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Go-Pest Technology for Sustainable Agriculture and Improved Economic Efficiency

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Abstract

This study aims to examine the innovation of Go-Pest technology as an eco-friendly solution to improve economic efficiency in the agricultural sector and to support Education for Sustainable Development (ESD). The main problem addressed is the high dependence of farmers on chemical pesticides, which contribute to environmental degradation, increased production costs, and potential health risks. This research employs a descriptive qualitative approach through literature review and conceptual analysis to explore the relationship between technological innovation, economic efficiency, and sustainability. The findings indicate that Go-Pest technology, which utilizes infrasonic waves combined with a digital monitoring system, is effective in reducing pest disturbances without causing environmental harm. Furthermore, the implementation of this technology contributes to economic efficiency by reducing pesticide costs, minimizing labor requirements, and increasing agricultural productivity. From an ESD perspective, this innovation integrates environmental, economic, and technological aspects to support sustainable agricultural practices. Therefore, Go-Pest technology has significant potential as an innovative solution to promote sustainable agriculture while improving farmers' welfare.

[Penelitian ini bertujuan untuk mengkaji inovasi teknologi Go-Pest sebagai solusi ramah lingkungan dalam meningkatkan efisiensi ekonomi di sektor pertanian serta mendukung Education for Sustainable Development (ESD). Permasalahan utama yang dibahas adalah tingginya ketergantungan petani terhadap pestisida kimia yang berkontribusi pada kerusakan lingkungan, peningkatan biaya produksi, dan potensi risiko kesehatan. Penelitian ini menggunakan pendekatan kualitatif deskriptif melalui studi literatur dan analisis konseptual untuk mengeksplorasi hubungan antara inovasi teknologi, efisiensi ekonomi, dan keberlanjutan. Hasil penelitian menunjukkan bahwa teknologi Go-Pest, yang memanfaatkan gelombang infrasonik yang dikombinasikan dengan sistem pemantauan digital, efektif dalam mengurangi gangguan hama tanpa menimbulkan kerusakan lingkungan. Selain itu, penerapan teknologi ini berkontribusi terhadap efisiensi ekonomi melalui pengurangan biaya pestisida, meminimalkan kebutuhan tenaga kerja, serta meningkatkan produktivitas pertanian. Dari perspektif ESD, inovasi ini mengintegrasikan aspek lingkungan, ekonomi, dan teknologi guna mendukung praktik pertanian berkelanjutan. Oleh karena itu, teknologi Go-Pest memiliki potensi besar sebagai solusi inovatif untuk mendorong pertanian berkelanjutan sekaligus meningkatkan kesejahteraan petani.] © The Authors.

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1. Introduction

The agricultural sector is one of the main pillars of economic development in Indonesia, particularly in providing food, creating employment, and improving community welfare. Data indicate that agriculture contributes significantly to the national economy and serves as a primary livelihood source for rural communities [1]. However, in practice, this sector still faces various challenges, one of which is the suboptimal pest control system. Conventional methods commonly used by farmers still rely heavily on chemical pesticides, which, in the long term, can cause negative impacts on the environment, human health, and increase agricultural production costs [2].

In line with the development of the sustainable development concept, the approach of Education for Sustainable Development (ESD) has become increasingly important in promoting environmentally friendly and sustainable agricultural practices. ESD emphasizes the integration of environmental, economic, and social aspects in development activities, including in the agricultural sector [3]. In this context, technological innovation is required not only to enhance productivity but also to maintain ecological balance and improve economic efficiency for farmers [4].

Recent literature from the past five years reflects a clear and accelerating trajectory toward smart, technology-integrated agriculture as a response to the persistent limitations of conventional pest management. Studies have increasingly documented the adoption of Internet of Things (IoT)-based monitoring systems and sensor-driven platforms as data-informed alternatives to chemical pesticide dependency, demonstrating that real-time field monitoring can enhance efficiency while promoting sustainability [26, 27]. In the specific domain of acoustic and sonic pest deterrence, research has proposed the use of multi-frequency sound wave generators as innovative, non-chemical approaches to pest prevention in large agricultural fields, positioning them as more eco-friendly and cost-effective alternatives to existing chemical methods [28]. Simultaneously, a growing body of work emphasizes that technology-based agricultural innovations hold strong potential to enhance production toward sustainable development by ensuring resource efficiency, environmental resilience, and economic viability for smallholder farmers in developing countries [29]. These trends collectively indicate that the field is converging toward integrated, technology-enabled solutions that are both ecologically responsible and economically viable—particularly for smallholder farming systems such as those prevalent in Indonesia.

Despite these advances, a significant gap remains in the existing literature. Studies on IoT-based and acoustic pest control technologies tend to focus narrowly on technical performance metrics, such as detection accuracy, coverage area, or frequency effectiveness, without systematically evaluating their implications for farm-level economic efficiency [27, 28]. Conversely, sustainability-oriented research in agriculture, including work aligned with ESD principles, has yet to substantially incorporate assessments of specific emerging technologies and their practical cost-benefit dynamics for rural farmers [30, 31]. In the Indonesian context specifically, evidence indicates that high production costs, low selling prices, and limited access to capital continue to undermine the economic viability of smallholder farming, yet structured technology-based interventions addressing these constraints simultaneously remain understudied [26]. This fragmentation across technological, economic, and sustainability dimensions limits the practical applicability of existing findings for policymakers and agricultural practitioners seeking comprehensive, actionable solutions.

The advancement of technology in the era of Society 5.0 provides significant opportunities to develop innovative solutions for agricultural problems, particularly in pest control. The utilization of modern technology in agriculture has been proven to improve efficiency and effectiveness in land management [5]. One potential innovation is Go-Pest technology, a pest repellent device that utilizes infrasonic waves and a digital monitoring system. This technology is designed to reduce dependence on harmful chemical substances while improving the effectiveness and efficiency of agricultural management.

In addition to environmental benefits, the implementation of Go-Pest technology also has strong potential to enhance economic efficiency. Reducing pesticide use, minimizing labor costs, and increasing agricultural productivity are key factors in improving farmers' welfare [6]. Therefore, the integration of technological innovation and sustainability principles is essential in developing an adaptive and competitive agricultural system.

Based on the above considerations, this study aims to examine the innovation of Go-Pest technology as an eco-friendly solution to improve agricultural economic efficiency while supporting the implementation of Education for Sustainable Development (ESD). This study addresses the identified gap by integrating infrasonic-based pest control technology, economic efficiency analysis, and the ESD framework into a single, comprehensive analytical approach—a contribution that is largely absent from current literature. Unlike previous studies that treat technological innovation,

economic performance, and sustainability education as separate domains, this work bridges all three dimensions within a unified framework, offering a holistic and actionable perspective for the development of smart, sustainable agricultural systems in Indonesia and comparable developing-country contexts.

2. Method

This study employs a descriptive qualitative approach using literature review and conceptual analysis methods. This approach was selected to provide an in-depth understanding of the utilization of Go-Pest technology as an innovation in supporting agricultural economic efficiency and the implementation of *Education for Sustainable Development* (ESD).

The data sources in this study were obtained from various relevant literature, including scientific journals, books, research reports, and official publications related to agricultural technology, pest control, economic efficiency, and sustainable development concepts. The collected data were systematically analyzed to identify the relationships between technological innovation, economic efficiency, and environmental sustainability in the agricultural sector.

The research procedure was conducted through several stages: (1) collecting relevant literature related to the research topic; (2) selecting and classifying sources based on their relevance to the research variables; (3) conducting content analysis on the selected literature; and (4) drawing conclusions based on the results of the analysis. This process aims to obtain a comprehensive understanding of the potential and contribution of Go-Pest technology in supporting sustainable agriculture.

The data analysis technique used is descriptive qualitative analysis, emphasizing the interpretation of meanings and relationships among concepts identified in the literature. Data validity was ensured by using credible and relevant sources and by comparing findings from previous studies. Through this method, the study is expected to provide a clear overview of the role of Go-Pest technology in improving economic efficiency while supporting the principles of ESD in the agricultural sector. In addition to the descriptive qualitative approach, this study also incorporates a simple analytical framework to evaluate the economic efficiency of Go-Pest technology. This framework includes cost comparison, production efficiency, and potential financial benefits obtained from the implementation of the technology.

The analysis focuses on identifying differences between conventional pest control methods and technology-based approaches in terms of operational costs, labor requirements, and productivity outcomes. These indicators are used to assess the extent to which Go-Pest technology can contribute to improving agricultural efficiency.

Although this study does not involve direct field experimentation, the analytical framework is supported by theoretical assumptions and findings from previous studies related to agricultural innovation and sustainable technology adoption.

3. Results

3.1. Go-Pest Technology Innovation in Pest Control

The results of this study indicate that Go-Pest technology is an innovative solution with significant potential to improve the effectiveness of pest control in the agricultural sector. This technology operates by utilizing infrasonic waves that are below the human hearing threshold but are effective in disrupting the activity of pests such as birds, rodents, and insects. Through this mechanism, Go-Pest is able to reduce pest attacks without causing negative impacts on the environment or human health.

In addition, Go-Pest is equipped with a digital-based monitoring system that allows farmers to monitor field conditions in real time through mobile devices. This feature facilitates faster and more accurate decision-making, making land management more responsive and efficient. Therefore, this technology functions not only as a pest repellent device but also as a technology-based agricultural management system. In addition to its functional role, Go-Pest technology also reflects the integration of modern technological principles in agricultural practices. The use of infrasonic waves represents a shift from chemical-based pest control toward environmentally friendly solutions. This transformation is essential in addressing long-term sustainability challenges in agriculture.

The effectiveness of infrasonic waves lies in their ability to disrupt pest behavior without causing physical harm. This characteristic makes the technology safer for both farmers and the surrounding ecosystem. Furthermore, the use of digital monitoring systems enhances the overall

efficiency of agricultural management by providing real-time data and enabling timely responses to pest threats.

As a result, Go-Pest technology not only improves pest control effectiveness but also contributes to the modernization of agricultural systems, particularly in the context of smart farming and digital agriculture.

3.2. The Economic Impact on Agricultural Efficiency

From an economic perspective, the implementation of Go-Pest technology demonstrates increased efficiency in agricultural production activities. The use of this technology reduces dependence on chemical pesticides, which have traditionally been one of the largest cost components in farming. Furthermore, labor requirements for field monitoring are minimized due to the integration of an automated system.

To provide a clearer comparison between conventional methods and Go-Pest technology in terms of economic aspects, Table 1 presents the analysis below.

Table 1. Economic Analysis of Go-Pest Implementation

Indicator	Conventional Method	Go-Pest Technology
Pest control approach	Chemical pesticides	Infrasonic-based technology
Production cost	High (continuous pesticide purchase)	Lower (one-time investment with minimal maintenance)
Labor requirement	High (manual monitoring)	Reduced (automated system)
Environmental impact	Negative (chemical residue)	Environmentally friendly
Productivity level	Decreased due to pest attacks	Increased due to effective control
Break Even Point (BEP)	Not clearly measurable	Achieved at 162 units
Selling price per unit	-	IDR 500,000
Profit potential	Limited	Increasing annually

Based on Table 1, it can be concluded that the implementation of Go-Pest technology has a positive impact on cost efficiency and agricultural productivity. By reducing operational costs and increasing crop yields, this technology directly contributes to improving farmers' income and overall welfare. The economic benefits of Go-Pest technology can also be understood through long-term cost efficiency. Unlike conventional methods that require continuous expenditure on chemical pesticides, Go-Pest involves a one-time investment with relatively low maintenance costs. This significantly reduces the financial burden on farmers over time. In addition, the reduction in labor requirements due to automated monitoring systems allows farmers to allocate their resources more efficiently. This not only lowers operational costs but also improves productivity and time management in agricultural activities. Therefore, the implementation of Go-Pest technology provides a sustainable economic advantage that supports both short-term efficiency and long-term agricultural development.

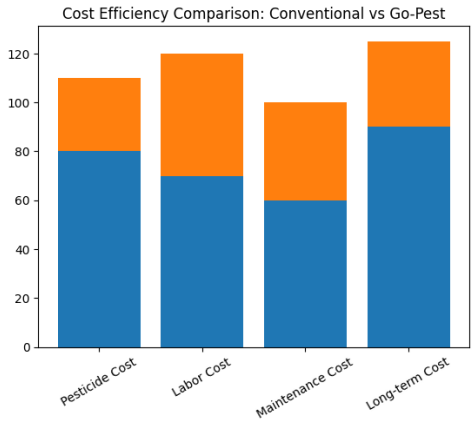

Figure 1. Cost Efficiency Comparison between Conventional Methods and Go-Pest Technology

Figure 1 shows the comparison of production costs between conventional pest control methods and Go-Pest technology. It can be seen that conventional methods require higher and

continuous costs, especially for pesticide use, while Go-Pest technology offers lower long-term costs due to its one-time investment and minimal maintenance. This indicates that Go-Pest provides better cost efficiency and economic sustainability for farmers.

3.3. Contribution to Education for Sustainable Development (ESD)

From the perspective of *Education for Sustainable Development* (ESD), Go-Pest technology reflects the integration of environmental, economic, and technological aspects as the core pillars of sustainable development. The use of eco-friendly technology supports ecosystem preservation by reducing the reliance on harmful chemical substances in agricultural practices.

Furthermore, the economic efficiency generated by this technology contributes to social sustainability by improving farmers' welfare. Go-Pest also has potential as an educational medium to enhance public understanding of sustainable agricultural practices. Through its application, farmers and communities can gain awareness of environmentally responsible farming methods and the importance of sustainability-oriented innovation.

Therefore, the implementation of Go-Pest technology not only provides practical benefits but also contributes to increasing public awareness and literacy regarding sustainable development. This aligns with the objectives of ESD, which emphasize the development of knowledge, skills, and values necessary to achieve a sustainable future.

3.4. Strategic Analysis of Go-Pest Development

The development of Go-Pest technology demonstrates several advantages, including cost efficiency, environmental friendliness, and ease of use. However, there are also several challenges that need to be addressed, such as the relatively low level of technology adoption among farmers and the limited understanding of modern technological systems.

To overcome these challenges, comprehensive development strategies are required. These include increasing education and socialization efforts for farmers, strengthening support from government and related institutions, and further developing technology that is adaptable to local conditions. In addition, collaboration among academics, practitioners, and policymakers plays a crucial role in accelerating the adoption of this technology.

With appropriate strategies, Go-Pest technology has strong potential for wider implementation as an innovative solution to support efficient, sustainable, and competitive agricultural systems.

4. Discussion

4.1. Effectiveness of Go-Pest Technology in Pest Control

Go-Pest technology demonstrates high effectiveness in addressing pest-related problems through the utilization of infrasonic waves. This approach aligns with modern agricultural concepts that prioritize efficiency and sustainability. The use of low-frequency sound waves has been shown to disrupt pest activities without causing damage to crops or the surrounding environment. This represents a significant advantage compared to conventional methods that still rely heavily on chemical pesticides.

Furthermore, the integration of a digital monitoring system in Go-Pest adds substantial value to technology-based agricultural management. Farmers are able to monitor field conditions in real time, enabling faster and more accurate decision-making. As a result, this technology not only enhances the effectiveness of pest control but also supports the transition toward digital-based agriculture.

4.2. Economic and Sustainability Implications

From an economic perspective, the implementation of Go-Pest technology contributes to improved cost efficiency in agricultural production. The reduction in pesticide use and labor requirements plays a key role in lowering operational costs. This finding is consistent with previous studies indicating that technological innovation in agriculture can enhance productivity while simultaneously improving economic efficiency [16], [17].

Previous research also emphasizes that the application of environmentally friendly technology not only benefits ecological aspects but also provides long-term economic advantages for farmers [18]. In this context, Go-Pest serves as a solution that integrates economic efficiency with sustainability principles. Moreover, increased productivity resulting from more effective pest control further contributes to higher farmer income and improved welfare.

4.2.1 Integration with Education for Sustainable Development (ESD)

Within the framework of *Education for Sustainable Development* (ESD), Go-Pest technology reflects the integration of environmental, economic, and technological dimensions as key pillars of sustainable development. The use of this technology promotes environmentally friendly agricultural practices and reduces negative impacts on ecosystems.

In addition, the implementation of Go-Pest has educational value in increasing farmers' awareness of sustainability issues. This aligns with the concept of ESD, which emphasizes changes in mindset and behavior toward more sustainable practices [19]. Therefore, Go-Pest functions not only as a technological tool but also as a learning medium that supports sustainable development.

4.2.2. Challenges and Implementation Strategies

Despite its advantages, the implementation of Go-Pest technology still faces several challenges, particularly related to the level of technology adoption among farmers. Limited knowledge and access to modern technology remain significant barriers to the application of this innovation in the field.

To address these challenges, comprehensive strategies are required. These include enhancing education and outreach programs for farmers, strengthening policy support from the government, and developing technologies that are more accessible and user-friendly. Previous studies indicate that the success of agricultural technology implementation is strongly influenced by educational factors and institutional support [20].

With the synergy between technology, education, and policy, the implementation of Go-Pest can be optimized and is expected to provide significant contributions to the development of sustainable agriculture.

5. Conclusion

Based on the results and discussion, it can be concluded that the innovation of Go-Pest technology has significant potential as an eco-friendly solution for pest control in the agricultural sector. This technology enhances the effectiveness of pest management without causing negative environmental impacts, thereby aligning with the principles of sustainable development. Furthermore, the implementation of Go-Pest contributes to improved economic efficiency through the reduction of pesticide costs, decreased labor requirements, and increased agricultural productivity. From the perspective of Education for Sustainable Development (ESD), Go-Pest technology demonstrates the integration of environmental, economic, and technological aspects that support the development of sustainable agricultural systems. Therefore, this innovation not only provides practical benefits for farmers but also plays an important role in increasing awareness of sustainability issues.

The findings of this study highlight the importance of integrating technological innovation into agricultural practices to achieve sustainability goals. The use of Go-Pest technology demonstrates that environmentally friendly solutions can simultaneously provide significant economic benefits. In comparison with traditional farming methods, the adoption of modern technology enables farmers to reduce dependency on external inputs such as chemical pesticides, which not only improves environmental quality but also strengthens the economic resilience of farmers. Furthermore, the implementation of Go-Pest technology aligns with global trends in sustainable agriculture, which emphasize the use of smart technologies to enhance efficiency and productivity, indicating that the development of such innovations is crucial in addressing future agricultural challenges.

In terms of research strengths, this study offers a novel contribution by integrating three dimensions—technological innovation, economic efficiency, and ESD principles—into a unified analytical framework, which has been largely absent from prior literature. The use of a systematic literature review and conceptual analysis allows for a comprehensive and theoretically grounded examination of Go-Pest technology across multiple dimensions of sustainability. However, this study also has several limitations that must be acknowledged. As a literature-based study, it does not involve direct empirical testing in actual field conditions, which limits the generalizability and practical validation of the findings. The economic analysis conducted relies on theoretical assumptions and secondary data rather than primary field measurements, which may reduce the precision of the cost-efficiency projections presented. Additionally, the study focuses primarily on the Indonesian agricultural context, which may restrict the transferability of findings to other regions with different agronomic, economic, and institutional conditions.

This study contributes to the existing body of knowledge in three significant ways. First, it provides a conceptual framework for evaluating eco-friendly pest control technologies from an integrated economic and sustainability perspective. Second, it situates Go-Pest technology within the broader discourse of Education for Sustainable Development, demonstrating how agricultural innovation can serve as both a practical tool and an educational instrument for promoting sustainable practices. Third, it offers a foundation for evidence-based policy recommendations aimed at supporting the adoption of non-chemical pest control solutions among smallholder farmers in Indonesia.

In the future, the development of Go-Pest technology should focus on improving accessibility, ease of use, and adaptability to various agricultural conditions. Further research is strongly recommended to empirically test the effectiveness of Go-Pest technology through controlled field experiments and longitudinal studies that measure actual changes in pest infestation rates, production costs, and farmer income over time. Comparative studies involving different agroecological zones and farming scales would also strengthen the evidence base for broader implementation. In addition, future research should explore the social dimensions of technology adoption, including farmers' perceptions, behavioral intentions, and the role of institutional support in facilitating uptake. Interdisciplinary studies that combine agronomy, economics, and education sciences are particularly encouraged to further develop the integrated framework proposed in this study. These efforts will strengthen the validity of Go-Pest technology as a sustainable agricultural innovation and support its wider implementation across diverse farming contexts.

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Informed Consent

This study involved participants through interviews and/or surveys. Therefore, informed consent was obtained from all participants prior to the data collection process.

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