

## **Intervention strategies to enhance food safety certification adoption among farmers in Malaysia: A system dynamics approach**

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**Abstract:** This study aims to identify the key elements influencing the adoption of food safety certification in Malaysia's agricultural industry. By analysing elements derived from past studies conducted between 2018 and 2023, expert agreement on these elements was obtained using the Fuzzy Delphi Method. Simulation modelling further examined these elements to identify the primary influencing elements and propose intervention strategies. Based on insights from 30 experts in the agriculture industry with over five years of experience in Malaysia, out of 33 identified elements, only 22 elements influence the adoption as influencing the adoption of food safety certification. A simulation model using system dynamics was used to test the agreed element. From these findings, 11 Causal Loop Diagrams were developed. Using the Causal Loop Diagram, a stock and flow analysis simulation model were created to test the elements affecting the adoption of food safety certification. Two of the five elements tested were identified as critical factors requiring attention for adopting food safety certification: awareness campaigns and enforcement. The findings of this research will offer significant insights to stakeholders, facilitating the improvement of current policy strategies to effectively encourage the adoption of food safety certification among farmers in Malaysia.

**Keywords:** Awareness campaign, Enforcement strategies, Food safety certification, Malaysian agriculture, Sustainable agriculture practices, System dynamics.

### **1. Introduction**

Certification in food safety has emerged as a critical component in guaranteeing the production of safe and high-quality food, especially as international markets increasingly require adherence to rigorous standards (WHO, 2019). In Malaysia, food safety certification is vital in promoting agricultural sustainability, boosting consumer confidence, and facilitating access to valuable domestic and international markets. Programs like Malaysia's Good Agricultural Practices (MyGAP) aim to improve the credibility and competitiveness of Malaysian agricultural products while promoting sustainable farming practices (Fam et al., 2019). Certification guarantees adherence to food safety standards and offers farmers economic advantages, such as improved pricing, enhanced market access, and diminished competition in premium markets (Omar et al., 2023).

Despite these benefits, the adoption rate of food safety certification among farmers in Malaysia still needs to be improved, particularly in rural areas. Previous studies have highlighted several barriers, including limited awareness (Seymour, 2018), high compliance costs (Patel, 2023), and technical challenges (Baglan et al., 2020). Although implemented nationwide, awareness campaigns have struggled to effectively communicate the benefits of certification, especially to smallholder farmers who

often need access to resources and information (Sujianto et al., 2022). Furthermore, enforcement mechanisms need to be more consistently applied, leading to a perception of weak regulatory oversight and diminishing the perceived importance of certification (Carlisle et al., 2022). This gap between policy implementation and farmer adoption threatens the potential of food safety certification to drive agricultural transformation in Malaysia.

The low adoption of food safety certification among farmers poses significant challenges to Malaysia's agricultural industry. With widespread compliance, the country can access lucrative export markets prioritising certified agricultural products. Studies have shown that market pull demand for certified goods remains a critical driver for certification adoption. However, due to structural and financial barriers, many Malaysian farmers need help to leverage this opportunity (Jaafar, 2020). Furthermore, failing to adhere to food safety standards risks customer trust and damages Malaysia's reputation as a trustworthy supplier of premium agricultural produce. It is crucial to address these challenges to guarantee the industry's strength and ability to compete internationally.

Previous research emphasises the need for a dual approach that combines awareness campaigns with strong enforcement measures. While awareness campaigns play a vital role in educating farmers about the economic and operational benefits of certification, they are often generic and fail to address the specific concerns of farmers, such as certification costs, technical knowledge, and administrative complexity (Adamchick & Perez, 2020). On the other hand, enforcement ensures adherence to certification standards and reduces the likelihood of certification withdrawal. However, it is most effective when paired with supportive measures like localised training and peer support systems, which help farmers navigate the complexities of certification processes (Razzif et al., 2020).

This study aims to identify effective intervention strategies to enhance the adoption of food safety certification among Malaysian farmers. Specifically, it evaluates the impact of awareness campaigns, enforcement mechanisms, and other key factors such as training, incentives, and market access. Using the Technology-Organization-Environment (TOE) framework and Eco-Innovation theory, this research investigates how these elements interact and influence certification adoption. A system dynamics approach models these interactions and provides data-driven insights for improving intervention strategies.

The findings of this study are significant for multiple stakeholders. Policymakers can use the insights to design more focused and impactful programs that address the specific needs of farmers. The study provides a clearer understanding of overcoming barriers to certification, enabling farmers to participate in high-value markets and improve their livelihoods. Additionally, the research contributes to agricultural sustainability by promoting safer and more efficient farming practices. This study advances Malaysia's efforts to establish a more resilient and competitive agricultural industry by bridging the gap between policy and practice.

## 2. Literature Review

Food safety certification has emerged as a critical mechanism to ensure food quality and safety, driven by increasing consumer awareness and stringent market demands. Globally, food safety certification systems such as GlobalGAP and HACCP have significantly contributed to enhancing the credibility of agricultural products and securing access to premium markets (Yadav et al., 2022). These certifications benefit farmers by improving marketability, increasing product value, and enabling participation in international trade (Federica et al., 2021). However, their adoption varies across regions due to differences in economic, regulatory, and infrastructural conditions. In developing countries, including Malaysia, the low adoption of food safety certification remains a pressing issue, with smallholder farmers facing challenges related to financial constraints, technical expertise, and inadequate policy support (Carlisle et al., 2022). This global context highlights the need for context-specific strategies to bridge the gap between certification requirements and farmer participation.

The Technology-Organization-Environment (TOE) Framework and Eco-Innovation theory provide a robust theoretical foundation for understanding the adoption of food safety certification. The TOE Framework considers technological readiness, organisational capacity, and environmental influences as key determinants of innovation adoption (Yusuf et al., 2018; Zainon et al., 2024). In food safety certification, technological readiness includes access to tools for compliance, such as record-keeping systems, while organisational capacity encompasses farmers' knowledge, skills, and resources to navigate certification processes. Environmental influences include regulatory frameworks, market demands, and community dynamics. Meanwhile, the Eco-Innovation theory emphasises the interplay between market pull and regulation push in driving sustainable practices, such as food safety certification (Hazarika & Zhang, 2019). This dual framework provides a comprehensive lens to examine how technological, organisational, and environmental factors interact with market and regulatory mechanisms to influence certification adoption.

Despite advancements in understanding certification adoption, significant research gaps still need to be addressed, particularly in evaluating the effectiveness of awareness campaigns and enforcement strategies. Awareness campaigns are widely recognised as essential for educating farmers about the benefits of certification. However, studies show that many campaigns fail to address farmers' needs, such as financial concerns or administrative challenges (Najm & Kubaisi, 2020). Campaigns often rely on generic messaging that may not resonate with rural farming communities, leading to limited behavioural change (Sai et al., 2019). On the other hand, enforcement strategies play a critical role in ensuring compliance but must be more utilised or consistently applied. There need to be more enforcement mechanisms to reduce the trustworthiness of certification programs, whereas overly harsh punishments with sufficient support can deter involvement (Yuan & Zhang, 2020). These gaps highlight the need for integrated approaches that combine targeted awareness campaigns with supportive enforcement measures to enhance certification adoption effectively.

Another challenge in certification adoption is more localised solutions tailored to rural farming communities. Research shows that rural farmers, especially in developing countries, often need more access to digital tools, technical training, and resources necessary for certification (Purwanto et al., 2023). While global frameworks for food safety certification exist, they often need to account for these communities' unique socioeconomic and infrastructural realities. In Malaysia, programs like MyGAP have made progress. However, the effectiveness of these initiatives is improved by a one-size-fits-all approach that only partially engages with the challenges faced by smallholder farmers. Bridging this gap requires integrating community-based initiatives like peer support systems and on-site training to address specific local challenges and build trust within farming communities.

Moreover, while enforcement and awareness are critical, studies suggest that incentives, such as subsidies or financial assistance, can significantly enhance the willingness of farmers to adopt certification. Alam et al. (2018) found that incentives tied to measurable outcomes, such as improved market access or productivity, effectively motivate farmers to invest in certification. These incentives reduce the perception of certification as a burden and instead present it as an opportunity for long-term gains. However, the challenge lies in designing incentive frameworks that address immediate financial concerns and encourage sustained compliance and integration of certification into regular farming practices. Future strategies must balance awareness, enforcement, and incentives to create a holistic framework for increasing adoption rates in Malaysia.

### 3. Methodology

This study employed a structured phase methodology to explore strategies for enhancing food safety certification adoption among farmers in Malaysia. The first step of this study identified key elements influencing certification adoption through a preliminary study and comprehensive literature review with published articles in reputable journals from 2018 to 2023. A thematic analysis was

conducted using the Technology-Organization-Environment (TOE) framework and Eco-Innovation theory to extract relevant themes. These elements were then validated using the Fuzzy Delphi Method (FDM), which gathered input from 30 experts with at least five years of experience in the agricultural field.

The next stage, focused on building a simulation model using System Dynamics (SD) to analyse complex interactions among the identified factors. A Causal Loop Diagram (CLD) was developed to map feedback loops and interrelationships, such as the reinforcing effects of awareness campaigns on farmer knowledge and balancing loops caused by high certification costs. These relationships were translated into a stock-and-flow model using Vensim software, allowing for the simulation of real-world scenarios. Key variables, such as awareness campaigns, enforcement, training, market access, and incentives, were incorporated into the model to evaluate their impact on certification adoption over time.

The insights derived from thematic analysis, FDM, and SD modelling were used to design intervention strategies. These strategies addressed barriers like limited awareness, high costs, and weak enforcement while leveraging market pull and regulatory support to drive certification adoption. The intervention strategies were refined into an adaptive policy framework that can respond flexibly to changing conditions in Malaysia's agricultural industry. This phase emphasised creating actionable recommendations for policymakers and stakeholders to promote sustainable farming practices and enhance food safety compliance.

This study utilised robust tools and methodologies to ensure Reliability. Thematic analysis and expert validation using FDM provided a strong foundation, while SD modelling in Vensim facilitated a detailed exploration of dynamic interactions. Validation processes, including expert reviews and data consistency checks, further ensured the accuracy and reliability of the findings. This comprehensive approach provided actionable insights for improving food safety certification adoption and informed evidence-based policy recommendations for the agricultural industry in Malaysia.

#### 4. Result and Analysis

Through an initial investigation and a thorough review of 348 reputable journals, 33 elements were identified as affecting food safety certification adoption. A structured questionnaire was developed based on these elements, and 30 experts were selected through convenient sampling. Following the distribution and analysis of the questionnaire, it was determined that out of the 33 elements impacting the adoption of food safety certification, 22 experts agreed upon the elements. The identified elements were subsequently organised into thematic analysis using the TOE Framework and Eco-Innovation. The accepted elements are presented in

Table .

**Table 1.**  
Accepted element by expert using fuzzy Delphi method.

| <b>Accepted element</b> |  |                                   |   |
|-------------------------|--|-----------------------------------|---|
| <b>Theme</b>            | <b>Element</b>                           | <b>Threshold value (<i>d</i>)</b> | <b>Percentage of expert agreement (%)</b> |
| Technology              | Technology affordability                 | 0.17                              | 97  |
|                         | Technology innovation introduced         | 0.14                              | 97  |
|                         | Technology transfer occurs in the market | 0.14                              | 93  |
|                         | Time constraints                         | 0.15                              | 77  |
| Organisation            | Farmer awareness regarding food safety   | 0.19                              | 93  |
|                         | Farmers future direction                 | 0.19                              | 90  |

|                      |  |      |     |
|----------------------|--|------|-----|
|                      | Farming experience   | 0.2  | 90  |
|                      | Farm size  | 0.19 | 93  |
|                      | Financial constraints  | 0.16 | 93  |
|                      | Cooperatives or Associations membership                      | 0.14 | 97  |
|                      | The contract offers  | 0.13 | 97  |
| Environment          | Government involvement and support                           | 0.12 | 100 |
|                      | Incentives offered by the government                         | 0.18 | 93  |
| Market Pull          | Premium price offers from the market                         | 0.08 | 97  |
|                      | Good demand for agricultural produce with a food safety logo | 0.15 | 100 |
|                      | Consumers recognising MyGAP and MyOrganic logos              | 0.19 | 93  |
|                      | Consumer awareness regarding food safety                     | 0.2  | 90  |
|                      | More market access or channel                                | 0.13 | 97  |
| Regulation Pull/Push | The high cost of renewal                                     | 0.17 | 97  |
|                      | Policies and regulations enforced by the government          | 0.16 | 100 |
|                      | A lot of documentation preparation                           | 0.17 | 90  |
|                      | Training   | 0.13 | 93  |

Meanwhile, Table 1 Presents the list of elements rejected by the experts. Although these elements were rejected, they will be considered in the simulation process to examine the relationships between one element and another.

**Table 1.**  
List of rejected elements using fuzzy Delphi method.

| <b>Rejected element</b> |   |                                   |   |
|-------------------------|---|-----------------------------------|---|
| <b>Theme</b>            | <b>Element</b>                                      | <b>Threshold value (<i>d</i>)</b> | <b>Percentage of expert agreement (%)</b> |
| Technology              | Technology acceptability                            | 0.24                              | 53  |
|                         | The output volume                                   | 0.28                              | 53  |
|                         | Having logistics or good supply chain management    | 0.33                              | 53  |
| Organisation            | The age of farmers                                  | 0.25                              | 63  |
|                         | Farmer education background                         | 0.23                              | 47  |
| Environment             | Competitive pressure                                | 0.23                              | 53  |
| Market Pull             | Higher return on investment                         | 0.23                              | 73  |
|                         | Limited demand from the market surrounding the farm | 0.28                              | 43  |
| Regulation Pull/Push    | The status of the farm (Tenure period)              | 0.24                              | 43  |
|                         | Legal liability makes farmers not interested        | 0.23                              | 47  |
|                         | Farm location close to the industry area            | 0.19                              | 67  |

Based on the findings from FDM, the subsequent analysis developed a simulation model using system dynamics. In system dynamics, developing a CLD explores the dynamic hypothesis to examine the interrelationships or interdependencies among the elements agreed upon by the experts in Phase 1.

Table 2 Presents the list of CLDs developed. Meanwhile Figure 1 Illustrates the visual interconnections between the elements that have been constructed.

**Table 2.**

List of causal loop diagram.

| <b>Element</b>       | <b>Loop</b> | <b>Description</b>  |
|----------------------|-------------|---|
| Technology           | R1          | FSC adoption → +Technology adoption → +Efficiency → +Productivity → +Market share → +FSC adoption   |
|                      | R2          | FSC adoption → +Technology adoption → +Production volume → +Market channel → +Contract offer → +FSC adoption  |
|                      | R3          | Technology adoption → +Operation cost → -Affordability → +FSC Adoption → Government incentive → +Technology adoption  |
| Organisation         | R4          | Farmers awareness → +FSC adoption → +Market channel → +Market price offer control → +Farmers awareness  |
|                      | B1          | Cooperative or association membership → +Market channel → +Production volume → +Contract offer → +Policies Enforced → +Farmers commitment → +FSC adoption → -Legal liability → -Cooperative or association membership |
|                      | B2          | FSC adoption → +Operation cost → -Financial sources → -Debt → -FSC adoption   |
| Environment          | R5          | Farmers readiness → +Government support → +Government Incentive → +FSC adoption → +Farmers readiness  |
|                      | R6          | FSC adoption → +Government initiative → +Consumer awareness → +Market demand → +Market share → +Farmers awareness → +FSC adoption   |
| Market pull          | R7          | FSC adoption → +Food quality → +Consumer trust → +Market Demand → +FSC adoption   |
| Regulation pull/Push | R8          | Policies enforced → +FSC adoption → +Government initiative → +Training → +Farmers knowledge → +Farmers awareness → +Policies enforced   |
|                      | B3          | FSC adoption → +Document preparation → +Operation time → +Operation cost → -FSC adoption  |



**Figure 1.**  
Visual causal loop diagram.

In Figure 1, 11 CLDs have been developed, of which 8 are Reinforcing (R) loops, and 3 are Balancing (B) loops. A significant relationship between technology adoption, efficiency, and production volume can be noticed. The adoption of new technology by farmers leads to improved efficiency and productivity, subsequently resulting in a higher production volume. Increased production allows farmers to tap into more market channels and secure favourable contract terms, underscoring the importance of adopting FSC practices. A highly interrelated getting together includes awareness among consumers, trust in consumers, and the demand within the market. With the rising awareness among consumers regarding food safety concerns, there is a significant rise in their trust and demand for certified products. This shift is compelling farmers to implement FSC to satisfy the growing expectations of the market. This cluster highlights the direct influence of consumer behavior on farmers' certification decisions.

Key interdependencies exist among factors concerning government support, operational costs, and financial sources. Government incentives are crucial in lowering operational costs and enhancing affordability, directly influencing farmers' capacity to implement FSC. The availability of financial resources is intricately linked to debt levels, which affect farmers' overall affordability and preparedness



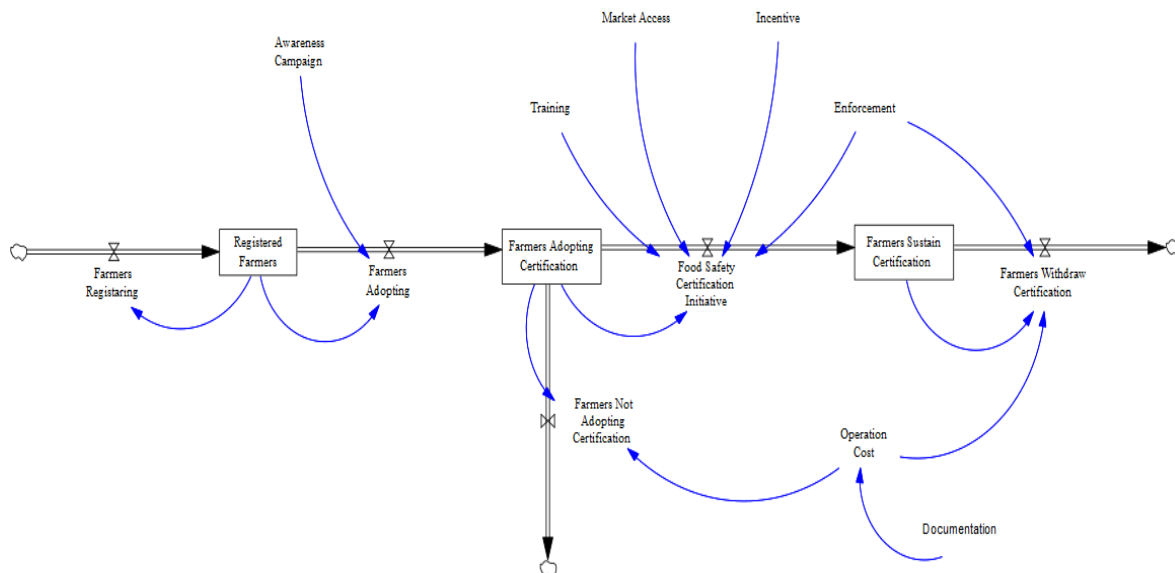
for certification. In a similar vein, the preparedness of farmers and the preparation of documents are closely linked; farmers must have the necessary documentation to advance with FSC, while the process of document preparation is contingent upon farmers possessing sufficient knowledge and training, frequently bolstered by government initiatives. The interdependencies indicate that effective FSC adoption necessitates a coordinated strategy, where the progress of one factor frequently depends on the development or consistency of others.

After the development of the CLD, it was discussed with three experts, as detailed in Table 4. The three experts agreed on the developed CLD, affirming that it accurately mirrors the conditions encountered in the field. Considering these findings, five elements highest impact on the interconnection between the elements were chosen to create a simulation model utilizing stock and flow. The choice of these five elements, as indicated by the experts, follows from their considerable impact on the adoption of food safety certification and the accessibility of data to facilitate the simulation. The components include Awareness Campaign, Training, Market Access, Incentives, and Enforcement.

**Table 3.**  
List of experts for model validation.

| Expert   | Expert position               | Company   | Years of experience |
|----------|-------------------------------|---|---------------------|
| Expert 1 | Chief operating officer (COO) | COE4HVC Sdn. Bhd  | 22                  |
| Expert 2 | Deputy director               | Federal agricultural marketing authority (FAMA) Negeri Kelantan | 18                  |
| Expert 3 | Chairman                      | Koperasi Gabungan Usahawan Tani Kuala Kangsar Bhd.              | 17                  |

This simulation model was developed based on the percentage allocation of the budget provided by the Ministry of Agriculture and Food Security (MAFS). The simulation model depicted in Figure 2 It was constructed utilizing stock and flow methodologies.



**Figure 2.**  
Food safety certification simulation model.



Figure 2 Illustrates a stock and flow model designed to analyse the impact of selected elements on the adoption of food safety certification among farmers in Malaysia. The simulation begins with the registration of farmers in the E-Ladang Kontrak system. Following registration, MAFS (2023) allocates its budget across various initiatives to encourage certification adoption. The budget allocation includes awareness campaigns (15%), training programs (15%), enforcement measures (10%), incentives (20%), and enhanced market access (25%). These efforts aim to motivate farmers to embrace food safety certification. Farmers who adopt certification benefit from improved knowledge through training, financial incentives, market opportunities for certified products, and enforcement measures to ensure compliance. While most participating farmers belong to a sustainability certification cluster, some may exit the program due to financial constraints or enforcement challenges.

**Table 5.**  
Simulation model result.

| <b>Year</b> | <b>Registered farmers</b> | <b>Awareness campaign</b> | <b>Training</b> | <b>Market access</b> | <b>Incentive</b> | <b>Enforcement</b> | <b>Farmers withdraw certification</b> |
|-------------|---------------------------|---------------------------|-----------------|----------------------|------------------|--------------------|---------------------------------------|
| 2021        | 168.337                   | 5.777                     | 4.017           | 3.467                | 924              | 4.207              | 489                                   |
| 2022        | 168.904                   | 5.357                     | 4.329           | 3.861                | 1.008            | 4.585              | 486                                   |
| 2023        | 169.444                   | 5.252                     | 4.464           | 3.940                | 1.050            | 4.727              | 478                                   |
| 2024        | 170.376                   | 4.779                     | 4.866           | 4.492                | 1.124            | 5.011              | 462                                   |
| 2025        | 171.019                   | 4.149                     | 5.402           | 4.965                | 1.219            | 5.247              | 434                                   |

Table 5 Showing the data obtained from the simulation model conducted. There has been a consistent increase in registered farmers from 2021 to 2025, and this pattern corresponds with the data documented in the E-Ladang Kontrak system. In 2021, the number of registered farmers stood at 168,337, which rose to 168,904 in 2022, reflecting an increase of approximately 0.34%. The growth persisted in 2023, culminating at 169,444, which signifies an additional 0.32% increase. In 2024, the figure reached 170,376, indicating a 0.55% rise, and in 2025, it increased further to 171,019, marking a 0.38% growth.

The data indicates a declining trend in registered farmers adopting food safety certification annually from 2021 to 2025, even considering awareness campaign efforts. In 2021, 5,777 farmers embraced food safety certification; however, this figure experienced a decline of 7.3% in 2022, resulting in a new total of 5,357. The decline persisted in 2023, resulting in a 2% reduction, which brings the total number of farmers to 5,252. In 2024, the figure fell to 4,779, indicating a more significant decline of approximately 9%. By 2025, the number will decline notably to 4,149, reflecting a 13% reduction from the prior year. Evidence indicates a consistent rise in training initiatives for registered farmers embracing food safety certification from 2021 to 2025. In 2021, a total of 4,017 farmers engaged in the training, and this figure rose to 4,329 in 2022, indicating an increase of approximately 7.8%. 2023, the figure rose to 4,464, reflecting a 3.1% growth. By 2024, training participation reached 4,866, reflecting an increase of approximately 9%. In 2025, trained farmers reached 5,402, reflecting an 11% increase compared to the prior year.

The market access activity indicates a consistent rise in registered farmers adopting food safety certification from 2021 through 2025. In 2021, 3,467 farmers achieved market access, rising to 3,861 in

2022, indicating a 11.4% growth. 2023, this figure rose to 3,940, indicating an approximate increase of 2%. In 2024, market access activity experienced a notable increase, reaching 4,492, marking a 14% rise. In 2025, the figure reached 4,965, reflecting an additional increase of 10.5% compared to the prior year.

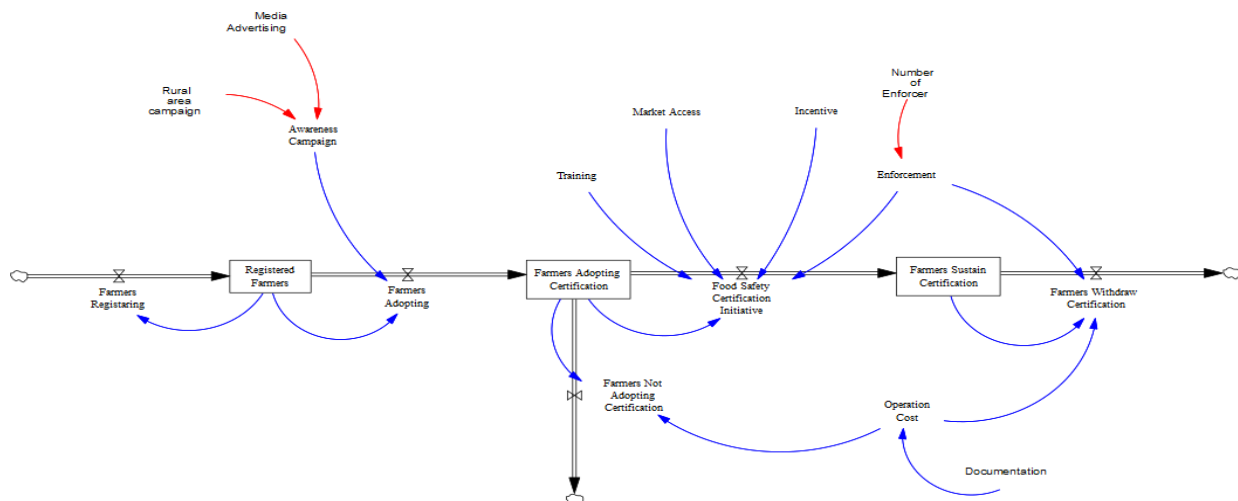
The analysis indicates that while there has been a consistent rise in registered farmers in Malaysia's E-Ladang Kontrak system from 2021 to 2025, the uptake of food safety certification presents a troubling decline. The percentage of farmers adopting certification decreased from 3.4% in 2021 to 2.4% in 2025, suggesting that the existing awareness campaigns have not achieved the intended effect. This decline indicates that although awareness initiatives have been implemented, they might not possess the necessary persuasiveness or relevance to address the challenges farmers encounter effectively. Consequently, it is essential to focus on enhancing these campaigns, ensuring they are more effective and customised to tackle issues, including perceived expenses and the intricacies of the certification process.

Enforcement activities have risen by 24.7% from 2021 to 2025, contributing to a decrease in farmers opting out of food safety certification from 0.29% in 2021 to 0.25% in 2025. This trend suggests that more stringent regulatory measures have effectively sustained certification among farmers. Even so, more than enforcement is needed to achieve substantial growth in adoption and should be accompanied by supportive initiatives. There has been a notable increase in training and market access activities, with training participation experiencing a rise of 34.5% during this period and market access expanding by 43.2%. The groundwork established is solid, yet the influence on adoption rates appears constrained.

The simulation indicates that the awareness campaign requires reconsideration due to a decline in farmers obtaining food safety certification. Likewise, enforcement requires assistance to diminish farmer attrition from the certification program. The stock and flow models were carried out once more to guarantee an increase in farmers adopting and maintaining certification programs. Figure 3 illustrates the stock and flow development for the intervention plan regarding the awareness campaign and enforcement, with the additional approach marked by a red connector.

To enhance the adoption of food safety certification among farmers via intervention strategies, two approaches will be implemented:

- i. Strategy 1: The funding for the awareness campaign will be augmented from 5% to 10% and subsequently to 15%.
- ii. Strategy 2: The quantity of enforcers will be augmented by 5%, 10%, and 15%.



**Figure 3.**  
Simulation model for intervention strategies.

**Table 6.**  
Result of awareness campaign intervention strategy.

| Year | Awareness campaign (Base case) | Campaign budget increase 5% (Scenario 1) | Campaign budget increase 10% (Scenario 2) | Campaign budget increase 15% (Scenario 3) |
|------|--------------------------------|--|---|---|
| 2021 | 5.743                          | 6.030                                    | 6.317                                     | 5.752                                     |
| 2022 | 5.325                          | 6.211                                    | 6.760                                     | 5.982                                     |
| 2023 | 5.231                          | 6.459                                    | 7.300                                     | 6.161                                     |
| 2024 | 4.754                          | 6.782                                    | 7.738                                     | 6.284                                     |
| 2025 | 4.117                          | 7.189                                    | 8.125                                     | 6.347                                     |

Table 6 Describes an intervention strategy to enhance the awareness campaign by 5%, 10%, and 15%. The plan moreover encompasses enhancing campaigns in rural areas and media advertising to bolster awareness initiatives. The outcomes of this intervention are as follows: An increase of 5% in the awareness campaign correlates with a positive rise in adoption rates, ranging from 3% to 19.2%. The acceptance rate of food safety certification among farmers increases by 7% to 28.6% when augmented by 10%. Nonetheless, growth persists when the increase attains 15%, albeit at a diminished rate of between 4% and 10.3%. Consequently, the budget and initiatives of the awareness campaign should be augmented by only 5% or 10% to effectively enhance food safety certification uptake among farmers while guaranteeing a substantial return on investment.

**Table 7.**  
Result of enforcement intervention strategy.

| Year | Enforcement (Base case) | Campaign budget increase 5% (Scenario 1) | Campaign budget increase 10% (Scenario 2) | Campaign budget increase 15% (Scenario 3) |
|------|-------------------------|--|---|---|
| 2021 | 481                     | 457                                      | 433                                       | 409                                       |
| 2022 | 477                     | 433                                      | 429                                       | 405                                       |
| 2023 | 467                     | 410                                      | 420                                       | 397                                       |
| 2024 | 450                     | 387                                      | 405                                       | 383                                       |
| 2025 | 422                     | 366                                      | 380                                       | 359                                       |

Table 7 Shows how to increase enforcement efforts by 5%, 10%, and 15% to illustrate an intervention strategy. The strategy seeks to assess how varying degrees of enforcement influence the dropout rates of farmers from the program. The outcomes of this intervention indicate that a 5% increase in enforcement correlates with a reduction in dropout rates ranging from 5% to 23.9%. When enforcement is augmented by 10%, the dropout rate diminishes further, reducing by between 10.2% and 27.2%. Ultimately, when enforcement is increased by 15%, there remains a decline in dropout rates, albeit milder, ranging from 15.0% to 25.4%. The simulation results indicate that augmenting the number of enforcers for enforcement actions will decrease the attrition rate of farmers in the food safety certification program.

## 5. Discussion

### 5.1. Awareness Campaign

The results presented in Table 6 Highlight the effectiveness of varying levels of intervention strategies to enhance awareness campaigns for increasing the adoption of food safety certification among farmers. The findings indicate a clear relationship between budget allocation for awareness initiatives and the corresponding adoption rates, though the rate of improvement diminishes beyond a certain threshold. An increase of 5% in the budget allocation for awareness campaigns yields a notable rise in adoption rates, ranging from 3% to 19.2%. This demonstrates that even a modest enhancement can significantly influence farmers' willingness to adopt food safety certification. Similarly, when the budget is increased by 10%, the adoption rate shows an even more significant improvement, ranging from 7% to 28.6%. These results suggest that a 10% increase is the most impactful and cost-effective level of intervention, as it maximises the adoption rate without requiring a disproportionately high increase in resources.

However, further increasing the budget allocation to 15% results in a minor improvement in adoption rates, ranging from only 4% to 10.3%. This diminishing return suggests that while additional spending on awareness campaigns beyond 10% still generates growth, the effectiveness per unit of investment declines. This plateau effect emphasises the importance of optimising resources to achieve the most significant impact. In addition to the quantitative findings, the intervention strategy includes expanding campaigns in rural areas and leveraging traditional and digital media to reach a wider audience. These enhancements are critical given that the majority of Malaysian farmers reside in rural areas and may rely more heavily on traditional forms of communication. Incorporating these localised and media-based approaches can further strengthen the overall effectiveness of the awareness campaign.

Based on these results, it is recommended that stakeholders focus on increasing the budget for awareness campaigns by either 5% or 10%, as these levels yield the most significant improvements in food safety certification adoption rates while ensuring an efficient return on investment. This approach allows for a balanced allocation of resources, enabling the implementation of additional complementary initiatives to further support farmers in adopting food safety certification.

### 5.2. Enforcement

The findings presented in Table Demonstrate the impact of varying degrees of enforcement efforts on reducing dropout rates among farmers participating in the food safety certification program. The intervention strategy evaluates the effectiveness of incremental increases in enforcement by 5%, 10%, and 15%, providing insights into how enhanced oversight influences farmer retention.

A 5% increase in enforcement correlates with a reduction in dropout rates ranging from 5% to 23.9%. This suggests that even a modest improvement in enforcement measures can lead to significant retention among farmers, particularly for those who may otherwise exit the program due to non-compliance or a lack of continued motivation. Increasing enforcement by 10% yields even more significant benefits, with dropout rates declining by 10.2% to 27.2%. These results highlight the effectiveness of enhanced enforcement within this range, as it ensures compliance and reinforces the importance of food safety certification.

Meanwhile, when enforcement is increased by 15%, the reduction in dropout rates shows a milder improvement, ranging from 15.0% to 25.4%. This indicates diminishing returns on investment at higher levels of enforcement. While the attrition rate continues to decline, the marginal improvement is less pronounced compared to the 10% increase. This suggests that over-enforcement might not be cost-effective or necessary to achieve the desired retention outcomes.

The results also emphasise the importance of resource allocation, particularly in terms of increasing the number of enforcers to carry out these actions. Enhanced enforcement efforts can address compliance challenges, mitigate the risk of program exits, and foster more outstanding commitment among farmers to maintain their food safety certification. By ensuring regular monitoring, support, and

corrective actions, when necessary, enforcement efforts can create an environment where farmers feel accountable and supported to remain in the program.

Based on the simulation results, it is recommended that enforcement efforts be increased by 10%, as this level offers the optimal balance between achieving significant reductions in dropout rates and ensuring resource efficiency. A 5% increase may be appropriate for programs operating with limited resources, as it still yields notable improvements. Conversely, increasing enforcement by 15% should be approached cautiously, given the diminishing returns observed at this level. By strategically optimising enforcement measures, stakeholders can effectively enhance farmer retention and overall program success.

## 6. Conclusion and Future Research Recommendations

In conclusion, the findings highlight the essential importance of awareness initiatives and regulatory measures in advancing food safety certification among farmers in Malaysia. The results indicate that insufficient outreach and education pose a considerable barrier, considering that many farmers either need to be aware of certification's advantages or understand its significance in risk management and market access. To address this issue, it is essential to create targeted and engaging awareness campaigns that highlight the practical benefits of certification while also dispelling misunderstandings, especially for rural farmers and the older population. The study highlights the effectiveness of enforcement measures in ensuring compliance and maintaining long-term adherence to food safety protocols. Enhancing the number of enforcement officers at the district level is crucial for better oversight and providing essential support to farmers during the certification process. Through the integration of focused awareness initiatives and reinforced enforcement measures, Malaysia's agricultural industry has the potential to promote wider acceptance of food safety certification, boost market competitiveness, and secure the sustainability of food safety practices.

A quantitative approach was used for this study. Further research increasing the range of qualitative methodologies, like in-depth interviews or focus groups, may yield richer insights into farmers' subjective experiences and perceptions concerning food safety certification. This would enhance the quantitative data and provide a more comprehensive insight into the challenges to adoption. Further research may explore the long-term impact of awareness campaigns and enforcement measures on adopting food safety certifications, employing longitudinal data to evaluate the sustainability of these interventions over time. Ultimately, additional investigation could examine how digital tools and technologies improve awareness campaigns and enforcement efforts, especially in effectively engaging rural and older farmer demographics. Integrating these aspects will enable future studies to establish a more thorough framework for enhancing food safety certification within Malaysia's agricultural industry.

### Acknowledgement:

Universiti Malaysia Pahang Al-Sultan Abdullah (RDU223410) and Majlis Amanah Rakyat (MARA) supported this study.

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