

Farmers' Perceptions, Knowledge, and Pesticide Use Behavior: A Basic for Sustainable Agriculture Strategy in Parongpong District, West Bandung

Ayu Pipit^{*}, Dwi Nowo Martono, Suyud Warno Utomo

Program Studi Magister Ilmu Lingkungan, Sekolah Ilmu Lingkungan, Universitas Indonesia, Jl. Salemba Raya No. 4, Jakarta, 10430 Indonesia

^{*}E-mail correspondence: ayuupipit@gmail.com

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ABSTRACT

The widespread use of chemical pesticides in Parongpong District poses significant risks to environmental and human health. This study aims to analyze the influence of farmers' perceptions and knowledge on their pesticide use behavior and to formulate sustainable agriculture strategies based on these insights. Using a quantitative approach, data were collected from 100 purposely selected farmers and analyzed through multiple linear regression. The findings show that 57% of farmers demonstrated good pesticide practices, while 43% were still engaged in risky behavior. Knowledge had a greater influence ($\beta = 0.208$) on behavior than perception ($\beta = 0.199$), although the low R^2 value (0.082) indicated that other factors also contributed. Despite awareness of pesticide risks, gaps remain in protective equipment use and waste management. The study highlights the need for multi-level interventions, including ICT-based farmer training, strengthened collaborative governance, and diversification through eco-friendly agricultural clusters based on Integrated Pest Management (IPM). These strategies aim to reduce pesticide dependency and promote sustainable agricultural practices. The integration of behavior-based insights with education, policy support, and technological innovation is essential for transforming agriculture in Parongpong into a safer and more environmentally responsible sector.

Keywords: farmer knowledge, perception, pesticide behavior, sustainable agriculture

INTRODUCTION

Agriculture plays an important role in Indonesia's economy, particularly in food security and poverty alleviation (Sarma, 2022). The Green Revolution significantly increased agricultural production through the intensive use of fertilizers and pesticides. However, its negative impacts on the environment and human health cannot be ignored (Sarfranz et al., 2023). Pesticides play a vital role in protecting crops from destructive pests and contribute substantially to increased agricultural productivity (Sarma, 2022). Despite these benefits, pesticide use remains controversial. Although effective in the short term, pesticides pose serious risks to human health and ecosystems (Souza et al., 2023). Due to their persistent nature, pesticides are considered environmental pollutants, as many compounds do not easily degrade (Palanimanickam & Sepperumal, 2017). Uncontrolled pesticide use can lead to pest resistance, soil and water contamination, and endanger the health of both farmers and consumers (Gangola et al., 2022).

Parongpong District in West Bandung Regency is known as a horticultural production center characterized by intensive pesticide use (Dimiyati et al., 2022). Previous research has revealed that farmers in this area still apply non-recommended pesticides, with residues levels exceeding permissible limits in several commodities (Amilia et al., 2016). These conditions suggest potential gaps in farmers' perceptions, knowledge, and behavior regarding pesticide use.

Farmers' perceptions of pesticides are influenced by experience, beliefs, and information received from various sources, including agricultural extension services and farmer groups (Haryadi & Setiawan, 2022; Kocher et al., 2002; Sirajuddin & Kamba, 2021; Sudarmadi et al., 2001). According to Damalas and Koutroubas, (2018), understanding farmers' perceptions of pesticide risks and safety is a persistent challenge. Perception is shaped by the living environment and may differ even when the object of observation is the same. Factors such as culture, beliefs, attitudes, education, and regulations play a role in shaping individuals' mindsets. Additionally, socio-economic and cultural factors also influence how farmers perceive pesticides (Remoundou et al., 2014).

Meanwhile, farmers' knowledge of pesticide types, appropriate dosages, and potential negative impacts plays a crucial role in their decision-making regarding pesticide use (Ahmed et al., 2015). Low literacy levels often lead to unsafe usage, harming both consumers and ecosystems (Damalas et al., 2024). Farmers' knowledge influences their actions, ranging from application skills to the selection of sustainable agricultural technologies (Pangihutan & Manalu, 2019). Formal education and training can raise awareness of pesticide risks and promote strategies to mitigate negative impacts (Maria et al., 2022). Furthermore, better knowledge enables farmers to understand safer pest control methods, which can help reduce pesticide residues (David et al., 2020).

Measuring farmers' behavior in pesticide use is important to prevent environmental pollution, protect farmers' health, and promote sustainable pest control. Farmers' perceptions, knowledge, and behavior are key factors in mitigating pesticide-related risks (Bagheri et al., 2019). A lack of understanding and concern regarding pesticide exposure can lead to unsafe practices, such as spraying without protective gear and improper mixing ratios (Sharma et al., 2019). Farmers' pesticide use behavior reflects the extent to which they understand risks and adopt safe and sustainable practices (Bagheri et al., 2019).

Although previous studies have examined farmers' perceptions, knowledge, and behavior regarding pesticide use, many of these studies rely primarily on descriptive analysis and are conducted in different regional contexts. Limited research quantitatively examines the predictive influence of perception and knowledge on pesticide use behavior using statistical model approaches, particularly in intensive horticultural areas such as Parongpong District. Moreover, few studies translate empirical findings on behavioral determinants into locally grounded sustainable pesticide use strategies. This creates a research gap in understanding not only whether cognitive variables significantly influence behavior, but also how these findings can inform context-specific interventions and policy design. From a development communication perspective, this study is positioned within the framework of Diffusion of Innovations theory (Rogers, 2003), which explains how new ideas and practices are adopted within social systems. In the context of pesticide use, safer and more sustainable agricultural practices can be viewed as innovations whose adoption is influenced by communication process, social networks, and perceived attributes of the innovation. This theoretical positioning provides an epistemological foundation for analyzing how perception and knowledge contribute to behavioral change among farmers.

Based on this gap, the research problem can be formulated as follows: (1) Do farmers' perception and knowledge significantly influence pesticide use behavior in Parongpong District? (2) How can the findings be translated into sustainable pesticide use strategies?

This study is significant because it provides empirical evidence on the behavioral determinants of pesticide use in a horticultural area characterized by intensive chemical application. The findings contribute to the development of evidence-based strategies aimed at promoting safer and more sustainable agricultural practices at the local level.

This study aims to analyze the influence of between farmers' perceptions and knowledge and their behavior in pesticide use in Parongpong District. In addition, it seeks to formulate a sustainable agriculture strategy based on these behavioral insights. By understanding the factors that influence farmers' behavior, more effective strategies can be designed to increase awareness and promote sustainable pesticide use practices.

METHODS

This research was conducted in Parongpong District, West Bandung Regency, from May to October 2024. The research location is shown in Figure 1.



Figure 1 Research Location

The population in this study consists of farmers who are actively cultivating agricultural land and have experience in using pesticides. Based on available data, the total number of farmers in Parongpong Sub-district is 10,965. The sample size was determined using the Slovin formula, as follows:

$$n = \frac{N}{1 + N.e^2} \quad (1)$$

Description:

- n = minimum sample size
 N = population size (10,965 farmers)
 e = margin of error (10% or 0.1)

$$n = \frac{10965}{1 + 10965 \times 0,1^2}$$
$$n = 99,09 \approx 100 \text{ respondents}$$

Thus, 100 farmers were selected as respondents. The sampling technique used was purposive sampling (Dolores & Tongco, 2007), with the criteria that respondents must be actively engaged in farming activities and have experience in pesticide application. Purposive sampling was employed to ensure that respondents had direct experience in pesticide application, which is essential for examining the studied variables. This technique enables the selection of information-rich participants aligned with the research objective (Dolores & Tongco, 2007). Given that not all registered farmers actively use pesticides, this approach improves the relevance and appropriateness of the data.

This study employed a quantitative approach using a structured questionnaire as the primary data collection instrument. The questionnaire measured three main variables:

1. Perception (X_1): farmers' understanding of the benefits and risks of pesticide use
2. Knowledge (X_2): farmers' comprehension of pesticide types, dosage, application methods, and environment and health impacts.
3. Behavior (Y): farmers' practices in selecting, applying, storing, and managing pesticides safely.

Data were analyzed using descriptive statistics and multiple linear regression analysis. The regression model was used to answer the research objective, namely to examine the influence of perception and knowledge on pesticide use behavior. The regression equation is formulated as:

$$Y = \alpha + \beta_1 X_1 + \beta_2 X_2 + e \quad (2)$$

Where:

- | | | | |
|-------|--------------------------|-------------------|---------------------------|
| Y | = pesticide use behavior | α | = constant |
| X_1 | = perception | $\beta_1 \beta_2$ | = regression coefficients |
| X_2 | = knowledge | e | = error term |

To examine the proposed relationship, the following hypotheses were formulated:

H_0 : Perception (X_1) and knowledge (X_2) do not have a significant effect on pesticide use behavior (Y)

H_1 : Perception (X_1) and knowledge (X_2) have a significant effect on pesticide use behavior (Y)

These hypotheses were tested using multiple linear regression analysis through partial (t-test) and simultaneous (F-test) significance testing at a 5% significance level ($\alpha = 0.05$) (Jorgi et al., 2019). The partial influence of each independent variable was tested using the t-test, while the simultaneous influence was examined using the F-test. The coefficient of determination (R^2) was used to assess the explanatory power of the model. This study is conceptually grounded in the Social Ecological Model (Mcleroy et al., 1988), which emphasizes that individual behavior is influenced by cognitive factors and the surrounding environment. In this research, perception and knowledge represent individual-level determinants expected to influence pesticide use behavior. This theoretical framework supports the selection of regression analysis to assess the predictive relationship between cognitive variables and behavioral outcomes. Prior to regression analysis, classical assumption tests were conducted to ensure the validity of the model.

In addition, this study also refers to the Theory of Planned Behavior (TPB), which posits that behavior is influenced by attitudes, subjective norms, and perceived behavioral control (Bagheri et al., 2021). In the context of pesticide use, perception, and knowledge are considered cognitive components that may shape behavioral intention and actual practice. This theoretical perspective supports the analysis of how individual-level determinants influence pesticide use behavior. This study received ethical clearance from the Ethics Committee of the School of Environmental Science, University of Indonesia, with the approval number: KET-093/UN2.F13.D1.KE1/PPM.00/2024.

RESULTS AND DISCUSSION

Respondent Characteristics

Variation in gender, age, educational background, and farming experience are internal factors that influence farmers' perceptions, knowledge, and behavior regarding pesticide use. The characteristics of respondents in this study are presented in Table 1.

Table 1 Respondent Characteristics

Category	Frequency	Percentage (%)
Gender		
Male	79	79
Female	21	21
Age (Years)		
< 20	5	5
20-29	7	7
30-39	27	27
40-49	25	25
50-59	28	25
> 60	8	8
Last Education		
Primary School	25	25
Junior High School	36	36
Senior High School	39	39
Farming Experience (Years)		
< 5	14	14
5 – 10	16	16
11 – 20	25	25
> 20	45	45

Source: Primary Data, 2024

Based on Table 1, the majority of respondents were male (79%) and within the productive age group, with the largest group being 30-39 years (27%) and 50-59 years (28%). The dominance of male farmers reflects the gendered structure of agricultural labor in rural contexts, where pesticide application is often perceived as physically demanding work (Food and Agriculture Organization, 2011). Being in productive age groups indicates that most respondents are actively involved in farming operations, which may increase their exposure to pesticide use practices.

In terms of education, most farmers had a moderate educational background, with 39% completing senior high school and 36% junior high school, while 25% had only primary education. Educational level plays an important role in shaping farmers' understanding of pesticide risks and safety procedures (Remoundou et al., 2014). Farmers with limited formal education may face challenges in interpreting pesticide labels and applying recommended safety standards. Farming experience was relatively long, with 45% having farmed for over 20 years. While extensive experience may improve technical skills in pest control, it can also reinforce habitual pesticide practices. Repeated use over a long period may normalize certain behaviors and reduce sensitivity to potential risks (Damalas & Koutroubas, 2018). Therefore, these characteristics suggest that although farmers possess substantial practical experience, structural, and habitual factors may influence their adoption of safer pesticide practices.

Farmers' Perception

The results show that farmers' perception in Parongpong District toward pesticides use is divided into two categories: Good and Poor. The questionnaire results indicate that most farmers in Parongpong have a poor perception of pesticide use, with 81% falling into this category, while 19% have a good perception. The distribution of perceptions is shown in Table 2.

The questionnaire findings indicate that many farmers believe that higher pesticide use leads to better harvest outcomes and that mixing different types of pesticides increases effectiveness in pest control, despite the associated environmental and health risks. At the same time, farmers demonstrate awareness of the potential negative impacts of pesticides and acknowledge the importance of safe pesticide use

training. Strong support for regulatory measures further suggests openness toward more sustainable agricultural policies.

Table 2 Distribution of Farmers' Perception toward Pesticides

Category	Number of Respondents	Percentage
Good	19	19%
Poor	81	81%
Total	100 people	100%

Note: Good = score 26-40; Poor = score 10-25. Source: Primary Data, 2024

The coexistence of production-oriented beliefs and environmental concern reflects a behavioral inconsistency that has been noted in previous studies, where farmers recognize pesticide risks but continue conventional practices due to perceived effectiveness and habit (Bagheri et al., 2019; Damalas & Koutroubas, 2018).

Farmers' Knowledge

Out of 100 respondents, 56% of farmers had good knowledge regarding pesticide use, while the remaining 44% had poor knowledge. This distribution is shown in Table 3

Table 3. Distribution of Farmers' Knowledge about Pesticides

Category	Number of Respondents	Percentage
Good	56	56%
Poor	44	44%
Total	100 people	100%

Note: Good = score 10-19; Poor = score 0-9. Source: Primary Data, 2024

The findings indicate that farmers' perceptions toward pesticide use are predominantly categorized as poor. Limited perception of pesticide risks may influence decision-making in pesticide application, particularly in assessing environmental and health consequences. Previous studies have reported that inadequate risk perception is associated with unsafe pesticide practices and excessive reliance on chemical inputs (Remoundou et al., 2014). Therefore, improving farmers' perception through education and risk communication is essential to support safer pesticide use behavior.

Farmers' Behavior

The distribution of farmers' behavior toward pesticide use is shown in Table 4. The results show that 57% of farmers in Parongpong have good behavior in pesticide use, while 43% have poor behavior.

Table 4. Distribution of Farmers' Behavior about Pesticides

Category	Number of Respondents	Percentage
Good	57	57%
Poor	43	43%
Total	100 people	100%

Note: Good = score 9-17; Poor = score 0-8. Source: Primary Data, 2024

The distribution of farmers' behavior indicates that a substantial proportion still engage in unsafe pesticide practices. This condition suggests a gap between awareness and actual implementation of safety measures. Previous studies have shown that unsafe pesticide handling, including improper disposal and inadequate use of personal protective equipment, contribute to environmental contamination and health risks among farmers (Rani et al., 2021). Therefore, improving behavioral compliance requires not only knowledge enhancement but also stronger institutional support and supervision.

Environmental awareness regarding pesticide waste management remains limited. Only a small number of farmers have participated in waste management training, and recycling of pesticide containers is rarely practiced. Most farmers still dispose of pesticide containers improperly, as shown in Figure 3.

The visual evidence confirms the persistence of unsafe pesticide management practices, particularly improper disposal of containers in open fields. Similar practices have been reported in other developing

agricultural regions, where inadequate waste management increase the risk of soil and water contamination (Rani et al., 2021). This finding reinforces the need for structured pesticide waste management program at the local level.



Figure 2. Food and Beverages Present During Pesticide Application. Source: Field Documentation, 2024

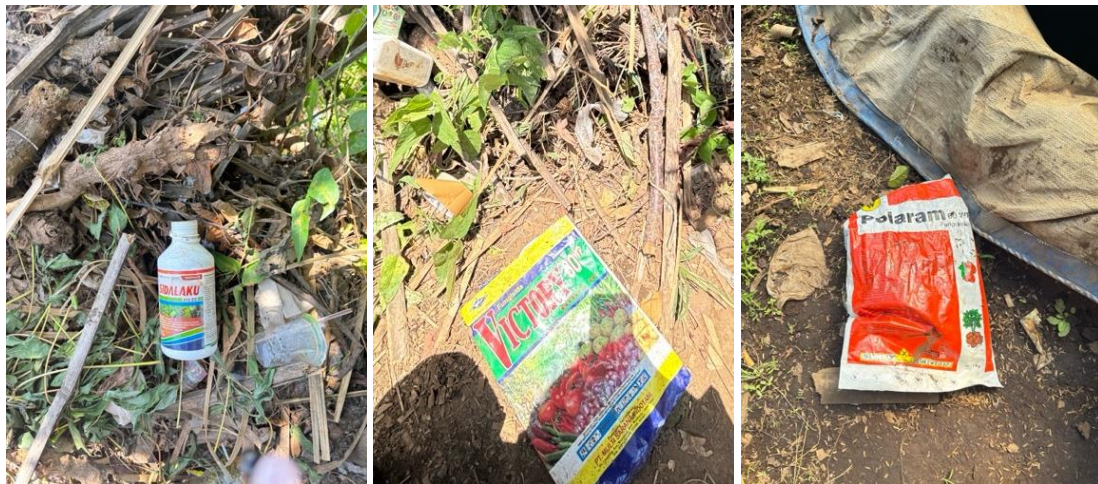


Figure 3 Improper Disposal of Pesticide Packaging Waste in Agricultural Fields. Source: Field Documentation, 2024

Analysis of the Influence of Farmers' Perception and Knowledge on Pesticide Use Behavior

Some farmers are aware of the negative impacts of excessive pesticide use, including pest resistance. However, dependence on pesticides remains high due to limited access to more environmentally friendly alternatives and lack of information about sustainable pest control methods.

Regression analysis shows that both perception and knowledge significantly influence pesticide use behavior, with the following regression equation:

$$Y = 3.951 + 0.132X_1 + 0.189X_2 + e \quad (3)$$

The coefficient for perception (0.132) shows that an increase in perception score is associated with an improvement in pesticide use behavior. Similarly, knowledge has a coefficient of 0.189, indicating a relatively stronger influence compared to perception. The standardized beta values further confirm that knowledge ($\beta = 0.208$) contributes slightly more to behavioral change than perception ($\beta = 0.199$). To further assess the explanatory power of the regression model, the coefficient of determinations (R^2) is presented in Tabel 5.

Table 5. Coefficient of Determination Test Results

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	0.286 ^a	0.082	0.063	2.65408

^a Predictors: (Constant), Knowledge (X2), Perception (X1). Source: Processed Primary Data, 2025

As shown in Table 5, the coefficient of determination ($R^2 = 0.082$) suggests that perception and knowledge explain 8.2% of the variation in pesticide use behavior. Although statistically significant, this relatively low explanatory power indicates that other factors beyond cognitive aspects may also influence farmers' practices. Previous research highlights those structural conditions, access to information, economic considerations, and institutional support may play important roles in shaping pesticide use behavior (Bagheri et al., 2021; Suryani et al., 2020). The overall significance of the regression model was tested using ANOVA, as presented in Table 6.

Table 6. Analysis of Variance (ANOVA) Results

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	60.880	2	30.440	4.321	0.016 ^a
	Residual	683.280	97	7.044		
	Total	744.160	99			

^a Predictors: (Constant), Knowledge (X2), Perception (X1). Source: Processed Primary Data, 2025

The F-test results shows an F value of 4.321 with a significance level (p-value) of 0.016, indicating that H_0 is rejected and H_1 is accepted, meaning that perception and knowledge together significantly affect farmers' pesticide use behavior.

This aligns with Soedradjat et al., (2024), who found that farmers' perceptions of pests and diseases are closely related to their pesticide use patterns. Farmers' behavior is a response to both internal and external stimuli. Their perception and knowledge of pesticide impacts are essential to promoting safer pesticide use. Other factors such as attitudes and independence also influence the adoption of safe practices (Bagheri et al., 2021; Damalas et al., 2024; Pangihutan S & Manalu, 2019; Prayitno et al., 2014)

Although most farmers understand the function of pesticides in pest control, there are still deficiencies in waste management and PPE usage. This study found that only 35% of farmers consistently use PPE during spraying, and only 3% have attended pesticide waste management training. The lack of education and training results in many farmers not practicing safe pesticide use, such as improperly disposing of waste, increasing pesticide doses, and applying pesticides more frequently than recommended (Handayani et al., 2024; Purbosari et al., 2021).

The results of this study indicate that the level of dependency on pesticides in Parongpong District remains high, even though some farmers are already aware of the negative impacts of excessive pesticide use, including pest resistance. This condition is largely attributed to limited access to more environmentally friendly alternatives and a lack of information regarding non-chemical pest control methods.

Regression analysis shows that farmers' knowledge significantly influences their behavior in pesticide use. Farmers with higher levels of knowledge tend to be more prudent in selecting the type of pesticide, determining the dosage, and choosing the appropriate application method. However, there are still gaps in understanding regarding pesticide waste management and the optimal use of personal protective equipment (PPE).

These findings can be interpreted through the perspective of Social Ecological Model (SEM) proposed by Mcleroy et al., (1988), which emphasizes that individual behavior is influenced by multiple interacting factors. At the individual level, farmers' knowledge, and perceptions regarding pesticide risks play an important role in shaping their decision-making. The interpretation is consistent with Damalas & Koutroubas (2018), who highlight that human behavior reflects responses to both internal and external stimuli, and that adequate knowledge contributes to safer pesticide practices.

The study also revealed that having good knowledge does not always translate into appropriate behavior. These findings can also be interpreted through the Theory of Planned Behavior (TPB), which suggests that behavior is shaped not only by knowledge but also by subjective norms and perceived behavioral control (Bagheri et al., 2021). In the context of pesticide use, even though farmers are aware of the

associated risks, the adoption of safer and more sustainable practices may be hindered by social pressure, prevailing habits in their environment, and the perception that they have no alternative other than using chemical pesticides. This is further reinforced by Bagheri et al. (2019), who found that although farmers had a relatively high level of knowledge about the dangers of pesticides, their behavior was still influenced by social norms and their perceived control over pesticide use situations.

Although this study focuses on individual-level determinants, the findings can be situated within the broader framework of the SEM. At the intrapersonal level, farmer groups, extension services, and social network may influence the dissemination of information and the adoption of safer pesticide practices. Empirical evidence suggests that limited access to training and peer-based support is associated with improper pesticide handling and increased environment and health risks (Sharifzadeh et al., 2018). These considerations indicate that behavioral improvement may require not only individual awareness but also strengthened social and institutional support systems.

The relatively low explanatory power of the regression model suggests that factors beyond individual perception and knowledge may influence pesticide use behavior. Previous studies indicate that institutional arrangements, regulatory enforcement, and extension services play a significant role in shaping farmers' pesticide management practices (Damalas & Koutroubas, 2018; Pretty & Bharucha, 2015). Within the SEM framework, institutional and policy-level factors interact with individual cognition to influence behavioral outcome (Mcleroy et al., 1988). Similarly, the TPB emphasizes that behavioral change is not solely determined by knowledge but is also shaped by social norms and perceived behavioral control (Bagheri et al., 2019). Empirical evidence further shows that structured training programs, regulatory framework, and access to sustainable agricultural technologies contribute to improved compliance and safer pesticide use (Sharifzadeh et al., 2018). Therefore, institutional support and policy reinforcement may complement individual-level interventions in promoting sustainable pesticide management.

Sustainable Pesticide Use Strategy

Based on the empirical findings of this study, a comprehensive strategy is required to improved sustainable pesticide use in Parongpong District. The regression results indicate that perception and knowledge significantly influence farmers' behavior, yet the relatively low explanatory power of the model suggests that additional structural and institutional factors also play a role. Furthermore, the findings reveal gaps in training participation, waste management practices, and consistent use of personal protective equipment. These conditions highlight the need for integrated interventions that address both individual-level determinants and broader support systems. Therefore, the following strategies are formulated by integrating the study result with relevant literature on sustainable agriculture development. This research proposes three key strategies:

Optimization of Training and Extension Services through Digital Technology. The lack of ongoing training has contributed to the continued use of chemical pesticides without adequate understanding of dosage and long-term environmental impacts. To address this, there is a critical need to strengthen agricultural education through innovative and intensive training programs. The findings of this study show that farmers' awareness regarding pest resistance and environmental contamination remains relatively low.

The Integrated Pest Management Field School (SLPHT) previously implemented in West Bandung Regency showed positive outcomes, including a reduction in pesticide dependence and increased crop health and productivity. However, the discontinuation of this program due to weak policy backing reflects a lack of sustainability. Mulyani et al., (2020) emphasize that long-term success of agricultural training programs depends on consistent government support and policy alignment.

This study recommends the integration of information and communication technology (ICT) to overcome training accessibility barriers. ICT-based training, including the use of mobile applications, online modules, instructional videos, and virtual consultations, allows for more flexible, scalable, and continuous delivery of information. Research by Wijaya et al. (2022) and Khowatini et al., (2023) shows that ICT-based training increased farmers' awareness of pesticide effects on health by up to 72% and improved safe pesticide practices by 74%. The use of interactive methods—such as video presentations, live discussions, practical demonstrations, and feedback sessions—has proven effective in engaging farmers and enhancing their learning outcomes.

Digital training also enhances farmers' skills in producing botanical pesticides using locally available ingredients such as neem leaves, lemongrass, and garlic. This is supported by evidence from Khowatini et al., (2023), which found that 100% of farmers in Panduman Village who received structured digital-based training understood the materials and expressed willingness to adopt organic pesticide practices. This reinforces the importance of using multimedia and digital platforms to amplify the reach and impact of agricultural extension efforts.

Strengthening Collaborative Governance in Sustainable Pesticide Use. The findings of this study reveal that pesticide use in Parongpong District is still dominated by conventional practices, with limited access to information on sustainable alternatives. While private sector programs and organic pesticide subsidies by the local government exist, these efforts remain fragmented and unsustainable.

A major challenge lies in the lack of coordination among stakeholders. Fragmented efforts by the government, private sector, academia, and farmer groups result in low effectiveness of extension programs and support systems. To address this, the study recommends establishing a collaborative governance framework that ensures all actors are actively involved in the planning, implementation, and evaluation of sustainable agriculture initiatives.

This approach is supported by Mukti et al., (2023), who argues that multi-stakeholder collaboration can drive innovation and reduce chemical pesticide dependency. Key areas of collaboration include:

- Technology development: Promoting advanced tools and systems (eg, precision farming, smart irrigation).
- Access to resources: Enhancing distribution channels for seeds, fertilizers, and tools through both public and private investment.
- Training and capacity building: Providing continuous technical support to improve farmers' competencies.
- Market access: Connecting farmers with broader markets to improve competitiveness.
- Research and development (R&D): Conducting joint studies to find context-appropriate pest control solutions.
- Financing: Mobilizing private capital and government incentives for sustainable agricultural investments.

To facilitate such collaboration, this study proposes the formation of a "Sustainable Agriculture Forum" in Parongpong, modeled after successful initiatives such as the Millennial Farmer Communication Forum in Sleman. However, the design of this forum must reflect local conditions—such as land tenure, digital literacy, and farmers' access to infrastructure—to ensure it meets the real needs of the farming community.

Diversification Through Environmentally Friendly Agricultural Clusters Based on Integrated Pest Management (IPM) as an alternative to chemical pesticide use. Diversification through eco-friendly agricultural clusters based on Integrated Pest Management (IPM) offers a practical and scalable solution to reduce pesticide dependency. This strategy is designed to be gradual, participatory, and contextual, aligning with the socio-economic characteristics and capacity levels of farmers' in Parongpong. The key components include:

- Pilot demonstration plots: These serve as learning centers for simple and effective IPM techniques, such as using pest-resistant varieties, natural enemies, pheromone traps, and botanical pesticides. Co-managed by farmers', extension agents, and field facilitators, the plots aim to build trust through direct observation and measurable outcomes.
- IPM Field Schools: Scheduled around farming calendars, these schools teach agroecological principles, pest threshold analysis, and the 5R principle (right type, dosage, timing, target, and application method). This aligns with the Theory of Planned Behavior which Bagheri et al., (2021) emphasizes that knowledge influences behavioral change.
- Gradual integration of IPM practices: Step-by-step adoption of pest-resistant varieties, sanitation, crop rotation, and synchronized planting ensures feasibility and local relevance. This follows Rogers' (2003) Diffusion of Innovation theory, which emphasizes simple, trialable, and adaptable solutions.
- Farmer learning communities: These groups serve as platforms for peer-to-peer learning, supported by extension officers, academia, and private sector actors. Community-driven knowledge sharing helps internalize IPM values and strengthens social networks.

- Technology introduction: Selective use of innovations such as electric sprayers, Agri Drone Sprayers, and IoT-based monitoring systems reduces direct pesticide exposure and enhances spraying efficiency. Gebbers & Adamchuk, (2010) and (Samsinar & Setiawan, (2023) have shown that such technology reduces labor costs, pesticide waste, and health risks. Contrary to the notion that automation is only viable for large-scale farming, Rachmawati (2020) finds that appropriately scaled IoT solutions are effective even for small holders.
- Institutional and market support: Farmers adopting IPM practices can be linked to certification programs (organic or eco-labels), improving their market position and income. This aligns with Porter's Cluster Theory (1998), emphasizing the importance of stakeholder synergy to foster innovation and competitiveness.

In summary, the sustainability of pesticide use in Parongpong District cannot be achieved through regulations or subsidies alone. Success depends on education infrastructure, access to agricultural technology, inclusive governance, and incentive-driven policies. The proposed cluster-based approach, combining education, demonstration, digital innovation, and institutional support, offers a replicable model for transforming agriculture into a more environmentally friendly and economically viable sector.

CONCLUSION

This study concludes that farmers' perceptions and knowledge significantly influence their pesticide use behavior in Parongpong District, West Bandung Regency. Among the two variables, knowledge was found to have a stronger impact than perception, suggesting that informed farmers are more likely to adopt safer and more responsible pesticide practices. However, the relatively low R^2 value (0.082) indicates that other unmeasured factors—such as institutional support, peer influence, access to environmentally friendly alternatives, and existing farming habits—also contribute significantly to farmers' behavior.

The findings indicate that although perception and knowledge significantly influence pesticide use behavior, substantial gaps remain in practical implementation, particularly in waste management and consistent use of personal protective equipment (PPE). This indicates that behavioral change is influenced not only by knowledge and perception but also by broader social and structural conditions. The results therefore support the relevance of the Theory of Planned Behavior and the Social Ecological Model in explaining how social norms and external support systems may shape farmers' practices.

Therefore, in order to effectively promote safer pesticide use and advance sustainable agriculture, multi-level interventions are required. These include improving access to farmer education and training, strengthening agricultural extension services, fostering peer-to-peer learning through farmer groups, and implementing stricter yet supportive regulations on pesticide distribution and application. Furthermore, integrating environmentally friendly pest management strategies, such as Integrated Pest Management (IPM), into local agricultural policies can play a key role in reducing chemical dependency.

By integrating statistical modeling of behavioral determinants with a development communication framework, this study provides empirical insight into pesticide use behavior in an intensive horticultural setting. The findings extend existing descriptive research by linking cognitive factors to context-specific strategic recommendations for sustainable agriculture.

In conclusion, sustainable agricultural transformation in Parongpong District requires a combination of enhanced farmer knowledge, supportive social environments, and strong institutional frameworks. Only through a collaborative and comprehensive approach can the harmful impacts of pesticide misuse be mitigated and long-term agricultural sustainability be achieved.

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