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Enhancing Hydroponic Farming with IoT: Empowering Innovative and Speculative Young Farmers

Anis Fuad Salam[1]*, Kartina AM[1], Mirajiani[1]
[1]Universitas Sultan Ageng Tirtayasa, Serang, Indonesia
*Corresponding author: anisfuadsalam450@gmail.com

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ABSTRACT

The integration of Internet of Things (IoT) technology into hydroponic farming systems presents a transformative opportunity to modernize agriculture and attract the younger generation to the sector. This study explores the effectiveness of IoT applications in hydroponic cultivation to foster a new wave of tech-savvy, innovative young farmers. Hydroponics, a soil-less farming method that utilizes nutrient-rich water, offers various advantages such as efficient water use, controlled environments, and suitability for limited land spaces. When combined with IoT—through the use of sensors, automation, and real-time monitoring—hydroponic systems become more efficient, sustainable, and appealing to youth interested in modern agriculture. The research outlines the types of hydroponic systems and their integration with IoT, highlights the benefits and challenges of such implementation, and emphasizes the pivotal role of government in supporting young farmers through education, infrastructure, financing, and policy. Key challenges identified include high initial costs, limited internet infrastructure, and lack of technological literacy among farmers. Despite these barriers, the adoption of IoT has the potential to increase productivity, reduce manual labor, and elevate the status of farming as a profitable and high-tech career path for young people. The study concludes that a strong collaboration between government, educational institutions, and the private sector is crucial to empower the next generation of innovative farmers and ensure the sustainability of the agricultural sector.

1. Introduction

Hydroponics or hydroponics is a method of cultivating plants without using soil as a planting medium (Hidayati, Rosawanti, and Yusuf, 2017). The word "hydroponics" comes from the Greek, namely hydro which means water and ponics which means workmanship, so hydroponics can be interpreted as a farming technique using water as the main medium.

The history of hydroponics has started as far back as three centuries ago. In 1669, the first hydroponics-related trials were carried out in a laboratory in England. A rapid development in this field occurred in 1936 when Dr. W.F. Gericke in California, United States, succeeded in growing a three-meter-tall tomato plant with a bountiful harvest in a container filled with a mineral solution. In the 1950s, Japan began to implement a hydroponic system extensively to meet the vegetable needs of United States soldiers stationed in the country (Syarifudin et al., 2022).

In Indonesia, the hydroponic system began to be known in 1970, although at first it was only applied in the academic scope in universities. It was only in 1980 that hydroponics began to be used more widely, especially in the cultivation of ornamental plants.

Hydroponic techniques have a number of advantages over conventional farming methods. One of the main benefits is the higher efficiency of water use, as the plant's roots come into direct contact with a nutrient solution that not only serves as a source of water but also provides the nutrients necessary for growth. In addition, hydroponics requires a smaller amount of land thanks to the vertical integration system, which allows plants to be planted in stages so that land use becomes more efficient. Another advantage is that the hydroponic system is not affected by climate change, since the environmental conditions in which the plants grow can be controlled specifically.

Technology in hydroponics is constantly evolving to improve the efficiency and productivity of soilless farming systems. Internet of Things (IoT) technology is increasingly being applied in modern agricultural systems, including the cultivation of hydroponic crops. IoT enables automatic and real-time monitoring and management of hydroponic systems through internet-connected devices.

Along with technological developments, the agricultural sector has undergone significant transformation through the application of the Internet of Things (IoT). This technology allows for automatic and real-time management of agricultural systems, including in hydroponic cultivation. One of the challenges in the world of agriculture today is the lack of interest of the younger generation to get involved in the sector. Therefore, the application of IoT in hydroponics can be a solution to attract the interest of young farmers, because it is more efficient, modern, and does not require large land.

The use of IoT in hydroponics not only increases agricultural efficiency and productivity, but also becomes an innovative solution to create a generation of young farmers who are more adaptive to technology. With a more modern farming system, the younger generation can see agriculture as a profitable and sustainable business opportunity.

2. Methodology

This study employs a qualitative descriptive approach aimed at exploring the effectiveness of Internet of Things (IoT) systems in hydroponic cultivation and their role in fostering interest among young farmers. The research is grounded in the analysis of existing literature, real-world case studies, and expert perspectives related to smart agriculture, hydroponics, and youth engagement in farming. Data collection was conducted through extensive literature review, examining scientific publications, books, and credible online sources that discuss the integration of IoT in agriculture, particularly hydroponic systems. In addition to literature review, the study also analyzes various case examples of IoT-based hydroponic farms both in Indonesia and internationally. These cases provide insight into system implementation, effectiveness, accessibility for young farmers, and outcomes in terms of productivity and sustainability. Where relevant, insights from practitioners, educators, and policymakers were also considered to enrich the analysis. The study focuses on three primary aspects: the technical effectiveness of IoT in enhancing hydroponic systems, the extent to which such technology encourages the participation of young farmers, and the role of government support in enabling this transformation. Data was analyzed using content analysis techniques to identify recurring themes, challenges, and strategies related to the successful implementation of IoT in agriculture. Although this study provides a comprehensive

overview, it is limited by the availability of empirical field data and focuses more on secondary sources and conceptual exploration. Nonetheless, it offers valuable insights into how modern technology can transform agriculture into a more attractive and viable sector for the younger generation.

3. Results and Discussion

3.1. The Use of the Internet of Things (IoT) System in Plant Cultivation Hydroponic System to Create Young Farmers Who Speculate High

The Internet of Things (IoT) is a technological concept in which physical devices (sensors, electronic devices, machines, and automated systems) are connected to each other via the internet to collect, transmit, and analyze data automatically without the need for direct human intervention.

In the context of agriculture, IoT is used to improve efficiency, productivity, and supervision of crops, soil, and environmental conditions through sensors and automated systems. There are several Challenges and Obstacles to the Application of IoT in Hydroponics, including:

1. High Initial Costs

One of the main challenges for young farmers in using agricultural technology is the high initial costs. Many modern systems such as the Internet of Things (IoT), agricultural drones, and automated robots require large investments before providing long-term benefits. Although the initial cost of agricultural technology is high, there are many solutions to make it more affordable for young farmers. With strategies such as funding, open-source innovation, and community collaboration, young farmers can adopt technology without being burdened with large costs.

2. Availability of Internet Infrastructure

One of the obstacles in the application of agricultural technology based on the Internet of Things (IoT) and digitalization is limited internet access in rural or agricultural areas. A stable internet connection is essential for real-time remote monitoring, automation, and processing of farm data. The challenge of internet availability in agriculture is still an obstacle that occurs until now where the internet network is uneven, internet costs are expensive, lack of telecommunication infrastructure and limited electrical power. Although the limitations of internet infrastructure are still a challenge, alternative technologies such as LoRa, satellite internet, and digital village networks can be solutions. Support from governments, tech startups, and communities is essential for young farmers to make the most of IoT-based agriculture.

3. Lack of Technological Knowledge by Farmers

One of the main challenges in the application of agricultural technology is the lack of technological knowledge and skills among young farmers. Although technologies such as IoT, drones, and agricultural e-commerce are evolving, many farmers still do not understand how to use, manage, and utilize these technologies to the fullest. Lack of technological knowledge can hinder growth and innovation in the agricultural sector. However, with education, training, and a simpler approach to technology, young farmers can more easily adopt IoT, automation, and digital marketing to increase their productivity and competitiveness.

Young farmers are a new generation of farmers who are more innovative, technology-adaptive, and business-oriented. They often combine digital technologies, IoT (Internet of Things), and sustainable farming practices to increase productivity and profits. Farmer regeneration is an interesting process and involves the younger generation to enter the agricultural sector to replace aging farmers. Currently, the average age of farmers in Indonesia and many other countries is over 50 years old, while the younger generation's interest in agriculture is still low.

The adoption of technology in agriculture is an important step to improve the efficiency, productivity, and sustainability of the agricultural sector. With technological advancements such as the Internet of Things (IoT), drones, artificial intelligence (AI), and data-driven agriculture, farmers can optimize crop yields and reduce operational costs. However, there are still various challenges in its implementation. The adoption of technology in agriculture offers great potential in increasing productivity and efficiency. However, training support, infrastructure, and funding are needed to make technology accessible to more farmers, especially the younger generation.

Although young farmers have great potential in developing technology-based agriculture, they still face various challenges that can hinder farmer regeneration and the sustainability of the agricultural sector. Here are some of the main challenges faced by young farmers:

1. Large Initial Capital, modern agricultural technology requires a fairly high initial investment.
2. Access to the market, price competition with conventional products is still a challenge.
3. Lack of Education and Support, many young farmers still need training in agricultural business management.
4. ocial stigma, agriculture is often considered less attractive than other sectors such as industry or services.

Young farmers have a key role to play in the modernization of agriculture by adopting new technologies, innovations, and business models. With the right support, they can make the agricultural sector more efficient, sustainable, and profitable. And technology plays a huge role in attracting young people to the agricultural sector, transforming them from conventional jobs into modern industries that are data-driven, efficient, and innovation-driven.

3.2. The Role of the Government in Supporting Young Farmers

The important role of the government according to Siagian (2012:142-149) has five main forms, namely:

1. Stabilizers, namely the role of the government as a stabilizer are very important and must be played effectively. The government maintains national stability so that it remains stable and controlled so that the policies that have been set will be implemented properly and plans, programs, and operational activities will run smoothly.
2. Pioneers, as pioneers of the government, must be able to become role models for the entire community. With pioneering, the government not only carries out its function as a policy formulator and development plan preparer, but also as an innovative development implementer that is able to solve various existing challenges and limitations.

3. Modernizers, to realize a modern country, systematic, pragmatic, and sustainable development is needed. For this reason, the government is tasked with leading the community towards a modern life.
4. As a catalyst, the government must be able to take into account all factors that affect national and regional development. Controlling negative factors that tend to be obstacles so that their impact can be minimized, and can recognize factors that drive the pace of development so that they are able to attract the greatest benefits.
5. Dynamizers, the government acts as a provider of guidance and direction to the community aimed at good attitudes, behaviors, and ways of working can be used as role models for the community in carrying out development.

Young farmers are the younger generation who are involved in agricultural activities, be it in the fields of production, management, and marketing of agricultural products. They can come from villages or cities, and often start farming with various challenges. Young farmers often bring fresh and innovative perspectives to the world of agriculture, using technology and more modern approaches to farm management.
Here are some of the characteristics of young farmers, including:

1. Innovative: Young farmers tend to be more open to new technologies, such as precision farming, the use of drones for crop monitoring, or digital-based applications for farm management.
2. Educated: Many young farmers have higher education backgrounds, either in agriculture, technology, or management. They are easier to access the latest information and knowledge in agriculture.
3. Prioritizing Sustainability: Young farmers are usually more concerned about environmental issues, such as eco-friendly agriculture, the use of organic fertilizers, and nature conservation.
4. Using Digital Platforms: Many young farmers are leveraging digital platforms to market their agricultural products, either through social media or online marketplaces, so they can reach a wider market.

Young farmers face a variety of challenges that can affect their ability to thrive and survive in the world of agriculture. Some of the main challenges faced by young farmers include:

1. Limited Access to Capital and Financing

   Young farmers often struggle to obtain the capital necessary to start or grow their farming ventures. Although there are several financing or credit programs for farmers, many of them do not yet have the collateral or experience to meet the requirements of banks or financial institutions.
2. Lack of Experience and Skills

   Many young farmers are just starting their careers in agriculture, so they may lack the skills or experience needed to manage farms efficiently. This can lead to errors in the management of agricultural businesses, such as resource management issues or financial management.
3. Difficulties in Accessing Technology

   Although many young farmers are interested in the use of advanced technologies in agriculture (such as drones, farm management applications, or smart irrigation systems),

many of them have difficulty accessing or utilizing such technologies. This can be due to the high cost of technology, lack of training, or limited infrastructure.

4. Market Access Issues

   Young farmers often face difficulties in marketing their agricultural products. They may not have an extensive marketing network or access to a larger market. In addition, reliance on middlemen or middlemen can make the prices that farmers receive very low, reducing the profits they can make.

5. Lack of Supporting Infrastructure

   In many rural areas, infrastructure such as poor roads, inadequate irrigation systems, and limited storage facilities can hinder the productivity and efficiency of young farmers. This condition also reduces the competitiveness of their agricultural products.

6. Shifting Interest to Other Sectors

   Many young farmers prefer to work in the industrial or technology sector because jobs in those fields are considered more lucrative and modern. This led to a decrease in the interest of the younger generation to survive in the world of agriculture, which ultimately reduced the number of young workers in the sector.

7. Climate Change Risks and Food Security

   Increasingly extreme climate change, such as erratic weather, drought, or flooding, can affect agricultural yields and harm young farmers who do not have experience in dealing with the crisis. Food security is also an important issue that needs to be considered to avoid major losses in the agricultural sector.

8. Limitations of Knowledge in Business Management

   Many young farmers may have technical skills in farming but lack knowledge in business management, marketing, and finance. Without these skills, they will have difficulty in developing their farming business to be more professional and profitable.

9. Limitations in Education and Counseling

   Although there are many extension and training programs, young farmers' access to quality education in agriculture is often limited. Especially in remote areas, information on the latest and environmentally friendly farming techniques is difficult for young farmers to access.

10. Stereotypes about Agriculture

    Many young generations see agriculture as a less attractive or unprofitable job, which leads to their low interest in entering the sector. In fact, with a more modern and sustainable approach, agriculture can become a very potential and profitable industry.

However, the government and various institutions have tried to provide various supports for young farmers to keep them motivated and successful in agriculture. Easier financing, training and education, and access to markets and technology can help them meet these challenges. Overall, young farmers play an important role in ensuring the sustainability of the agricultural sector and increasing agricultural productivity in the future.

The government has an important role in supporting young farmers so that they can survive and thrive in the world of agriculture. Here are some of the roles that the government can play in supporting young farmers:

1. Counseling and Education

   The government needs to provide extension and training programs for young farmers so that they have the necessary knowledge and skills to manage agriculture in a modern

and efficient manner. This includes the introduction of the latest technologies, environmentally friendly farming techniques, as well as agricultural financial management.

2. Access to Financing and Capital

   Many young farmers have difficulty accessing financing to start or grow agricultural businesses. The government can provide access to low-interest agricultural credit or subsidy programs to purchase agricultural tools and machinery, fertilizers, and superior seeds.

3. Agricultural Infrastructure

   The provision of adequate infrastructure, such as good roads, irrigation systems, and agricultural product storage facilities, is essential to support the success of young farmers. The government needs to build and improve infrastructure in agricultural areas so that young farmers can access the market more easily.

4. Technology Access Facility Program

   The introduction and application of technology in agriculture, such as precision agriculture, the use of drones for crop monitoring, or smart irrigation systems, can improve agricultural yields. The government can provide programs to make it easier for young farmers to access and utilize this technology.

5. Increasing the Competitiveness of Agricultural Products

   The government can also assist young farmers in introducing their products to the market, both local and international markets. Support in terms of branding, digital marketing, and certification of environmentally friendly or organic products can increase the competitiveness of agricultural products.

6. Marketing and Market Facilities

   The government can help young farmers by creating an easily accessible market or opening up digital platforms for the marketing of agricultural products. This will make it easier for them to sell agricultural products directly to consumers or large companies.

7. Supportive Policies and Regulations

   The government can create policies that provide incentives to young farmers, such as lighter taxes, easier business licenses, and legal protection for their agricultural products. Clear and supportive policies will provide a sense of security for young farmers to invest in agricultural ventures.

With these roles, it is hoped that young farmers can be more motivated to enter the world of agriculture, develop their businesses, and ultimately improve food security and overall farmers' welfare.

4. Conclusion

1. The Internet of Things (IoT) is a technology that allows physical devices to be connected to each other to collect, send, and analyze data automatically. In the context of agriculture, IoT has great potential to improve efficiency and productivity, as well as provide better oversight of crops, soil, and environmental conditions. However, the application of IoT in agriculture, especially hydroponics, still faces several challenges, including: high initial costs, availability of internet infrastructure, lack of technological knowledge by farmers.
2. The government has a very important role in supporting the development of young farmers and the agricultural sector as a whole. According to Siagian (2012), the role of the government can be divided into five main forms, namely as a stabilizer, pioneer,

modernizer, catalyst and dynamizer. Each of these roles has a significant contribution in creating conditions conducive to the growth of the agricultural sector and the welfare of young farmers. Young farmers, as the next generation of the agricultural sector, have characteristics that include innovation, higher education, a focus on sustainability, and the use of digital technology. However, they also face various challenges that can hinder their progress, such as limited access to capital, lack of experience and skills, difficulties in accessing technology, and limited market access.

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