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Transforming the Role of *Pesantren* in Food Security and Economy through Smart Farming Life Cycle

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Abstract
As an educational institution where communities live and interact, *Pesantren* must enhance its independence and management development, food security, and economic initiatives to support the sustainability of its academic processes. This paper outlines the best management practices related to food security and economic development for *Pesantren*. The methodology employed is a case study of *Pesantren* Assa'adah in Cikeusal Serang, utilizing a literature review to provide a foundational basis for the analysis. The findings indicate that waste management concepts have been effectively carried out by processing both organic and inorganic waste. Additionally, automatic watering systems with soil moisture sensors have been deployed near fish ponds, ensuring plants receive the essential water elements efficiently. This system is powered by solar energy, making it an environmentally friendly option. Furthermore, the student (*santri*) consume livestock and agricultural products, demonstrating that the *pesantren* has a sustainable resource source, reducing daily accommodation expenses. Smart farming can also serve as a basis for educational tourism. From an economic standpoint, these practices are being developed, and further research is anticipated to enhance Pesantren's financial prospects.
Keywords: pesantren's food security and economic, smart farming lifecycle

Introduction

In 1970, there was a significant paradigm shift, prompting many Pesantrens to reposition themselves in response to the evolving social landscape. One such repositioning involves transforming Pesantren into agents of economic development. The Three-Dimensional Pesantren Foundation in Pangkep, South Sulawesi, exemplifies this approach by acting as both an agribusiness agent and a center for maritime programs. This initiative was proposed by the Regent of Pangkep, Baso Amirullah, rather than originating from the pesantren community itself. Consequently, the pesantren community has not been actively involved in shaping the culture of economic development within the pesantren; instead, dominant bureaucratic influences dictate these programs. This situation has led to a decline in the effectiveness of economic development initiatives in the Pesantren (Basri, 2017).

Pesantren, as an educational institution where the community resides and interacts, needs to enhance its independence and the development of its management, food security, and economic sectors to support the sustainability of its educational processes. Various economic initiatives have already been undertaken within pesantren, such as those at Sirojul Huda Pesantren, which focuses on brooch production, and Makki in Bondowoso Regency, which involves vanilla cultivation (Adawiyah, 2018). Additionally, Karnawijaya has introduced the "Kimi Bag" initiative at Pesantren Al Qohar Klaten (Karnawijaya & Aini, 2020). The adaptability of pesantren is evident in its efforts towards economic empowerment, tailored to meet the fundamental economic needs of the community (Fauzi, 2017).

Pesantren can be categorized into four groups. The first is the salaf pesantren, where students (santri) adhere to traditional practices. The second is the modern pesantren, which integrates the traditional system with formal school education. The third is the actual pesantren, characterized by active student engagement. Finally, there is the pesantren that does not primarily focus on teaching religious knowledge but instills a sense of religious spirit through daily activities within the dormitory (Mubarok, 2008). Pesantren Modern is interpreted through various definitions, and in reality, there is no singular, clear-cut definition or set of criteria for them.

Pesantren Modern Assa'adah chose an integrative curriculum, adopting the Gontor curriculum as the identity of Pesantren modern in daily activities and combining the national curriculum with the Gontor curriculum in terms of implementing the educational process in teaching and learning activities. Pesantren Modern Assa'adah possesses significant agricultural land potential, with approximately 7 hectares out of a total 10 hectares designated for cottage facilities. The remaining land is largely untapped. A notable advantage is that this agricultural area is adjacent to three sizable fish ponds, which ensures an adequate water supply for farming activities.

In terms of human resources, Pesantren Modern Assa'adah has innovatively developed a robotics extracurricular program, equipping students (*santri*) with knowledge in micro-controller-based robotics. Many *santri* have excelled in various competitions at both national and international levels, and some of their works have been published in scientific journals, such as the research by Wahyudi and Aziz (Wahyudi & Aziz, 2022) concerning robotics-based automatic ablution tools. This represents a promising foundation for advancing smart farming initiatives.

However, there is untapped potential in sustainable material management, particularly regarding waste management at the Pesantren Modern Assa'adah. Currently, the pesantren collaborates with relevant agencies to transport waste to the Final Disposal Site, which highlights an opportunity to improve processing, especially of organic waste that could be recycled into fertilizer. This paper aims to propose a concept for enhancing management at Pesantren Modern Assa'adah, focusing on food security and economic empowerment through a smart farming life cycle.

Smart farming, initially referred to as Precision Agriculture, is expected to become an essential agricultural paradigm in the face of limited land resources. This innovative approach utilizes advanced technologies such as big data, machine learning, robotics, and the Internet of Things (IoT) to enhance both the quality and quantity of agricultural production. The focus on smart farming emphasizes new methods for data collection, transmission, storage, and analysis, along with the development of appropriate solutions.

Many developed countries have actively promoted Research and Development in the concept and implementation of Smart Farming, yielding significant benefits for their food production sectors. This work aims to document and provide an overview of the current status of the smart farming project. Research conducted by Collado in Panama focuses on the opportunities and challenges associated with the study, development, and implementation of Smart Farming as a technological solution in the country's agricultural sector (Collado et al., 2019).

One crucial solution in agriculture is the adoption of technologies that communicate with one another through communication networks, a concept referred to as "Smart Farming". In Indonesia the concept and its implementation is explained by (Budiharto, 2019) sensors used in agricultural land are used to determine the chemical condition of the soil, the quality of plant health and other useful information. Chuah et.al (Chuah et al., 2019) implementing a cyber-physical system (CPS) can provide farmers with a framework to remotely monitor and control various factors affecting plant growth. The goal of the project is to implement CPS into a vertical farming system where an Android-based remote monitoring and control system is developed based on CPS.

IoT in a few decades began to be adopted in the smart agriculture sector. The term Smart farming represents the implementation of Modern technology into conventional farming methods. Smart farming will create a huge impact on

the agricultural sector by adopting smart technology, farmers can easily manage agricultural practices remotely and sensors are run on farmland, livestock, and land for real-time data measurement. These opportunities and challenges are summarized by (Aarthi & Sivakumar, 2019) faced by IoT smart farming technologies.

The use of literature study methods in research provides a foundation for interpretation in any academic inquiry. This literature review focuses on the development of economic management and the empowerment of the pesantren community through relevant previous research and contemporary studies, which may include scientific journals as well as reports on research and community service related to the economic development of Pesantrens. The results of these studies are analyzed for their relevance and impact, contributing to ongoing development efforts.

This research employs a qualitative approach, utilizing data collection techniques that involve describing, classifying, and analyzing data, ultimately leading to well-founded conclusions. It incorporates emerging qualitative investigation methods, emphasizing natural data collection, detailed examination of the people and settings involved, and inductive data analysis to identify patterns or themes. This study adopts qualitative and narrative descriptive research techniques to unveil interconnected procedures and literature, while maintaining a strong focus on the relevant material (Moleong, 2019).

Result and Discussion

Pesantren serve a vital role in the education and development of youth in numerous Muslim-majority countries. The existence of pesantren is essential in community development efforts, mainly because it is sourced from community aspirations and reflects community needs (Hakim & Aksa, 2021). As these institutions adapt and grow, the integration of modern agricultural practices can greatly improve food security and stimulate economic development. Implementing smart farming techniques, which utilize technology and data analytics, presents a promising opportunity to transform traditional farming methods within these Pesantren.

A smart farming model in Pesantrens is feasible, given the potential identified in Lestari's research (Lestari, 2020). These institutions have begun to recognize their role as social and economic entities capable of significantly impacting the community. Implementing smart farming to solve the negative

impacts of human evolution on earth, water, pollution, and feed quality. They propose an aquaponics system designed to enhance gardening efficiency and recover up to 90% of the water used for plants (Ezzahoui et al., 2021). Additionally, Kim and Shin (Kim & Shin, 2018) introduced a thermal and warm energy management system for fish farming.

Integrating mechanical innovations with information and communication technology (ICT) and precision agriculture, alongside advanced waste treatment technologies, can significantly improve farming's biological potential. Additionally, the methodological framework promotes co-designing climate-smart agricultural systems with local stakeholders (Andrieu et al., 2019).

Currently, the Internet of Things (IoT) is the latest technology where devices around us can communicate with each other through the internet network, Said Mohamed (Said Mohamed et al., 2021) revealed that IoT is one of the important pillars in smart systems, because it connects sensor devices to perform various basic tasks and is widely used in the implementation of smart farming, its implementation has also been widely carried out for implementation needs smart farming.

Scott Allen Buresh conducted a study focusing on the development of Pesantrens in Indonesia, revealing that substantial progress can be made, particularly in the economic realm (Buresh, 2002). According to Fauroni & Quraisy (Fauroni & Quraisy, 2019) the economic development of Pesantrens hinges on several factors: (a) the kyai's ability to assess, define, utilize, and manage available resources, (b) geographical conditions, and (c) social and cultural dynamics both within and outside the institution.

Various strategies have been proposed to enhance the independence of Pesantrens. One such approach, suggested by Efendy (Efendy & Anisyah, 2019), involves organizing a creativity competition among *santri*. This initiative not only encourages innovation but also serves as a catalyst for the economic development of Pesantrens, emphasizing that the advancement of human resources is fundamental to development.

Pesantren can implement several strategies, beginning with human resource development. This includes the internalization of values, effective human resource management, and the establishment of support systems. The second aspect involves the production process, which starts with potential analysis, supplier selection, product differentiation, and extends to innovation and quality control. The marketing approach should incorporate both open-system and closed-system marketing strategies (Ta'rif & Adhim, 2021).

Pesantren Salafiyah Syafi'iyah Situbondo Pesantren, emphasizing the need for improvements in management systems and professional control over production and distribution via a Pesantren-Owned Enterprise (Syafi'i & Wisri, 2017). Additionally, research by Bryant highlights the necessity for collaboration with expert advisors in the successful implementation of smart farming technology in Australia's rice cultivation, addressing specific challenges faced in this area (Higgins & Bryant, 2020).

The integration of the Internet of Things in agriculture introduces unique challenges, including handling spatial data, variable environments, diverse tasks, and mobile devices, which differ from other farming systems. (Villa-Henriksen et al., 2020). To effectively implement this smart farming life cycle concept, several stages must be followed, as illustrated in Figure 1. These stages include observation, data collection, data analysis, decision-making based on the diagnosis, and subsequent implementation (Khanna & Kaur, 2022).

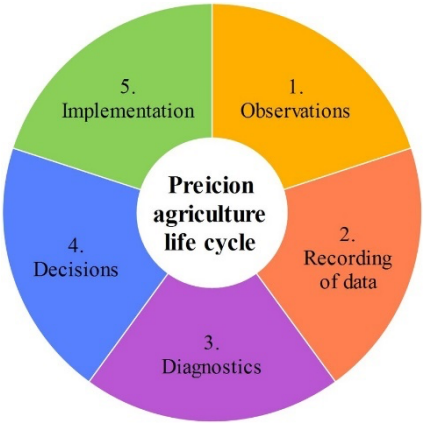

Figure 1: Smart farming life cycle model (Khanna & Kaur, 2022)

The concept aligns closely with the smart farming life cycle model proposed by Mohamed (Mohamed et al., 2021) as illustrated in figure 2, which utilizes cloud-based event and data management. While the stages are not explicitly defined, the core idea is similar to Khanna's framework: all data is stored digitally in the cloud, and the observation and analysis phases prior to implementation are enhanced by technology facilitated through smart systems, as well as smart sensing and monitoring. Therefore, what objectives are intended to be achieved in the implementation of the smart farming life cycle?

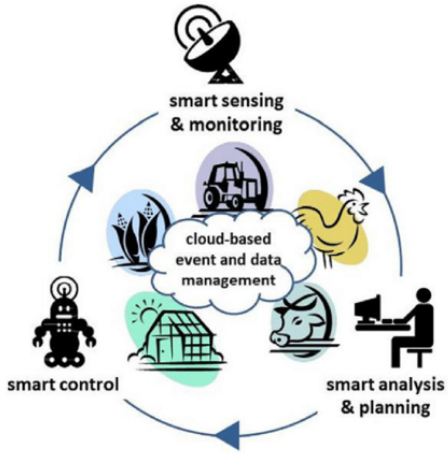

Figure 2: Smart farming life cycle model by (Mohamed et al., 2021).

Referring to the smart farming life cycle model in the context of food security and economic management above, the concepts that can be implemented in the Pesantren Modern Assa'adah are;

1) Proper waste processing involves both organic and nonorganic waste. Organic waste is obtained into fertilizer, and nonorganic waste is turned into eco-bricks, which are the role holders of the sustainability of materials for agriculture.
2) Automatic watering tools using soil moisture sensors can be placed on the banks of fish ponds. This tool can properly obtain water with the elements needed by plants and automate it, using *a solar system* as an environmentally friendly power source.
3) Livestock and crops are consumed by students (*santri*), which is an indicator that pesantren have a sustainable source of food so that daily accommodation expenses can be reduced.
4) The concept of *smart farming* can be used to create educational tourism objects, and it has been developed economically.

Smart farming leverages data analytics to enhance crop yields. By utilizing sensors, drones, and IoT devices, Assa'adah Pesantren can effectively monitor crop health, soil conditions, and weather patterns, facilitating informed decision-making and efficient resource management. To successfully implement smart farming practices, the Pesantren should invest in training programs for both staff and *santri*. Hosting workshops on the latest agricultural technologies can nurture a culture of innovation and promote continuous learning.

Ensuring sustainability in implementation requires strict supervision concerning optimal resource utilization and long-term viability. Therefore, it is essential to focus on and enhance the following aspects:

1) The concept of an integrated management information system should serve not only the needs of school management but also encompass the realms of economics and the development of the smart farming life cycle.
2) This integrated approach, spanning from upstream to downstream processes, along with sustainability management, must be continuously refined to effectively secure both food and economic stability in Pesantrens.
3) Innovations ranging from waste processing to the creation of robotic tools that facilitate smart farming solutions must be consistently pursued.

Implementing a program presents challenges, particularly when a structured plan is absent. However, by developing a comprehensive strategy, food and economic security management can be effectively enhanced within a pesantren environment.

Pesantren Assa'adah is fortunate to possess significant land resources. By adopting smart farming techniques, the institution can increase local food production, thereby reducing dependence on external food sources. This improvement not only bolsters food security but also provides *santri* with valuable insights into sustainable agricultural practices.

The implementation of a smart farming life cycle necessitates an assessment of soil health, climate conditions, and market demands. Assa'adah Pesantren has the opportunity to grow a diverse array of crops, including both staple and high-value varieties, which can contribute to nutritional diversity and economic stability. Furthermore, by utilizing organic waste from the school and the broader community to create compost, the soil can be enriched, promoting sustainable farming methods. This holistic approach not only supports food production but also instills a sense of environmental stewardship among the *santri*.

Pesantren Assa'adah has the opportunity to collaborate with local farmers and agricultural experts to develop programs that benefit both *santri* and the wider community. Such partnerships can stimulate local economies and create job opportunities, ultimately contributing to regional economic development. Involving *santri* in smart farming initiatives can also promote

entrepreneurship by providing them with insights into business models, marketing strategies, and supply chain management, thereby equipping them with valuable skills for success in the agricultural sector and beyond.

The findings from this research suggest that the management concepts for independent and economic development within Pesantren, particularly the Pesantren Modern Asa'adah, can be effectively implemented by leveraging the inherent potential of the institution. Moreover, Pesantren Assa'adah can enhance the profitability of their agricultural products by processing them into value-added goods like jams, pickles, or packaged meals. This approach not only increases revenue but also offers *santri* practical experience in food processing and marketing.

However, there are challenges and considerations to address when implementing smart farming initiatives. Transitioning to this model requires substantial initial investments in technology and training. To facilitate this transition, Assa'adah Pesantren may need to seek partnerships, grants, or government support. Furthermore, any new farming practices must align with the community's cultural and religious values. Engaging stakeholders in the planning process will help ensure that innovations are embraced and effectively integrated. It is also essential to ensure that smart farming practices are environmentally sustainable, with continuous monitoring and adaptation needed to mitigate any potential negative impacts on local ecosystems.

Conclusion

Integrating smart farming into the management of food security and economic development within pesantren modern presents a valuable opportunity to educate and empower students (*santri*) while enhancing community resilience. By cultivating a culture of innovation and collaboration, these institutions can take the lead in promoting sustainable agricultural practices that benefit both their students and the wider community. With appropriate support and resources, pesantren can evolve into centers of food security and economic vitality in their regions. The findings from this research suggest that the management concepts for independent and economic development within Pesantren, particularly the Pesantren Modern Asa'adah, can be effectively implemented by leveraging the inherent potential of the institution. The smart farming life cycle, in the context of food security and economic management, can be implemented through four straightforward steps, ensuring both effective execution and sustainability.

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