interviews were conducted either face-to-face or via online communication platforms depending on informant availability and geographic location, with each session lasting approximately 45–60 minutes and conducted in the Indonesian language to ensure clarity and participant comfort. With informed consent, all interviews were recorded and transcribed verbatim to support rigorous qualitative analysis. In addition, supporting secondary data—such as policy documents, program reports, and relevant publications—were utilized to enrich contextual understanding and triangulate the interview findings.

3.4 Data Analysis

Data analysis was conducted using a thematic analysis approach, beginning with a familiarization stage in which the researcher repeatedly reviewed the interview transcripts to develop a comprehensive understanding of the data. This was followed by open coding, where meaningful segments of text were systematically labeled based on emerging concepts related to IoT implementation, sustainability outcomes, and transformations in agricultural sales systems. The coded data were subsequently organized into broader categories and themes, including technological functions, economic benefits, environmental implications,

social impacts, and implementation challenges, which were refined through an iterative process of comparison and interpretation to ensure analytical rigor and internal consistency. These finalized themes served as the foundation for interpreting the role of IoT in shaping sustainable agricultural product sales systems in Indonesia.

4. Results and Discussion

4.1 Forms of IoT Implementation in Agricultural Product Sales Systems

The findings indicate that the implementation of IoT in agricultural sales systems is primarily concentrated on post-harvest monitoring, quality control, and the integration of sales-related information. Informants described the use of sensors to monitor storage conditions, product freshness, and distribution processes, all of which are directly linked to sales readiness. This monitoring enables agricultural actors to ensure product quality prior to sale and to reduce the risk of quality deterioration during storage and distribution.

One informant explained, "We use sensors to monitor warehouse temperature and humidity, so before the products are sold, their quality can be ensured and reported to buyers" (I1). Another informant highlighted that IoT-generated data are directly integrated into digital sales platforms used for coordination, stating, "The data from IoT goes directly into the sales system, so we know stock levels, quality, and the best time to sell" (I3). These findings demonstrate that IoT is not only applied at the production stage but has become an integral component of agricultural sales system management, supporting previous studies that emphasize the role of IoT in enhancing transparency and coordination across agricultural value chains.

4.2 Economic Sustainability Impacts

Economically, the implementation of IoT was perceived to enhance efficiency, reduce post-harvest losses, and strengthen the bargaining positions of farmers and sellers. Informants consistently noted that access to real-time and objective data enabled more transparent price negotiations and reduced reliance on speculative pricing practices, particularly those dominated by intermediaries. By providing measurable evidence of product quality and condition, IoT data allowed agricultural actors to engage more confidently in market transactions.

As one informant stated, "With data from sensors, we can demonstrate product quality objectively, so prices are no longer determined unilaterally by middlemen" (I2). Another informant emphasized the role of IoT in reducing losses, explaining, "Post-harvest losses have decreased because we know the right time to sell the products, rather than waiting until quality declines" (I4). These findings are consistent with the literature that highlights the role of digital technologies in enhancing economic sustainability through improved market efficiency and income stability. Nevertheless, several informants pointed out that these economic benefits tend to be more pronounced among actors with greater access to capital and technological resources.

4.3 Environmental Sustainability Impacts

From an environmental perspective, the findings indicate that IoT contributes to waste reduction and more efficient resource use within agricultural sales and distribution processes. Informants emphasized that improved monitoring of storage and transportation conditions helped minimize product spoilage and reduce unnecessary disposal of agricultural products, thereby supporting more environmentally responsible sales practices.

As one informant explained, "Previously, many products were damaged during transportation, but now they can be monitored, which helps reduce waste" (I5). Another informant linked the use of IoT to environmentally oriented market positioning, stating, "Consumers now want to know

whether the production and distribution processes are environmentally friendly, and IoT data helps us explain that" (I3). These findings are consistent with sustainability-focused literature that views IoT as an effective tool for enhancing environmental accountability and reducing inefficiencies; however, informants also noted that the realization of environmental benefits depends on responsible system management and the efficient use of energy resources.

4.4 Social Sustainability and Stakeholder Relationships

In terms of social sustainability, the implementation of IoT was found to enhance trust and transparency among stakeholders within agricultural sales systems. Informants described improved relationships between farmers, cooperatives, and buyers as a result of shared access to reliable and verifiable data, which reduced information asymmetry and strengthened mutual confidence in sales transactions.

As one informant explained, "Buyers now have greater trust because all the data can be accessed, not just based on verbal promises" (I1). Another informant emphasized the role of IoT in collective decision-making, stating, "Within farmer groups, IoT data becomes a shared basis for discussion when determining sales strategies" (I4). However, informants also highlighted challenges related to digital literacy, noting that not all farmers are able to interpret data independently, as reflected in the statement, "Not all farmers can read the data, so ongoing assistance is still needed" (I2). These findings indicate that while IoT strengthens social trust and collaboration, sustained capacity-building efforts are essential to prevent new forms of dependency or inequality within agricultural communities.

4.5 Transformation of Sales Systems and Market Access

The findings reveal that IoT contributes to a gradual transformation of agricultural sales systems from traditional and opaque mechanisms toward more data-driven and transparent models. Informants reported improved access to modern markets and institutional buyers as a result of enhanced traceability and quality assurance enabled by IoT technologies, which allow agricultural products to meet clearer and more standardized market requirements.

As one informant stated, "With this system, our products can enter markets that were previously difficult to access because clear quality standards are in place" (I5). Another informant added, "IoT helps us shorten the distribution chain because buyers can directly trust the available data" (I3). This transformation is consistent with the digital agriculture literature, which highlights the role of technology in integrating small-scale producers into higher-value and sustainability-oriented markets through improved transparency, efficiency, and market connectivity.

4.6 Challenges and Enabling Factors in IoT Implementation

Despite its potential benefits, the implementation of IoT in agricultural sales systems faces several significant challenges. Informants identified high initial investment costs, limited infrastructure, and difficulties related to data integration as major barriers to adoption, particularly for small-scale farmers and local agricultural actors. These constraints often limit the scalability and inclusiveness of IoT-based systems within agricultural markets.

As one informant explained, "The initial costs are quite high, so without support, small farmers find it difficult to participate" (I2). Concerns regarding data governance were also raised, with one informant noting, "There are still questions about who owns the data and how its security is ensured" (I4). Conversely, informants highlighted enabling factors such as institutional support, cooperative-based implementation models, and targeted training programs, as reflected in the statement, "When

there is assistance and collaboration with cooperatives, IoT adoption becomes more realistic" (I1). These findings suggest that overcoming implementation barriers requires not only technological solutions but also supportive institutional arrangements and capacity-building initiatives.

4.7 Discussion

Overall, the findings demonstrate that IoT implementation has a meaningful impact on sustainable agricultural product sales systems in Indonesia by enhancing economic efficiency, environmental responsibility, and social transparency [21]. The interview evidence indicates that IoT functions not merely as a technological tool but as a socio-technical mechanism that reshapes interactions, trust, and value creation within agricultural markets [22]. By enabling data-driven decision-making and improving transparency across sales processes, IoT supports more sustainable and accountable market practices [23].

Consistent with prior studies, this research shows that IoT adoption contributes to sustainability outcomes when it is accompanied by institutional support and human-capacity development. In the absence of such support, however, the risk of exclusion and unequal distribution of benefits persists, particularly among small-scale agricultural actors [24]. Therefore, this discussion reinforces the argument that IoT-driven sustainability in agricultural sales systems requires an integrated approach that balances technological innovation with governance mechanisms and social inclusion. These findings offer important implications for policymakers and practitioners seeking to promote sustainable digital transformation in Indonesian agriculture, especially in designing inclusive IoT adoption models that align technological advancement with broader sustainability objectives.

5. Conclusion

This study concludes that the implementation of the Internet of Things (IoT) plays a significant role in supporting sustainable agricultural product sales systems in Indonesia by enabling real-time monitoring, quality assurance, and traceability that enhance transparency and efficiency across sales processes. Economically, IoT contributes to the reduction of post-harvest losses, improves pricing mechanisms, and strengthens the bargaining power of farmers and sales actors, while environmentally it supports waste reduction and more efficient resource use, thereby reinforcing the sustainability of agricultural distribution systems. From a social perspective, increased transparency and data sharing foster trust and collaboration among stakeholders, although disparities in digital literacy and access to technology remain important challenges. Despite these positive impacts, IoT adoption in agricultural sales systems is constrained by high investment costs, limited infrastructure, and concerns related to data management and governance; therefore, successful and sustainable implementation requires integrated strategies that combine technological innovation with institutional support, capacity-building initiatives, and inclusive policy frameworks. By addressing these challenges, IoT can serve as a powerful enabler of sustainable agricultural development and market integration in Indonesia.

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