Increasing Adoption of the Internet of Things in Indonesian Agriculture Based on a Review of Everett Rogers' Diffusion Theory of Innovation

Desi Elvera Dewi[1], P. N. Aprilliyana Cahyani[2], and Lokita Rizky Megawati[1](✉)

[1] School of Business, IPB University, Bogor, Indonesia
lokita.rizky@apps.ipb.ac.id

[2] Department of Agribusiness of Economics and Management, IPB University, Bogor, Indonesia

Abstract. Year after year, the global human population grows while agricultural land is shrinking. The loss of agricultural land is made worse by the depletion of natural resources and the emergence of unanticipated environmental crisis problems like global warming, salinization, and flooding. Due to this situation, food security has become the top priority for all countries in the world. Therefore, smarter, better, and more effective approaches are required to solve the issues posed by the challenges of decreasing agricultural land, one of which is the use of the Internet of Things for agriculture. This essay aims to examine the current situation of IoT adoption in Indonesian agriculture and to put forward and develop strategies for increasing IoT adoption in Indonesian agriculture. The method used in this study is a qualitative approach based on Rogers' diffusion theory and data were obtained through a literature review. There are five attributes to be considered in increasing the adoption of IoT in agriculture. The innovation attributes are relative advantage compatibility, complexity, trialability, and observability. Optimizing the millennial generation as early adopters is one option for increasing agricultural technology adoption. However, special efforts are required to increase the participation of the millennial generation in government policy agriculture. One of them is to provide adequate infrastructure to support the creativity of the millennial generation.

Keywords: Agriculture · Rogers' Diffusion Theory of Innovation · Smart Farming · Millennial Farmer

1 Introduction

The human population is growing every year on the planet. The world's population is anticipated to reach 10 billion people by 2050 (UN 2019). Meanwhile, the population of Indonesia in 2020 is expected to be 270.20 million, a 32.56 million increase over the previous ten years [2]. As a result, the demand for agricultural products fluctuates from time to time.

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On the other hand, agricultural land is shrinking. According to statistical data, the use of agricultural land in Indonesia, both wet and dry land, has continued to decline sharply over the last five years (2015–2019). The area of land use for rice fields decreased by nearly 50% from 99.73 million hectares in 2015 to 51.14 million hectares in 2019. Similarly, the use of a non-paddy land area of 102.36 million hectares in 2015 increased to 69.1 percent in 2019 [3]. Depletion of natural resources and the rise of unforeseen environmental crisis issues like global warming, salinization, and flooding worsen the loss of agricultural land. Due to this circumstance, food security has emerged as the world's top concern for all nations.

The problem of global food security necessitates immediate solutions and breakthroughs. To meet the ever-increasing demand for food and the challenges of shrinking fertile land, smarter, better, and more efficient farming methods are required, one of which is the application of technology 4.0 to agriculture. Smart farming is a platform that uses various technological devices and information systems to increase agricultural production. The Internet of Things is a technology that is widely used in agricultural systems (IoT). In agriculture, the Internet of Things (IoT) refers to a network in which physical components such as animals and plants, environmental elements, production tools, and various virtual objects are linked to the internet via an information system. The primary motivation for implementing IoT in agriculture is to help farmers increase productivity, and profitability, reduce human labor, and increase production efficiency [12]. Sensor perception technology, information transmission technology, information processing technology, radio-frequency identification, and 3S technology (remote sensing, global navigation satellite system, and geographic information system) are the five main components of IoT in agriculture [12]. Wireless sensors, UAVs, cloud computing, communication technology, and other IoT-based architectures and platforms are used in agricultural applications [1]. According to Quy et al. (2022), the use of IoT in agriculture is aimed at monitoring production processes (such as soil moisture, air humidity, temperature, pH level, and so on); product tracking to increase consumer confidence in product safety and health; process automation with smart precision farming through the use of global navigation satellite system (GNSS) and global positioning system (GPS); and environmental engineering through greenhouses [9].

IoT innovation and development have been massive, and it has been proven to increase agricultural product productivity. However, the use of technology 4.0 in agriculture, particularly IoT, faces the challenges of a slow diffusion process and low adoption rate. Farmers in developed countries can easily access technology, making this issue simple to resolve. On the other hand, this issue presents a big barrier in developing countries since the majority of farmers in rural areas have extremely limited access to cutting-edge technology. As a result, the adoption and distribution of these technologies are required due to the growing use of IoT technology in agriculture [13].

The two main objectives of this study are to (1) examine the current situation of IoT adoption in Indonesian agriculture and (2) analyze strategies for increasing IoT adoption in Indonesian agriculture. The approach of Everett Rogers' theory of diffusion of innovation is used to examine the degree of technological adoption and diffusion. Secondary data from multiple publications were used to generate the data for this paper.

2 Material and Method

The approach used to analyze the level of technology adoption in this study is to use Everett Rogers' theory of diffusion of innovation. This theory is one of the best approaches for analyzing the factors that influence the rate of diffusion and adoption of an innovation. Rogers (2003) defines diffusion as "the process by which an innovation is communicated over time among members of a social system through certain channels" (p. 5). Furthermore, the adoption rate is defined as "the relative speed with which a social system's members adopt an innovation" (p. 221). In order to assess the feasibility of an innovation being adopted by society, Rogers developed five attributes that have an impact on the extent of market adoption of an innovation. The innovation attributes are (1) relative advantage, (2) compatibility, (3) complexity, (4) trialability, and (5) observability. [10].

According to Rogers (2003), the relative advantage is "the degree to which an innovation is perceived to be superior to the idea it replaces" (p. 229). This attribute is positively correlated with the rate of adoption, implying that the greater an innovation's relative advantage, the easier it will be to adopt the innovation. Compatibility can be characterized as the extent to which a new innovation complies with the values, experiences, and requirements of potential adopters. Complexity explains to what extent the innovation is simple to comprehend and apply. In contrast to other attributes, complexity is negatively correlated with adoption rates. Thus, an innovation's excessive complexity is a significant barrier to its adoption. Trialability is the extent to which a new invention can be tested out on a small scale. Observability is "the degree to which the outcomes of an innovation are visible to others" (p. 16). Peer observation (or role modeling) is a major motivator in technology adoption and diffusion [10].

The method used in this study is a qualitative method through the approach of Rogers' diffusion theory. The data used in this essay is secondary data which were obtained through a literature review.

3 Results and Discussion

3.1 IoT Adoption in Agriculture

Relative Advantage

Technology 4.0 in this sense refers to a development that seeks to enhance or replace conventional agriculture. The relative benefit components of cost and efficiency serve as the main benchmarks in the technology adoption process.

According to Solodovnik et al. (2021), agricultural digitization increases efficiency and productivity in industries where the use of IoT in agriculture is the direction of technological breakthroughs that can save agricultural resources. According to the most recent osservatori.net report, Agriculture 4.0's use of digital technology has reduced costs per hectare by 13% and consumption of water, fuel, fertilizers, and pesticides by 30%, while crop carbon footprints have decreased by 15% for environmental sustainability [5]. Applications based on IoT technology, such as self-driving tractors, GPS field mapping, automated sensors on farm equipment, IoT-based field-level weather forecasts, machine optimization tools, and productivity measurement tools, help produce better crops in regions with limited arable land, water, and resources [7].

Based on the findings of these and other studies, it is possible to conclude that IoT technology has a comparative advantage over traditional agriculture, where IoT adoption can significantly increase productivity while increasing the efficiency with which agricultural resources such as land, water, and fertilizer are used.

Compatibility

According to some diffusion studies, relative advantage and compatibility are conceptually similar. Existing skills and practices and values and norms are two distinct aspects of compatibility. The degree to which an innovation matches a potential adopter's existing skills, tools, procedures, and performance criteria is critical and relatively easy to assess. IoT and technology compatibility is generally related to the applicable technology standards in this case.

According to Solodovnik et al. (2021), standardization - the creation of uniform security standards for the Internet of things, the development of working standards, the creation the development of standards for database compatibility, and the development of indicator standards for various digital platforms - is one of the challenges to the implementation of IoT in rural areas [11]. This is consistent with the Ministry of Communication and Information website, which states that there are three major barriers to IoT adoption: frequency standardization, device standardization, and TKDN. The government has stated that the Domestic Content Level (TKDN) scheme for IoT devices will be implemented [6].

Based on this, it can be concluded that despite the compatibility of IoT use, there are still challenges that can impede the level of adoption of these innovations. In this case, the government intends to issue a standardization regulation for the IoT industry, which is expected to make it easier for innovators and adopters to develop mass use of the technology.

Complexity

Farmers perceive IoT in the agricultural industry to be complex and difficult [11]. IoT operations necessitate a thorough understanding of the various software, hardware, and communication components of an IoT-based platform. At the IoT adoption stage, skilled agricultural workers are required to operate these technological devices. This complexity is undoubtedly an impediment to adoption, particularly in agriculture in rural areas where most farmers have not been exposed to sophisticated equipment. However, this level of complexity has the potential to be reduced because the Indonesian people already have good capital, namely a high level of internet use (204.7 million people in 2022). One of the steps expected to increase farmers' adoption of smart agricultural technology is the development of various digital platforms in agriculture with advanced and user-friendly features. Furthermore, it is necessary to conduct socialization and training in operating IoT-based devices through the optimization of agricultural extension workers for better adoption.

Trialability

According to Rogers (2003), trialability is the degree to which an idea can be tested on a small scale. A higher rate of adoption is connected to this trait. It is possible to avoid failure by running innovation trials. Additionally, IoT device installation is pricey, which will surely be a hardship for farmers. [10].

To increase the trialability factor, the government must intervene by optimizing technology development centers owned by the government as pilot project laboratories for smart agricultural innovations before they are finally released to the public.

Observability

Observability is positively correlated with the rate of acceptance of an innovation, just like a relative advantage, compatibility, and trialability. The government must promote smart agriculture methods in order to spread word of mouth among the greater community and boost observability. They must be simple to obtain and provide an understandable message in order to persuade people to adopt these beneficial behaviors.

3.2 Increasing the Adoption of IoT in Agriculture

Individuals going through the adoption process are also involved in the innovation diffusion process. Innovation does not occur in a social system at the same time. Instead, they adopt in chronological order and can be classified into adopter categories based on how long it takes them to implement a new idea. Adopters are defined by Rogers (2003) as “a classification of members of a social system based on innovation” (p. 22). Innovators, early adopters, early majority, late majority, and laggards are all included in this category. The ability of leaders or policymakers to identify these groups will improve and speed up the adoption of an innovation [10].

Individuals who create innovations and introduce them into the system are known as innovators. Meanwhile, early adopters typically have the capital to invest, enjoy being trendsetters, and hold positions of leadership in social systems. Additionally, the early majority interacts positively with other social system participants but takes longer than innovators and early adopters demand. One-third of all social system members make up the late majority because they wait to implement the innovation until the bulk of society has done so. Although they are skeptical of innovation, peer pressure can persuade them to adopt it. Last but not least, laggards have constrained resources in addition to a lack of awareness and understanding of innovation. Before putting an idea into practice, they want to be sure it works well.

The personality of the early adopters is what makes this group of adopters so interesting. This group has a significant impact on product innovation as well as the process of innovation diffusion in marketing. They are frequently regarded as “thought leaders” among their peers due to their high participation rate on social media and their proclivity to review new innovations (Roger 2003). As a result, identifying this group is critical to success in the process of increasing the adoption of technology 4.0 in agriculture. The success of leveraging the knowledge and enthusiasm of the 4.0 technology development trend will have a positive impact on the process of innovation adoption.

When examined further, the characteristics described by Roger about early adopters resemble those of the millennial generation. According to Connaway et al. (2008), the distinguishing feature of millennials is that they are “digital natives,” having been raised with technology that has always been present throughout their lives. According to Connaway, 20% of Millennials first used a computer between the ages of five and eight. Unlike Boomers and Generation Y workers, 72 percent of this population check their email at least once a day, and 78 percent enjoy recreational web browsing [4]. Because of these characteristics, millennials are actors with significant potential as early adopters of technology. 4.0.

However, there are not many millennial generations in Indonesia who choose to work as farmers. According to the Central Statistics Agency (BPS), the number of farmers reached 33.4 million in 2019. Only 2.7 million, or 8%, of Indonesia's young farmers between the ages of 20 and 39 fall into this category. As a result, additional incentives and efforts are required to encourage millennials to enter agriculture, ultimately increasing the adoption of technology 4.0 in agriculture.

4 Conclusion

A review of the factors affecting the degree of adoption of technology 4.0 in agriculture indicates that the relative advantage of IoT technology is the most important and beneficial attribute. Compatibility and complexity, on the other hand, continue to be barriers to technology adoption. To overcome these obstacles, various digital platforms in the agricultural sector must be developed with advanced features that are more user-friendly and compatible with community technological standards [8]. Furthermore, the trialability and observability factors remain a challenge and, if not addressed properly, can be an impediment to the adoption process in the long run. Trialability in IoT technology observability necessitates government incentives and support, particularly for medium and small agricultural producers.

One possibility for increasing technology adoption in agriculture is to optimize the millennial generation as early adopters. However, special efforts are required to increase the participation of the millennial generation in government policy agriculture. One of them is to provide adequate infrastructure to support the creativity of the millennial generation.

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