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Comparative Analysis of Integrated Crop Management (ICM) Implementation on Hybrid Maize Production and Farmers' Income (Zea mays L.)

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Abstract: Hybrid maize (Zea mays L.) is one of the strategic commodities in Indonesia that plays an important role in supporting national food security and farmers' income. One of the technologies introduced to improve maize productivity is Integrated Crop Management (ICM), which integrates several agronomic practices such as the use of improved varieties, optimal plant population, balanced fertilization, and integrated pest management. However, the level of ICM adoption among farmers is still varied, which may affect production performance and farm income. This study aimed to evaluate the implementation of Integrated Crop Management (ICM) technology and to compare the production and income of hybrid maize farmers who implement ICM technology and those who do not. The research used a quantitative survey approach involving hybrid maize farmers as respondents. Data was collected through field observations, interviews, and farm records. The results showed that the implementation of ICM technology significantly improved hybrid maize production and farmers' income. Farmers implementing ICM technology achieved an average income of IDR 6,247,824 per hectare per planting season, while farmers applying non-ICM practices earned IDR 2,475,494 per hectare per planting season. The higher income was mainly driven by better crop management practices, including optimal plant population, balanced fertilization, and integrated pest management. These findings indicate that Integrated Crop Management technology contributes to improving production efficiency and farm profitability. Therefore, strengthening the dissemination and adoption of ICM technology is important to enhance the sustainability of hybrid maize farming systems.

Keywords: Agricultural Technology; Farm Income; Hybrid Maize; Integrated Crop Management; Production.

Introduction

Maize (Zea mays L.) is one of the most important food and feed crops in Indonesia, playing a strategic role in national food security and agricultural sustainability. The increasing demand for maize, particularly for feed industries, requires improvements in production efficiency and farming productivity. However, maize productivity at the farm level is still influenced by various factors such as cultivation practices, input management, and farmers' access to agricultural technology.

Integrated Crop Management (ICM) technology has been introduced as an agricultural innovation designed to improve crop productivity through the integration of site-specific technologies (Febriyanto et al., 2024). Technology includes several important components such as the use of improved hybrid varieties, quality seeds, optimal plant population, balanced fertilization, soil and water management, integrated pest and disease control, and appropriate

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harvesting techniques (Wahyudin & Marina, 2024; Rahma & Marina, 2023).

Several previous studies have reported that the adoption of improved agricultural technologies can increase crop productivity and farmers' income. However, most studies focus primarily on agronomic performance, while limited research has analyzed the comparative economic performance between farmers who adopt ICM technology and those who do not adopt the technology under actual farming conditions (Sukmawati & Suhendar, 2015).

Therefore, understanding the effectiveness of ICM implementation at the farmer level is important to evaluate its contribution to agricultural productivity and farmers' welfare (Widata et al., 2025).

Based on this background, the research problems in this study can be formulated as follows:

1. How is the level of implementation of Integrated Crop Management technology among hybrid maize farmers?
2. Are there differences in production performance between farmers who apply ICM technology and those who do not?
3. How does the implementation of ICM technology affect farmers' income?

Based on these research problems, this study aims to evaluate the implementation of Integrated Crop Management technology and analyze its impact on the production and income of hybrid maize farmers.

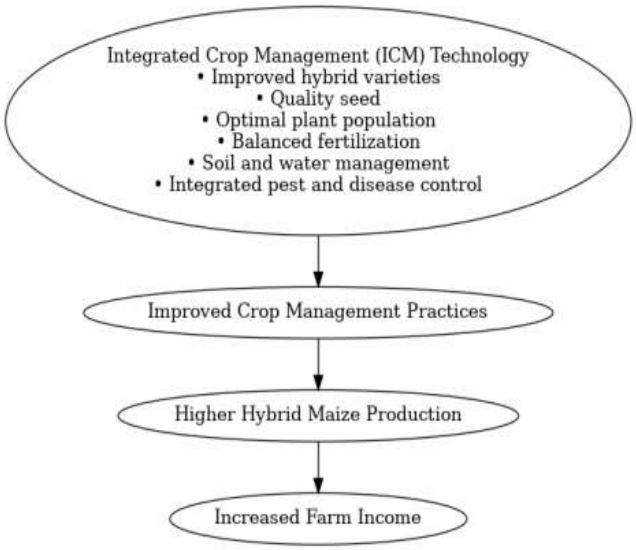

Figure 1. Conceptual framework of Integrated Crop Management (ICM) in hybrid maize production systems.

The implementation of ICM is designed to enhance crop productivity while maintaining resource efficiency and environmental sustainability. Nevertheless, the level of ICM adoption among farmers varies, which may influence production outcomes and farm income (Santoso et al., 2023).

Table 1. Core components of Integrated Crop Management (ICM) technology applied in hybrid maize cultivation

ICM Component	Description
Improved hybrid varieties	Use of high-yielding and site-adapted hybrid maize varieties
Quality seed	Application of certified seed with high germination rate
Plant population management	Adjustment of plant density to optimize growth and yield
Balanced fertilization	Fertilizer application based on soil nutrient status and crop requirements
Soil and water management	Land preparation, drainage, and irrigation management
Integrated pest and disease control	Combination of cultural, mechanical, and chemical control methods
Timely harvesting and post-harvest handling	Harvesting at physiological maturity and proper drying

Evaluating the implementation of ICM technology is essential to understand its effectiveness under actual farming conditions. Differences in farmers' practices, resource availability, and management decisions can affect the performance of ICM components and their overall impact on production and economic returns. Therefore, systematic evaluation is required to assess how ICM technology contributes to improvements in hybrid maize production systems (Apriyani et al., 2025; Tohir et al., 2025).

This study aims to evaluate the implementation of Integrated Crop Management technology and its impact on the production and income of hybrid maize farmers (Sujadi et al., 2023). The findings are expected to provide scientific evidence on the role of ICM technology in supporting sustainable maize production and improving farmers' economic performance, as well as to serve as a reference for the development and dissemination of agricultural technologies in maize-based farming systems (Dinar et al., 2023).

Method

This study employed a quantitative research design with a survey approach to evaluate the implementation of Integrated Crop Management (ICM) technology and its impact on hybrid maize production and farmers' income. The research was conducted in a hybrid maize production area where farmers apply both ICM and non-ICM cultivation practices. The population consisted

of hybrid maize farmers in the study area. Respondents were selected using purposive sampling, considering that the selected farmers had experience in hybrid maize cultivation and were actively involved in maize farming activities.

The total number of respondents consisted of two groups of farmers, namely farmers implementing ICM technology and farmers applying conventional (non-ICM) practices. Data were collected through: (1) field observation; (2) structured interviews using questionnaires; (3) documentation of farm production and costs. The variables observed in this study included hybrid maize production, production costs, and farm income.

Data analysis was conducted using descriptive quantitative analysis and comparative analysis to compare production performance and farm income between ICM farmers and non-ICM farmers. Farm income was calculated using Formula 1.

$$\text{Farm Income} = \text{Total Revenue} - \text{Total Production Cost} \quad (1)$$

The comparison between the two farmer groups was used to evaluate the effectiveness of Integrated Crop Management technology in improving hybrid maize production and farmers' economic performance (Ayu Andayani et al., 2024).

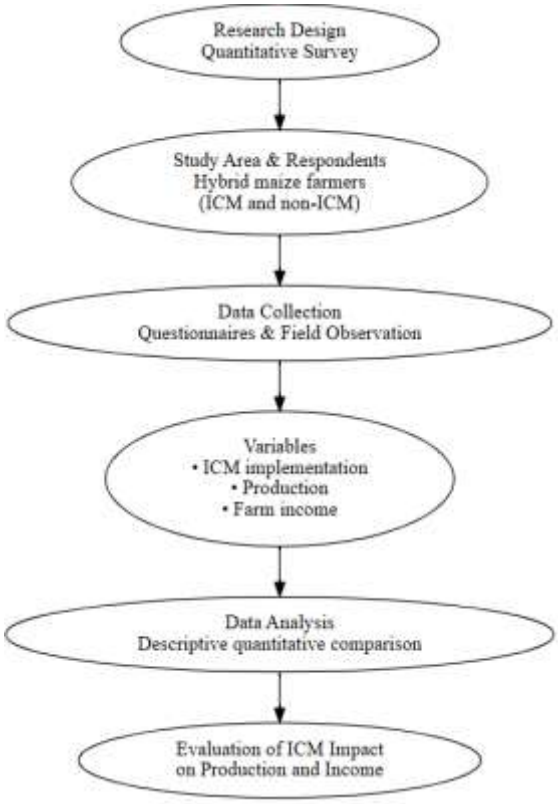

Figure 2. Methodological framework for assessing the impact of Integrated Crop Management (ICM) on hybrid maize production and income

The ICM implementation variables included the use of improved hybrid varieties, quality seed, optimal plant population, balanced fertilization, soil and water management, integrated pest and disease control, and appropriate harvesting practices. Farm income was calculated based on the difference between total revenue and total production costs per cultivation season (Fajrin et al., 2024; Huda et al., 2024). Data analysis was carried out using descriptive quantitative methods by comparing production and income performance between ICM and non-ICM farmers. The results were used to evaluate the effectiveness of ICM technology implementation under actual farming conditions.

Result and Discussion

The results of this study indicate that the implementation of Integrated Crop Management technology provides significant benefits for hybrid maize farming systems. Farmers applying ICM technology achieved higher production and income compared to farmers who applied conventional cultivation practices.

The increase in production can be explained through several key components of ICM technology. First, the use of improved hybrid varieties and quality seeds ensures better germination rates and higher genetic yield potential. Second, optimal plant population improves the efficiency of land utilization and increases the number of productive plants per hectare.

Balanced fertilization also plays an important role in supporting plant growth. Adequate nutrient supply enables maize plants to develop stronger vegetative growth and produce larger and healthier ears. In addition, integrated pest and disease management helps reduce crop losses caused by pest attacks and plant diseases, which ultimately contributes to higher productivity.

From an economic perspective, although farmers implementing ICM technology tend to incur higher production costs due to the use of improved inputs and better management practices, the increase in crop yield significantly compensates for the additional costs. As a result, the net income obtained by ICM farmers is substantially higher than that of non-ICM farmers. Another important aspect observed in this study is the level of adoption of each ICM component. The results indicate that some components, such as the use of improved varieties and quality seeds, have been widely adopted by farmers. However, other components such as balanced fertilization and integrated pest management still show varying levels of implementation. This suggests that farmers' knowledge,

access to information, and support from agricultural extension services may influence the adoption of certain technologies. Therefore, strengthening agricultural extension programs and technology dissemination is essential to improve farmers' understanding and adoption of Integrated Crop Management practices.

The implementation of Integrated Crop Management (ICM) technology showed clear differences in hybrid maize production performance and farm income when compared to non-ICM farming practices. Farmers who applied ICM technology demonstrated better crop management practices, particularly in the use of improved hybrid varieties, quality seed, balanced fertilization, optimal plant population, and integrated pest and disease control. These components contributed to more uniform crop growth and improved yield performance (Santoso et al., 2023).

Table 2 presents the general characteristics of hybrid maize farmers involved in the study, including age, education level, farming experience, and land size. These characteristics are important to describe the profile of respondents and to provide contextual information for interpreting differences in production performance and farm income between farmers implementing Integrated Crop Management (ICM) technology and those applying non-ICM practices.

Table 2. Characteristics of hybrid maize farmers participating in the study

Variable	ICM Farmers	Non-ICM Farmers
Average age (years)	Productive age group	Productive age group
Education level	Primary–secondary education	Primary–secondary education
Farming experience (years)	More than 10 years	More than 10 years
Average land size (ha)	Small to medium scale	Small to medium scale

The results indicate that the characteristics of ICM and non-ICM farmers were relatively similar. Both groups were dominated by farmers in the productive age range, had primary to secondary education levels, possessed more than ten years of farming experience, and managed small to medium-scale land holdings. This similarity suggests that differences in production and income observed in this study are more likely attributable to variations in crop management practices, particularly the implementation of ICM technology, rather than differences in farmers' socio-demographic characteristics (Zakiyah et al., 2022).

Hybrid Maize Production Performance

The results indicated that hybrid maize production under ICM practices was higher than that of non-ICM systems. Improved agronomic management, especially appropriate plant population and nutrient management, played a crucial role in optimizing crop growth and yield formation. Integrated pest and disease control also reduced yield losses, contributing to more stable production outcomes. These findings suggest that the effectiveness of ICM technology lies in the integration of multiple crop management components rather than reliance on a single input (Gunawan et al., 2023).

The improved production performance reflects the ability of ICM technology to enhance production efficiency under actual farming conditions. This confirms that site-specific and integrated management practices are more effective than conventional practices that tend to be partial and less systematic.

Production Costs and Farm Income

Differences in production performance were directly associated with differences in farm income. Although farmers implementing ICM technology incurred relatively higher production costs due to the use of quality inputs and better management practices, the increase in production output and product quality resulted in higher total revenue. As a result, net farm income for ICM farmers was substantially higher than that of non-ICM farmers (Mahmud et al., 2023; Idin et al., 2025).

Figure 3 illustrates the comparison of net farm income between ICM and non-ICM farmers. The graphical representation highlights the substantial income advantage obtained by farmers implementing ICM technology, confirming the economic benefits of integrated crop management practices.

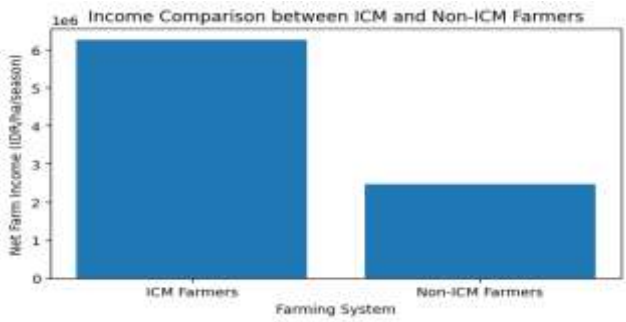

Figure 3. Comparison of net farm income between Integrated Crop Management (ICM) and non-ICM hybrid maize farmers.

The analysis showed that farmers applying ICM technology achieved an average income of IDR 6,247,824 per hectare per season, while non-ICM farmers earned only IDR 2,475,494 per hectare per season. This

significant income gap highlights that the economic benefits of ICM technology outweigh the additional costs required for its implementation. Improved productivity and better crop quality contributed to higher selling prices and increased profitability.

Table 3 compares hybrid maize production performance, production costs, and farm income between farmers implementing Integrated Crop Management (ICM) technology and those applying non-ICM practices. This comparison is used to evaluate the economic and production-related outcomes associated with the adoption of ICM technology under actual farming conditions.

Table 3. Comparison of production, costs, and income between ICM and non-ICM farmers

Indicator	ICM Farmers	Non-ICM Farmers
Hybrid maize production (kg/ha/season)	Higher	Lower
Total production cost (IDR/ha/season)	Higher	Lower
Total revenue (IDR/ha/season)	Higher	Lower
Net farm income (IDR/ha/season)	6,247,824	2,475,494

The results show that farmers applying ICM technology achieved higher maize production and total revenue than non-ICM farmers, although their production costs were also higher. The increase in output and product quality under ICM practices compensated for the additional costs, resulting in substantially higher net farm income. ICM farmers obtained an average income of IDR 6,247,824 per hectare per season, whereas non-ICM farmers earned only IDR 2,475,494 per hectare per season. This finding indicates that the economic benefits derived from improved crop management and integrated technological practices outweigh the additional production costs, highlighting the effectiveness of ICM technology in enhancing farm profitability (Kamil et al., 2023).

Implications of ICM Technology Implementation

The findings demonstrate that ICM technology is not only agronomically effective but also economically beneficial for hybrid maize farmers. The integration of recommended technologies enhances production stability and reduces inefficiencies in resource use. Higher income levels among ICM farmers indicate that the technology supports farm sustainability by improving farmers' economic resilience.

From a broader perspective, the adoption of ICM technology can contribute to strengthening hybrid maize production systems and supporting food and feed supply. The results emphasize the importance of technology dissemination and farmer capacity building to increase adoption levels and maximize the benefits of ICM implementation (Sujadi et al., 2023; Andayani et al., 2022).

Overall, the results confirm that Integrated Crop Management technology plays a significant role in improving hybrid maize production and farm income. Its application under real farming conditions demonstrates strong potential as a practical approach to enhance productivity, profitability, and sustainability in maize-based agricultural systems (Dasipah et al. 2024).
Table 4 summarizes the level of Integrated Crop Management (ICM) technology implementation across its main components in hybrid maize cultivation. This table provides an overview of how consistently farmers applied the recommended ICM practices, which is essential for understanding the relationship between technology implementation, production performance, and farm income.

Table 4. Level of Integrated Crop Management (ICM) technology implementation

ICM Component	Implementation Level
Use of improved hybrid varieties	High
Quality seed utilization	High
Plant population management	Moderate–High
Balanced fertilization	Moderate
Soil and water management	Moderate
Integrated pest and disease control	Moderate–High
Timely harvesting and post-harvest handling	High

The results indicate that the implementation of ICM technology was generally high, particularly in the use of improved hybrid varieties, quality seed, and timely harvesting and post-harvest handling. Components such as plant population management and integrated pest and disease control were implemented at moderate to high levels, while balanced fertilization and soil and water management were implemented at moderate levels. This variation suggests that farmers tended to prioritize easily observable and directly yield-related practices, whereas practices requiring more technical knowledge or site-specific assessment were less consistently applied (Harti et al., 2025) Nevertheless, the overall moderate to high level of ICM implementation was sufficient to improve production performance and farm income, highlighting the importance of integrated and complementary crop management practices rather than reliance on a single technological component.

Conclusion

The results of this study show that the implementation of Integrated Crop Management (ICM) technology significantly improves hybrid maize production and farmers' income. Farmers who apply ICM technology achieve higher productivity and obtain greater farm income compared to farmers who use conventional cultivation practices. The integration of several ICM components, including the use of improved hybrid varieties, optimal plant population, balanced fertilization, and integrated pest management, contributes to increased crop productivity and better farm management. These findings highlight the importance of strengthening agricultural extension services and promoting the adoption of ICM technology to improve the sustainability and profitability of maize farming. Future studies are recommended to involve a larger number of respondents and apply more advanced analytical methods to further examine the economic impact of ICM technology.

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Author Contributions

Conceptualization, D.S. and I.M.; methodology, M.S.; formal analysis, M.S.; investigation, M.S.; data curation, M.S.; writing—original draft preparation, M.S.; writing—review and editing, D.S., I.M., and S.U.; visualization, M.S.; supervision, D.S. and I.M.; project administration, D.S.; funding acquisition, D.S. All authors have read and agreed to the published version of the manuscript.

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Conflicts of Interest

The authors declare no conflict of interest. The funders had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript; or in the decision to publish the results.

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