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SUSTAINABLE AGRICULTURE IN THE INDUSTRIAL ERA 5.0

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Abstract Indonesia is an agricultural country whose primary income comes from the agricultural sector. Agricultural technology is the key to agricultural transformation, which marks changes in every era, including the Industrial 5.0 era. The industrial revolution has occurred continuously, including the agricultural revolution, which has led to advances in digital technology for sustainable agriculture. This writing aims to understand the sustainable agricultural revolution in the industrial era 5.0. In the 5.0 era, agriculture will incorporate technology to replace and complement continuous agricultural activities. Sustainable agriculture has the idea of meeting the needs of the present without jeopardizing the needs of future generations. This article was created based on the results of reviews from several journals that have been published. To encourage sustainable agricultural development, investing in technological innovations such as artificial intelligence (AI), the Internet of Things (IoT), big data, remote sensing, and cloud computing is necessary. This technology can increase crop production and save time to end hunger per the SDG goals. Agriculture 5.0 is a way of intelligent farming that implements sustainable farming systems where unmanned farming will become more common, which will be beneficial when labour is scarce.

Keywords: Agricultural Technology; Farmers; Globalization

INTRODUCTION

The Industrial Revolution has evolved from 1.0 to 4.0, and now we are in the era of industry 5.0. The Industrial Revolution represents a fundamental change in how humans work and introduces new things that can help improve human life. It is a continuous process, and in 2021, it was officially marked by the European Commission as the beginning of the Industry 5.0 era (Martos et al., 2021). Indonesia is an agrarian country, with one of its primary sources of income coming from the agricultural sector. Technology has played a crucial role in the transformation of agriculture, marking changes in each era (Malik et al., 2020). Agriculture in the 1.0 era ushered in traditional farming, which relied heavily on human and animal labor. Agriculture 2.0 prioritized efficiency and productivity through the use of chemicals. Agriculture 3.0 emerged from the rapid development of computing and electronics. Sensible work distribution on agricultural machines reduced the use of chemicals and improved irrigation precision (Zhai et al., 2020).

In Agriculture 4.0, farming optimizes technology, information systems, genetic code deciphering, and more. Agriculture is now entering the era of Agriculture 5.0, utilizing the latest technologies such as Artificial Intelligence (AI), the Internet of Things (IoT), Big Data, Remote Sensing, and Cloud Computing (Martos et al., 2021). The concept of the 5.0 era is the optimization of technology developed for human needs (Setiawan et al., 2020). In the 5.0 era, agriculture will integrate technologies to replace and complement ongoing farming activities. Sustainable agriculture has the idea of meeting current needs without jeopardizing the needs of future generations (Malik et al., 2020).

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In the 5.0 era, agriculture must produce more food with less land and fewer inputs. The world heavily relies on technology to produce the necessary food to support the human population. Abandoning modern farming techniques would lead to widespread hunger, but continuing these practices could result in land degradation and reduced crop productivity. Farmers can mitigate environmental impact by implementing sustainable farming supported by digital technology systems and agricultural biotechnology (Zhai et al., 2020). According to the Food and Agriculture Organization (FAO), current agricultural production must increase by 70% by 2050, given the growing demand for high-quality and environmentally friendly food. In 2015, the United Nations (UN) approved the agenda "Transforming our world: the 2030 Agenda for Sustainable Development Goals (SDGs)," which is an action plan for human and Earth's well-being (Martos et al., 2021). Agriculture is crucial in achieving SDGs, such as ending poverty and hunger, addressing climate change, and promoting sustainable agricultural production (Mucharam et al., 2022). Within the SDGs, Zero Hunger aims to support sustainable agriculture and enhance global food resilience (Liu, 2023). According to Roy and Chan (2012), sustainable agriculture is a farming practice that permanently fulfils ecological, economic, and social conditions. Therefore, this writing aims to understand the sustainable agriculture revolution in the era of Industry 5.0.

METHOD

A comprehensive literature review was conducted on the development of Industry 5.0 at the global level and its application in the context of sustainable agriculture. The literature study covered academic journals, scientific articles, research reports, books, and other reliable sources relevant to the research topic. Information obtained from the literature review was utilized to comprehend the concept and characteristics of Industry 5.0, its impact on sustainable agriculture, challenges in implementation, and initiatives taken in Indonesia.

RESULTS AND DISCUSSION

Scope of Sustainable Agriculture

The definition of sustainable agriculture for Indonesia is suggested as agricultural efforts capable of delivering optimal harvest results in terms of quantity and quality, accompanied by efforts to preserve the quality of agricultural resources and the environment so that agricultural resources remain productive and environmental quality is maintained for the benefit of future generations. A development activity is considered sustainable if it is economically, ecologically, and socially sustainable. Sustainable agriculture, which is widely accepted, focuses on three pillars: economic, social, and ecological (Figure 1).

There are five criteria for managing an agricultural system to become a sustainable system, namely (1) economic viability, (2) ecologically sound and friendly, (3) socially just, (4) culturally appropriate satisfaction, and (5) a systems and holistic approach, as shown in Figure 2.

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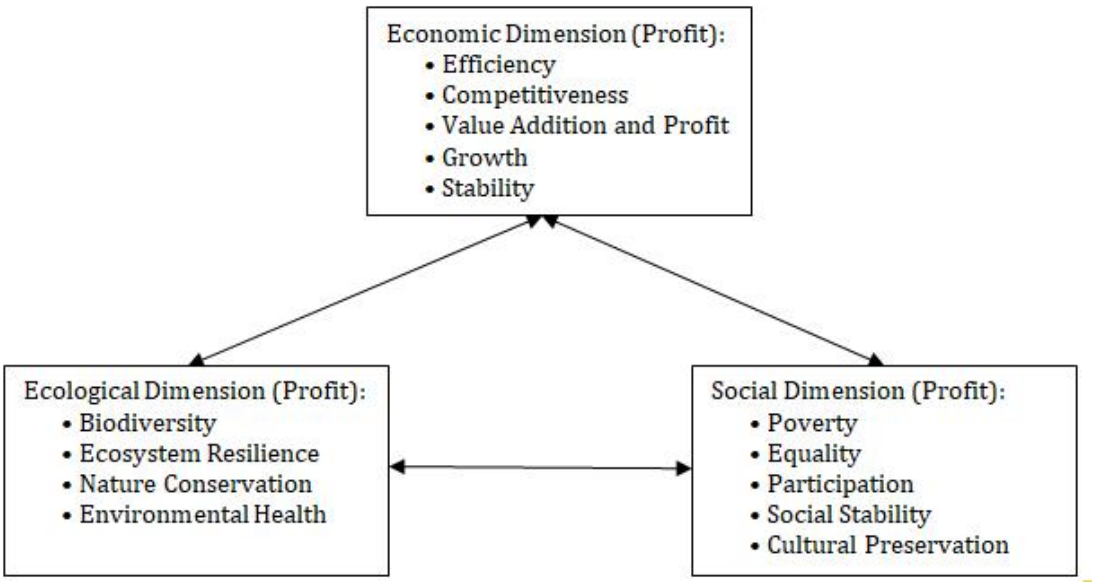

Figure 1. Triangle of Sustainable Agriculture Pillars

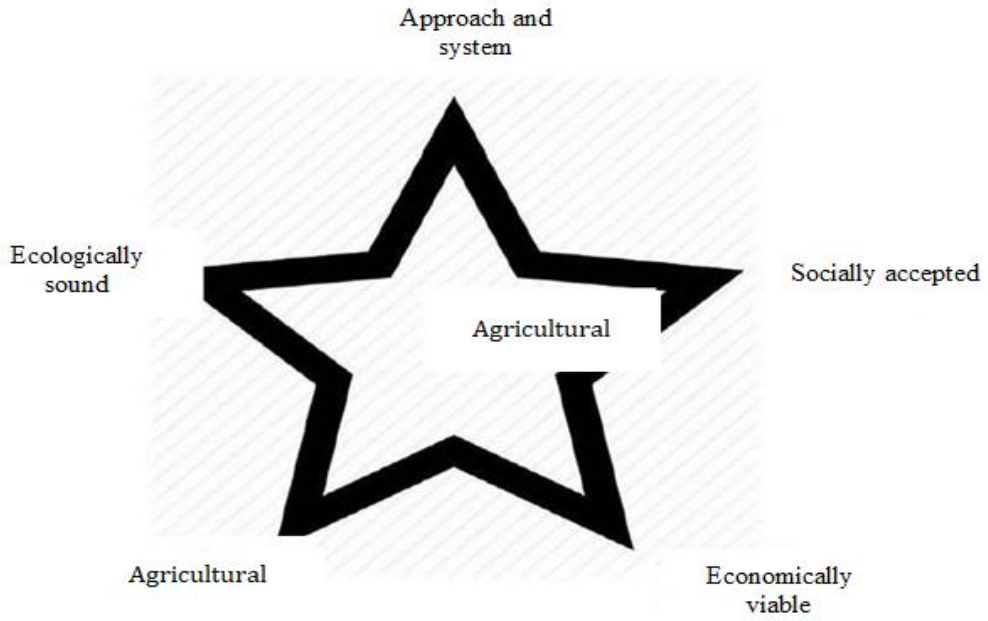

Figure 2. Framework of Sustainable Agricultural System (Rachmawatie et al., 2020)

The goals of sustainable agriculture are (1) to preserve and enhance the integrity of natural land resources and protect the environment, (2) to ensure income for farmers, (3) to guarantee energy conservation, (4) to enhance productivity, (5) to improve the quality and safety of food materials, and (6) to create harmony between farmers and their socio-economic factors (Parr et al., 1985, as cited in Rachmawatie et al., 2020).

Sustainable agriculture goes beyond increasing crop yields, commodity production,

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food diversification and infrastructure development. Sustainable agriculture must also ensure food security for the people and the nation. One example of the implementation of sustainable agriculture is the agroforestry system. The application of the agroforestry system achieves a balance between land utilization, conservation efforts, ecosystem preservation, and the sustainability of soil conditions (Putri et al., 2022). According to Ruba et al. (2023), a significant portion of the literature has discussed the efficiency of agroforestry systems in enhancing food security, creating employment opportunities, and contributing to economic growth that is efficient in achieving SDGs such as Zero Hunger, Affordable and Clean Energy, Climate Action, and Good Health and Well-being.

Development of the Industrial Revolution

Technological advancements, marked by the emergence of industrial revolutions from 1.0 to 4.0, have significantly influenced societal life. The world is entering a new era known as Industry 4.0 or Artificial Intelligence. However, with the continuous evolution of technology, the concept of Industry 4.0 is further enhanced into Industry 5.0, involving integrating digital technology with the physical world and enhanced interaction with humans.

In the 5.0 Industrial Revolution era, agricultural research became crucial in addressing sustainability challenges and advancing the agricultural sector. Sustainable agriculture in the Industry 5.0 era emphasizes the application of sustainable technology, human-centric approaches, and innovation to achieve sustainable development goals.

1. Implementation of Sustainable Technology

Industry 5.0 emphasizes the application of sustainable technology in agriculture to enhance crop productivity and mitigate environmental impacts. Technology is also utilized in optimizing food status. In this regard, improving the Food Value Chain (FCV) is related to the flow of food products, which is crucial in ensuring food availability. The application of sustainable technology includes

- Remote Sensing in the Era of Agriculture 5.0: Agricultural remote sensing (RS) has the potential to become one of the most crucial technologies for agriculture in the Industry 5.0 revolution. RS can extract valuable information, such as leaf area index (LAI), chlorophyll content, soil moisture, and vegetation indices (Martos et al., 2021).
- Robots and Drones Used in Farming: Robots can be used for fruit picking, pesticide spraying, soil sampling, and cultivation. These robots can enhance production efficiency and reduce production costs. Drones support crop monitoring, pesticide spraying, and fertilization (Lee et al., 2023).
- IoT used in Farming: Internet of Things (IoT) technology involves wireless network communication (Pangestu et al., 2021), making it potential for automation systems in agriculture (Vaishali et al., 2018). IoT can connect sensors and other devices in a single network, allowing data to be collected and analyzed efficiently. IoT can use devices such as robots and drones to automatically monitor and control the agricultural environment. Around 10%-15% of farmers in the United States use IoT solutions on 1.2 billion hectares of farmland. By 2050, IoT can potentially increase agricultural productivity by up to 70%. The main advantages of using IoT include higher crop yields and lower costs (Saiz-Rubio et

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al., 2020).

2. Human-Centric Approach

The era of Industry 5.0 demands a human-centric approach to agricultural development, focusing on balancing economic progress and solving social issues. The principle of balance related to SDGs involves aligning economic development (energy needs, food requirements, well-being) with the resolution of social issues (impact on the environment, industrialization affecting employment, quality of human resources) to integrate them effectively (Faruqi, 2019).

3. Reduction of Greenhouse Gas Emissions (GHG)

Agricultural activities, from the digestive processes of livestock to synthetic fertilizers, contribute to greenhouse gas (GHG) emissions, further intensifying environmental concerns and other factors. The urgent need for solutions has driven the exploration of technology and innovation as potential avenues to enhance agricultural productivity and reduce the effects of GHG emissions (Qayyum et al., 2023). Sustainable agriculture in the Industry 5.0 era aims to reduce greenhouse gas emissions by implementing environmentally friendly technology.

4. Utilization of Green Technology

In agricultural production, green technology innovation reduces pollution from fossil fuels and increases the use of clean energy, aiming for sustainable agricultural development (Sun, 2022). Green technology in agriculture in the 5.0 era aims to create an environmentally friendly and sustainable production system.

5. Smart Farming Innovation

Smart farming, characterized by the increased use of machines and sensors, has become a focal point in achieving sustainable agriculture with advanced technological systems.

Challenges of Industry 5.0 in Indonesia

Agriculture in Indonesia is a crucial sector that provides food for the Indonesian population and is a livelihood source for many. However, Indonesian agriculture still faces various challenges in the context of the Industry 5.0 era. Some challenges in facing the Industry 5.0 era include:

1) Climate change: Climate change can affect the productivity and quality of agricultural products, leading to changes in planting patterns, pest and disease disturbances, and production instability.
2) Changing consumer behaviour: Consumers are becoming more intelligent and more concerned about the safety and quality of their products. They expect healthier, safer, and higher-quality products.
3) Globalization pressure: Increased globalization pressure, such as competition in pricing and product quality with other countries with more advanced technology.
4) Lack of government support: The government still needs more support for developing intelligent farming technology in Indonesia, including support in the form of training, funding, and adequate infrastructure.

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In facing these challenges, the agriculture sector in Indonesia needs to be ready to implement several strategies.

1. They are implementing new technologies in agriculture, such as drones, robotics, and the Internet of Things (IoT). These technologies can help enhance production efficiency, improve agricultural product quality, and facilitate crop monitoring and surveillance.
2. Through training and education, they are improving the quality of human resources, including farmers, agricultural experts, and agricultural extension workers. Good human resource quality can enhance the efficiency and effectiveness of agriculture and strengthen the competitiveness of Indonesian agricultural products.
3. They implement environmentally friendly farming practices, such as organic farming and proper agricultural waste management. Environmentally friendly farming practices can help maintain ecosystem balance and improve the quality of agricultural products.

They are expanding target markets, both domestically and internationally. Expanding target markets can make the agricultural sector more productive and sustainable.

CONCLUSION

Indonesia's agriculture is significant in the nation's economy and providing food for its citizens. Nevertheless, this sector encounters diverse challenges amid the emergence of Industry 5.0. These hurdles encompass climate shifts, evolving consumer behaviours, and escalating global pressures. Indonesian agriculture must prepare across various facets, including adopting innovative technologies, enhancing human resource capabilities, implementing eco-friendly farming practices for sustainability, and broadening market horizons. With thorough preparation for the Industry 5.0 era, the Indonesian agriculture sector can evolve into a more productive and sustainable entity, contributing to the overall societal well-being. Addressing these challenges requires concerted efforts from the government, agricultural enterprises, and the community.

The government should augment investments in agriculture and fortify the agricultural infrastructure. Agricultural enterprises should elevate product quality and extend their market presence. Simultaneously, the community needs to prioritise natural resources and environmental consciousness while fostering an understanding of the importance of consuming locally produced agricultural goods. In summary, Indonesia's preparedness for the 5.0 era of industry in agriculture necessitates improvement. However, considering the outlined aspects and collaborative endeavours from all stakeholders, there is optimism that Indonesian agriculture can transform into a more robust and sustainable sector.

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