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Optimalisasi Optimizing Agricultural and Plantation Land through Modern Irrigation Systems

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Abstract: The optimization of agricultural and plantation land is a major challenge in supporting food security and enhancing national productivity. One strategic solution is the application of modern irrigation systems, which can overcome water scarcity, improve distribution efficiency, and reduce the risk of crop failure due to climate change. This study aims to analyze the role of modern irrigation systems in improving land productivity and promoting sustainable resource utilization. Using a literature study approach, this research highlights the effectiveness of drip irrigation, sprinkler systems, and sensor-based technologies in increasing crop yields, improving water efficiency, and enhancing farmers' welfare. The results are expected to provide recommendations for the development of sustainable agricultural policies in Indonesia.

Keyword: Land Optimization, Agriculture, Plantation, Modern Irrigation, Food Security

INTRODUCTION

Agriculture and plantations are vital sectors in the Indonesian economy, primarily supporting food and industrial raw materials. However, the sustainability of this sector faces significant challenges, particularly related to limited land and water resources, climate change, and inefficient traditional management practices (Suryana, 2018). One crucial issue that frequently arises is low productivity due to dependence on erratic rainfall patterns. This situation demands innovation in the use of technology, particularly in irrigation systems. Traditional irrigation systems in Indonesia generally still use gravity flow systems, which tend to be water-wasting and inefficient. These limitations mean that not all land can be irrigated evenly, resulting in many agricultural and plantation areas experiencing drought or excessive waterlogging (Hermanto, 2019). In fact, according to data from the Central Statistics Agency (BPS), approximately 70% of national water needs are used for the agricultural sector, yet its contribution to productivity is not optimal (BPS, 2022). This highlights the need for irrigation system modernization to support land optimization.

Irrigation modernization is not limited to the construction of water channel infrastructure, but also involves the use of technologies such as drip irrigation, sprinkler

irrigation, and sensor-based and automation systems (Agustina, 2021). These systems have been proven to save up to 40% on water use and increase agricultural yields by up to 30% compared to conventional methods (Rahardjo, 2020). By implementing modern irrigation systems, it is hoped that farmers and planters can be more adaptive to climate dynamics, maximize productivity, and maintain environmental sustainability. Furthermore, the implementation of modern irrigation systems aligns with the Sustainable Development Goals (SDGs), particularly Goal 2: ending hunger, achieving food security, and improving nutrition through sustainable agriculture (United Nations, 2015). Therefore, land optimization through modern irrigation systems is not only a technical necessity but also a national strategy for maintaining food sovereignty.

Research Objectives

This research has several main objectives:

1. To analyze the role of modern irrigation systems in increasing agricultural and plantation land productivity.
2. To identify the advantages of modern irrigation technology compared to traditional systems in terms of water efficiency and production yields.
3. Explain the impact of implementing modern irrigation systems on farmer welfare and environmental sustainability.
4. Provide policy recommendations related to the implementation of modern irrigation for land optimization in Indonesia.

Supporting Theories

1. Production Efficiency Theory
   According to production efficiency theory, optimizing agricultural yields can be achieved by utilizing inputs more appropriately and efficiently (Farrell, 1957). In this context, water is a crucial input that must be carefully managed to increase productivity without significantly increasing production costs. Modern irrigation systems support this efficiency by distributing water according to crop needs.
2. Sustainable Agricultural Development Theory
   Sustainable agriculture emphasizes the wise use of resources to maintain ecological, social, and economic balance (Conway, 1997). Modern irrigation aims not only to increase crop yields but also to reduce overexploitation of water resources, thereby supporting environmental sustainability.
3. Diffusion of Innovation Theory
   Rogers (2003) explains that the adoption of technological innovations in society is influenced by factors such as usefulness, ease of use, and social environmental support. In this case, the successful implementation of modern irrigation systems on agricultural land depends heavily on farmers' willingness to adapt and government policy support.

METHOD

This research uses a descriptive qualitative approach with a literature review to analyze the optimization of agricultural and plantation land through the implementation of modern irrigation systems. This approach was chosen because the research aims to explore the concepts, strategies, and impacts of using modern irrigation technology on land productivity and farmer welfare, rather than simply calculating quantitative figures. Research data was obtained through a literature review of national and international journals, books, official government reports, publications from international organizations (FAO, World Bank, United Nations), and previous research relevant to the topic of modern irrigation. Secondary data was analyzed using content analysis methods to identify patterns, trends, and

key findings related to the implementation of modern irrigation in the agricultural and plantation sectors. The research stages include:

a. Problem identification: suboptimal utilization of agricultural land due to limited water and traditional irrigation infrastructure.
b. Data collection: searching for scientific literature and empirical data related to the use of modern irrigation systems.
c. Data analysis: comparing the advantages, disadvantages, and effectiveness of drip, sprinkler, and sensor-based irrigation systems.
d. Interpretation: drawing conclusions regarding the contribution of modern irrigation to the optimization of agricultural and plantation land in Indonesia.

RESULTS AND DISCUSSION

1. Condition of Agriculture and Plantations in Indonesia

Indonesia is an agricultural country with vast agricultural land, but its productivity often falls short of its potential. According to the Statistics Indonesia (BPS) (2022), approximately 33 million people work in the agricultural sector, but this sector's contribution to GDP is only around 12.4%. One cause of low productivity is reliance on inefficient traditional irrigation systems. Most rice paddies still rely on gravity irrigation systems, where water distribution is often uneven. During the dry season, much of the land dries out, while during the rainy season, the land often becomes flooded. As a result, crop yields often fluctuate. Similar problems also arise for plantations such as oil palm, tea, coffee, and rubber. Water limitations result in suboptimal plant growth, resulting in decreased production quality and quantity (Hermanto, 2019).

2. Traditional vs. Modern Irrigation Systems

Traditional irrigation systems have major weaknesses: they are wasteful of water, difficult to control, and not adaptable to climate change. In contrast, modern irrigation systems—such as drip irrigation, sprinklers, and automatic sensor-based irrigation—are more efficient and adaptive.

a. Drip irrigation can deliver water directly to plant roots, allowing water use efficiency to reach 90%.
b. Sprinkler irrigation distributes water evenly, similar to artificial rainfall.
c. Sensor-based irrigation utilizes IoT technology to detect plant water needs in real time (Agustina, 2021).According to Rahardjo (2020), implementing modern irrigation can save up to 40% on water and increase crop yields by 25–30% compared to conventional irrigation.

3. Impact of Modern Irrigation on Land Productivity

a. Water Use Efficiency
   Water is a key input in agriculture. The FAO (2018) reports that 70% of global water demand is used for agriculture, but nearly 60% of it is lost due to distribution inefficiencies. With modern irrigation systems, this waste can be significantly reduced.
b. Increased Crop Yields
   Research conducted in West Java showed that the application of drip irrigation to horticultural crops increased tomato productivity by up to 35% (Sutrisno, 2019). A similar trend occurred in coffee plantations in Lampung that implemented sprinkler irrigation, where yields increased by 28% (Rohman, 2021).
c. Farmer Welfare
   Water efficiency and increased crop yields have a direct impact on farmer income. With more stable yields, farmers have better bargaining power in the market. Furthermore, the

use of automated systems reduces farmers' workload, freeing up energy for more productive activities.

4. Implementation Challenges in Indonesia

Despite its numerous benefits, the implementation of modern irrigation systems faces several obstacles:

a. High investment costs: drip and sprinkler irrigation equipment is relatively expensive for smallholder farmers.
b. Lack of technical knowledge: many farmers do not yet understand how to operate and maintain modern systems.
c. Limited policy support: government irrigation modernization programs still focus on building traditional canals.

To address this, subsidies, technical assistance, and collaboration with the private sector are needed to ensure widespread access to modern irrigation technology.

5. Land Optimization with Modern Irrigation

Land optimization is not simply about expanding planting areas, but also maximizing the productivity of existing land. With modern irrigation, previously unproductive marginal land can be revived. For example, dry land in East Nusa Tenggara, which was difficult to grow rice, has been successfully utilized for horticultural cultivation using a drip irrigation system (Widodo, 2020).

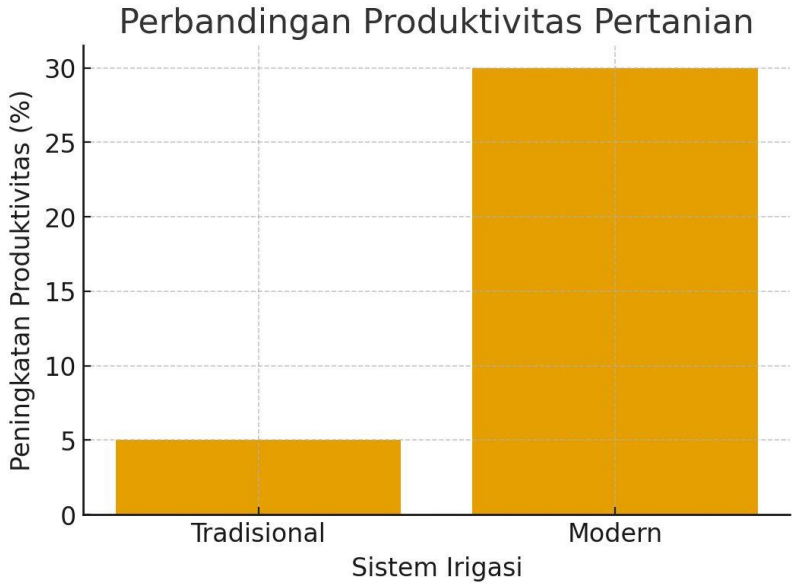
6. Linkage to SDGs and Food Sovereignty

The implementation of modern irrigation supports SDG 2 (Zero Hunger) and SDG 6 (Clean Water and Sanitation) by increasing food security and water use efficiency. Furthermore, this strategy aligns with the Indonesian government's vision to achieve national food sovereignty (Suryana, 2018).

Analysis Results Graph

The following graph compares agricultural productivity with traditional and modern irrigation (based on literature data):

•Traditional → Average productivity increases by 0–5% per year
•Modern → Productivity increases by 20–30% per year



CONCLUSION

This study shows that optimizing agricultural and plantation land through the implementation of modern irrigation systems significantly increases productivity, water efficiency, and farmer welfare. Traditional irrigation systems have proven inadequate in facing the challenges of climate change, water scarcity, and increasing food production needs. In contrast, modern irrigation systems such as drip irrigation, sprinkler systems, and sensor-based systems can increase crop yields by up to 30% and save water by up to 40%. Beyond technical aspects, the implementation of modern irrigation also has social and economic impacts, such as reducing farmers' workloads, increasing incomes, and opening up opportunities for utilizing marginal land. However, challenges such as high investment costs, limited technical knowledge, and minimal policy support need to be addressed immediately. This can be achieved through government support in the form of subsidies, farmer training, collaboration with the private sector, and agricultural policies oriented towards sustainable development. Therefore, it can be concluded that modernizing irrigation systems is a key strategy for realizing national food security and sovereignty, while also supporting the achievement of the Sustainable Development Goals (SDGs).

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