

## **Pesticide Application in Trinidadian Food Supply Chain: Food Safety and Sustainability Implications**

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### **Abstract**

The use of pesticides, although ensures crop protection and enables to achieve food security, often causes negative externalities for both human and the environment. This study sought to identify the factors that influence pesticide application in Trinidad, a major CARICOM nation, by conducting structured interviews with 174 farmers in eight municipal counties. The data were analysed using Ordered Probit Model. While gender and age showed no significant impact on pesticide use frequency, farm size and experience influenced application behaviours. Larger farms and experienced farmers displayed distinct patterns, calling for customized interventions. Notably, secondary and collegiate education was linked to reduced pesticide use, aligning with sustainability goals. Crop-specific trends were seen with an increase in the use of pesticides in the Solanaceae crop and leafy vegetables, underscoring the need for tailored approaches. Insect and weed issues had a limited impact, however, management of crop diseases was essential in reducing pesticide use. This study emphasizes the need for multi-disciplinary interventions that take into account the size of the farm, the level of experience, the level of education, and the types of crops grown in Trinidad, to promote the sustainable use of pesticides in agriculture. Such comprehensive strategies are essential for enhancing food safety and long-term sustainability of the Trinidad food supply chain, while also mitigating the negative externalities of pesticide application.



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## Introduction

Crop protection mechanisms, including the use of pesticides, are vital for safeguarding crops from organisms that affect their growth and development. Such mechanisms were advocated and profusely used during the era of green revolution to feed the growing population with limited arable land. This trend continues even today as a large portion of agricultural land being lost to commercial and residential development.

In agricultural practises, pesticides are frequently used to mitigate or avoid damage caused by pests, which eventually improves crop quality and yield—a consideration that is frequently important to customers.<sup>1,2</sup> Globally, more than 1000 pesticides are used in agriculture, legally or illegally, for crop and soil treatment.<sup>3</sup> It is worth noting that certain older, off-patent pesticides, such as DDT and lindane, have the ability to persist in soil and water for extended durations.<sup>4</sup> It is imperative to note that about 24.5 million square kilometres, or 64% of agricultural land worldwide, is vulnerable to pesticide contamination from several active ingredients, with 31% of that area being at high risk.<sup>5</sup>

The benefits of pesticide use are accompanied by potentially harmful effects on human and environment. The hazardous effects of pesticides have exposed farmers to significant risks. Approximately 385 million unintentional acute pesticide poisoning incidences reported globally every year, resulting in approximately 11,000 fatalities. With an estimated worldwide farming population of around 860 million, this implies that approximately 44% of farmers experience pesticide poisoning annually.<sup>6</sup> The potential toxicity and health hazards of pesticides were reported by many. Research by Now *et al*, and Gill and Garg have highlighted the short-term consequences of pesticide exposure,<sup>7,8</sup> while numerous scholars have reported the long-term effects such as thyroid dysfunction, decreased sperm counts, congenital abnormalities, cancer, reproductive and immune system dysfunctions, hormonal issues, dermatitis and behavioural disorders.<sup>9-16</sup>

Those farmers involved directly in mixing and spraying pesticides are posed with health risks as they mishandle these chemicals.<sup>17-20</sup> Further, short-term and long-term impacts of these harmful

chemicals cause serious environmental degradation. The consumers too are at risk of pesticide exposure through residues on food commodities and drinking water sources.<sup>17-19</sup> In addition, misuse of outdated pesticide containers for the storage of food and water, ill-maintained or inappropriate spraying equipment, improper storage procedures, and inaccurate application techniques can all harm people and the environment.<sup>21-23</sup>

Indiscriminate pesticide usage has led to a generalised of contamination of food commodities and the food supply chain, posing significant health hazards to consumers.<sup>24</sup> Yen *et al* have reported that the farmers in Trinidad consistently used higher levels of pesticides to produce fruits and vegetables, locally.<sup>25</sup> Also, farmers were found to apply pesticides beyond recommended levels by 40% and 100% on Cabbage and Tomato production, respectively.<sup>26</sup> Although pesticides are effective in controlling pests and diseases, researchers were concerned over the presence of pesticide residues on the foods consumed.<sup>19,27,28</sup>

Food security encompasses the provision of an ample, secure, and wholesome food supply that caters to individuals' dietary requirements and desires.<sup>29</sup> The widespread utilization of chemical fertilizers and pesticides is a necessity for feeding the ever-increasing global population, but their excessive use has emerged as a concerning factor affecting the quality and nutritional safety of our food supply.<sup>30</sup>

Besides the challenges posed by natural calamities such as droughts and floods, the farmers encounter damages due to pests and diseases to an estimated 45% of global fruit and vegetable production.<sup>4,31</sup> Caribbean islands, with limited domestic production capacity and frequent hurricanes, floods, and droughts, face additional risks. Examining factors related to pesticide application can help develop a targeted approach to ensure secure food sources for developing populations. While the theory of planned behavior<sup>32</sup> has made valuable contributions to pesticide use research,<sup>33-38</sup> it is important to complement this approach with a holistic understanding of the broader context in which behaviors occur. By incorporating a more comprehensive perspective, researchers and policy-makers can develop strategies that effectively

address the complex challenges associated with pesticide use while considering the diverse factors that influence decision-making and behavior in this domain.

This study was carried to identify the determinants of pesticide applications in the food supply chain of Trinidad. By examining these factors, an all-inclusive approach can be developed to ensure food safety and sustainability. The results of this study would aid in evolving strategies for mitigating pesticides' risks, and promoting sustainable agriculture in Trinidad and regions similar.

**Materials and Methods**

The research was carried out in Trinidad, a Caribbean Island northeast of Venezuela, covering an area of 4,825 sq. km. Agricultural activity accounted for 16.71% of land usage, approximately 81,750 hectares, with a contribution of 1.02% to the GDP in 2004.<sup>39</sup> Most farm plots were around 0.5 hectares in size and relied on rain-fed irrigation with an average annual rainfall of 2010.9 mm (CSO, Trinidad, 2004). Data was collected from 174 farmers in Trinidad, randomly selected from eight municipal counties. Data collection was conducted using a well-organized and pre-evaluated interview schedule.

The study employed the Ordered Probit Model to analyse determinants influencing pesticide utilization frequency among Trinidadian farmers. This model was chosen to overcome limitations of the linear probability model, which assumes constant fractional effects and fixed probabilities.<sup>40</sup> The Ordered Probit analysis takes into consideration the ranked characteristics of response variables, representing farmers' preferences for pesticide application frequency. It treats the underlying response as a continuous latent variable with a normally distributed random error. In contrast, neither Probit not Multinomial Logit Models take into account the ordinal nature of the data, which in turn, necessitate the estimation of a greater number of parameters, and may exhibit undesirable characteristics such as the presence of the independence of irrelevant alternatives<sup>41</sup> or the lack of a likelihood function in closed-form.<sup>42</sup>

Utility function or preference ordering of individual farmers was represented by their application ratings (R) on a scale of 0 to 3 (0-Never, 1-Rarely, 2-Sometimes, 3-Usually). These ratings were arrived at through a single-element vector (X) containing the socio-economic and demographic attributes of the survey participants (Table-1).

**Table 1: Descriptions of variables within the Ordered Probit (OP) model**

Independent variable	Classification	Description	Predictor in model
Gender <sup>a</sup>	Male; Female	1 - If male; 0 – otherwise	X <sub>1</sub>
Age: 26–40 years <sup>b</sup>		1 – If 26 – 40; 0 – otherwise	X <sub>2</sub>
Age: 40– 60 years <sup>b</sup>	< 26; 26 – 40;	1 – If 41- 60; 0 – otherwise	X <sub>3</sub>
Age > 60 years <sup>b</sup>	41 – 60; > 60	1 – If > 60; 0 – otherwise	X <sub>4</sub>
Farming Experience: 5 – 10 years <sup>c</sup>	< 5; 5 – 10; >10	1 – If 5 -10 years; 0 – otherwise	X <sub>5</sub>
Farming Experience: > 10 years <sup>c</sup>		1 – If > 10 years; 0 – otherwise	X <sub>6</sub>
Farm Size: 2.1 – 3.0 Acres <sup>d</sup>	≤ 2.0; 2.1-3.0;	1 – If 1-2 acres; 0 – otherwise	X <sub>7</sub>
Farm Size: 3.1 – 5.0 Acres <sup>d</sup>	3.1-5.0; > 5	1 – If 3-5 acres; 0 – otherwise	X <sub>8</sub>
Farm Size: > 5.0 Acres <sup>d</sup>		1 – If > 5 acres; 0 – otherwise	X <sub>9</sub>
Education: Secondarye	Primary;	1 – If Secondary; 0 – otherwise	X <sub>10</sub>
Education: Collegiatee	Secondary; Collegiate;	1 – If Collegiate; 0 – otherwise	X <sub>11</sub>
Encountered Insects Problems	Yes; No	1 – If yes; 0 – otherwise	X <sub>12</sub>
Encountered Disease Problems	Yes; No	1 – If yes; 0 – otherwise	X <sub>13</sub>
Encountered Weeds Problems	Yes; No	1 – If yes; 0 – otherwise	X <sub>14</sub>

Cultivates Solanaceae Crops	Yes; No	1 – If yes; 0 – otherwise	$X_{15}$
Cultivates Leafy Vegetables	Yes; No	1 – If yes; 0 – otherwise	$X_{16}$
Cultivates Root Crops	Yes; No	1 – If yes; 0 – otherwise	$X_{17}$
Cultivates Tree Crops	Yes; No	1 – If yes; 0 – otherwise	$X_{18}$

Reference categories: a – Female; b – Less than or equal to 26 Years; c – Less than 5 years; d – Less than or equal to 2 acres; e – Primary Education

Dependent Variable: How often do you apply pesticides on your crops (R)? (0-Never; 1-Sometimes; 2-Rarely; 3-Usually)

**Table 2: Factors Influencing Pesticide Use Frequency: Ordered Probit Model**

Predictor	Regression coefficient	SE	Z value	P value
Gender <sup>a</sup>	0.0797	0.2569	0.31	0.756
Age: 26–40 years <sup>b</sup>	0.0499	0.5682	0.09	0.930
Age: 40– 60 years <sup>b</sup>	0.2711	0.5778	0.47	0.639
Age > 60 years <sup>b</sup>	0.2133	0.6535	0.33	0.744
Farming Experience: 5 – 10 years <sup>c</sup>	-0.8192*	0.4196	-1.95	0.051
Farming Experience: > 10 years <sup>c</sup>	-0.9059**	0.3862	-2.35	0.019
Farm Size: 2.1 – 3.0 Acres <sup>d</sup>	0.6122	0.4416	1.39	0.166
Farm Size: 3.1 – 5.0 Acres <sup>d</sup>	0.7380**	0.3603	2.05	0.041
Farm Size: > 5.0 Acres <sup>d</sup>	0.6888**	0.3486	1.98	0.048
Education: Secondary <sup>e</sup>	-0.4464**	0.2005	-2.23	0.026
Education: Collegiate <sup>e</sup>	-1.0676***	0.3893	-2.74	0.006
Encountered Insects Problems	0.2322	0.2058	1.13	0.259
Encountered Disease Problems	0.4591**	0.1867	2.46	0.014
Encountered Weeds Problems	-0.0038	0.0245	-0.16	0.875
Cultivates Solanaceae Crops	0.5015**	0.2049	2.45	0.014
Cultivates Leafy Vegetables	0.7404***	0.2178	3.40	0.001
Cultivates Root Crops	-0.1816	0.2267	-0.80	0.423
Cultivates Tree Crops	0.0797	0.2569	0.31	0.756
Log likelihood	-196.2			
Number of observations	174			
Model Chi – Square	57.50			
chi <sup>2</sup> (p value)	0.000			
Pseudo R <sup>2</sup>	0.1278			

Reference categories: a – Female; b – Less than or equal to 26 Years; c – Less than 5 years; d – Less than or equal to 2 acres; e – Primary Education

\*Significance at 0.10 level; \*\*Significance at 0.05 level; \*\*\*Significance at 0.01 level

Values in brackets represent SE.

The STATA-14® programme was utilised to pursue the ordered probit model that was employed in this study. The model specification employed is as follows:

$$T_n^* = \beta'z_n + \epsilon_n; \text{ Where,}$$

- $T_n^*$  = unobservable and continuous measure of the respondent's preference,
- $z_n$  = an explanatory variable vector that characterises the respondent,
- $\beta$  = an estimate-relevant vector of parameters,

$\epsilon_n$  = a stochastic disturbance term assumed to be distributed normally.

$T_n^*$  was derived from the model as below:

$$T_n^* = \begin{cases} 0 & \text{if } -\infty \leq T_n^* \leq \mu_0 (\text{never}) \\ 1 & \text{if } -\mu_0 \leq T_n^* \leq \mu_1 (\text{sometimes}) \\ 2 & \text{if } -\mu_1 \leq T_n^* \leq \mu_2 (\text{rarely}) \\ 3 & \text{if } -\mu_2 \leq T_n^* \leq \mu_3 (\text{usually}) \end{cases}$$

Where the  $\mu_i$ s represent the thresholds to be estimated.

The likelihoods corresponding to the categorized responses in an Ordered Probit Model are as indicated below:

$$P_n(0) = \Pr(T_n = 0) = \Pr(T_n^* \leq \mu_1) = \Pr(\beta'z_n + \epsilon_n \leq \mu_1) = \Pr(\epsilon_n \leq \mu_1 - \beta'z_n) = \Phi(\mu_1 - \beta'z_n)$$

$$P_n(1) = \Pr(T_n = 1) = \Pr(\mu_1 < T_n^* \leq \mu_2) = \Pr(\epsilon_n \leq \mu_2 - \beta'z_n) - \Pr(\epsilon_n \leq \mu_1 - \beta'z_n) = \Phi(\mu_2 - \beta'z_n) - \Phi(\mu_1 - \beta'z_n)$$

$$P_n(k) = \Pr(T_n = k) = \Pr(\mu_k < T_n^* \leq \mu_{k+1}) = \Phi(\mu_{k+1} - \beta'z_n) - \Phi(\mu_k - \beta'z_n)$$

$$P_n(K) = \Pr(T_n = K) = \Pr(\mu_K < T_n^*) = 1 - \Phi(\mu_K - \beta'z_n)$$

Where  $n$  represents respondent,  $k$  stands for his option,  $\Pr(T_n = k)$  denotes the likelihood of respondent  $n$  responding in a style  $k$ , and  $\Phi(\cdot)$  represents the cumulative distribution function for the standard normal distribution. The model's coefficient,  $\beta$ , provides the key insight that positive coefficients suggest a stronger preference as the related variable values increase, whereas negative coefficients suggest the reverse.

**Results and Discussion**

**Results of Ordered Probit Model**

The research employed the Ordered Probit (OP) analysis to examine the factors affecting pesticide application frequency. Demographic, socio-economic, and crop-related variables were included, and the outputs are presented in Table-2.

The model showed a good fit (log likelihood = -196.2) and the chi-square results (57.50,  $p = 0.000$ ) indicated a significant relationship between the regressors and regresand. As expected, the Pseudo  $R^2$  values were lower in ordered probit models.

The results of OP model exhibited that the gender factor had no significant effect on farmers' choice of pesticide use frequency. This suggests that both male and female farmers have similar likelihoods of falling into the response categories of "Never," "Sometime," "Rarely," or "Usually" to apply pesticides during cultivation.

Similarly, the age categories (years): "26-40" ( $p = 0.930$ ), "40-60" ( $p = 0.639$ ), and "> 60" ( $p = 0.744$ ) have exhibited no significant influence on pesticide use frequency, compared to the reference category (age less than 26 years). The results implied that age may not significantly impact farmers' choice of pesticide application frequency.

While analyzing the effect of farming experience on farmers' response categories for pesticide application frequency, it was found that the farmers with 5-10 years of experience had slightly lower probability towards higher response categories ( $p = 0.051$ ) and those with more than 10 years of experience had a significant negative probability ( $p = 0.019$ ). These findings indicated that farming experience influenced response probabilities, with longer experience associated with lower probabilities of higher response categories in Trinidad. These results contradict the findings of Li *et al* and Pongvinyoo *et al*<sup>43,44</sup> in other regions of the world, yet they imply that the experienced farmers would adopt a more sustainable pest controlling practices such as Integrated Pest Management.

The analysis to examine the influence of farm sizes on response categories of pesticide use frequency showed that those holding 2.1 - 3.0 acres did not have significant ( $p = 0.166$ ) effect on response probabilities. However, those holding 3.1 - 5.0 acres ( $p = 0.041$ ) and >5.0 acres ( $p = 0.048$ ) had significantly favored higher response categories compared to the farmers with 2 acres or less. Aligning previous studies,<sup>43-47</sup> this study also showed that larger farm sizes are connected to the higher response categories. The Large farms are skewed towards higher pesticide application frequencies might be due to their resource richness and scale economies.

**Table 3: Marginal Effects and Predicted Probabilities of Ordered Probit (OP) Model**

Predictor	Pr (Never=0)	Pr (Sometime=1)	Pr (Rarely=2)	Pr (Usually=3)
Gender <sup>a</sup>	-.0314	0.0026	0.0125	0.0164
	-0.1019	-0.0099	-0.041	-0.0512
Age: 26–40 years <sup>b</sup>	-.0194	0.0012	0.0076	0.0106
	-0.2233	-0.0128	-0.0874	-0.1233
Age: 40– 60 years <sup>b</sup>	-.1064	0.0081	0.0421	0.0562
	-0.2276	-0.0203	-0.0903	-0.1182
Age > 60 years <sup>b</sup>	-.0818	0.0016	0.0308	0.0494
	-0.248	-0.0084	-0.088	-0.1674
Farming Experience: 5 – 10 years <sup>c</sup>	.3156**	-.0606	-.1295**	-.1255***
	-0.1481	-0.0476	-0.0637	-0.047
Farming Experience: > 10 years <sup>c</sup>	.3257***	0.1858	-.1039***	-.2403**
	-0.1204	-0.0285	-0.033	-0.1212
Farm Size: 2.1 – 3.0 Acres <sup>d</sup>	-.2218	-.0158	.0716**	0.166
	-0.1401	-0.0351	-0.0333	-0.1446
Farm Size: 3.1 – 5.0 Acres <sup>d</sup>	-.2778**	0.002	.9999**	.1760*
	-0.1276	-0.0157	-0.0438	-0.0966
Farm Size: > 5.0 Acres <sup>d</sup>	-.2648**	0.0139	.1005**	.1504*
	-0.1303	-0.0142	-0.0499	-0.0809
Education: Secondary <sup>e</sup>	.1739**	-.0098	-.0672**	-.0968**
	-0.0767	-0.0096	-0.0315	-0.0454
Education: Collegiate <sup>e</sup>	.3916***	-.0992*	-.1603***	-.1321***
	-0.1153	-0.0529	-0.0508	-0.0312
Encountered Insects Problems	-.0918	0.0081	0.0367	0.0469
	-0.0814	-0.0103	-0.0336	-0.0398
Encountered Disease Problems	-.1785**	0.0093	.0688**	.1005**
	-0.0712	-0.0097	-0.0292	-0.0432
Encountered Weeds Problems	0.0015	-.0001	-.0006	-.0008
	-0.0097	-0.0006	-0.0038	-0.0052
Cultivates Solanaceae Crops	-.1974**	0.0198	.0788**	.9871**
	-0.0798	-0.0149	-0.0347	-0.0389
Cultivates Leafy Vegetables	-.2727***	-.0095	.0924***	.1899***
	-0.0724	-0.0179	-0.0272	-0.066
Cultivates Root Crops	0.0718	-.0065	-.0288	-.0365
	-0.0901	-0.0109	-0.0369	-0.0435
Cultivates Tree Crops	0.0031	0.0002	0.0012	0.0017
	-0.154	-0.0097	-0.0605	-0.0837
Predicted probability	0.4373	0.2197	0.2124	0.1306

Reference categories: a – Female; b – Less than or equal to 26 Years; c – Less than 5 years;  
d – Less than or equal to 2 acres; e – Primary Education

\*Significance at 0.10 level \*\*Significance at 0.05 level \*\*\*Significance at 0.01 level Values in brackets represent SE.



OP analysis exhibited the significant influence of educational levels on farmers' pesticide application frequencies. Farmers with secondary education showed a significant negative probability (-0.4464,  $p = 0.026$ ) towards higher response categories compared to those with primary education. Similarly, those with collegiate education displayed an even stronger effect, with a more significantly negative probability (-1.0676,  $p = 0.006$ ) for higher response categories. These findings emphasized the significant positive association between education and pesticide impacts. Higher education levels enable farmers to make informed decisions on pesticide use, leading to the adoption of safer and sustainable practices. Hence, incorporating education as a key element while making interventions is vital for promoting a responsible pesticide application practices.

The OP analysis found no significant (0.2322,  $p = 0.259$ ) association between the factors, 'encountered insects problems' and response categories for pesticide use frequency, indicating that insect problems may not significantly influence farmers' choice of pesticide use frequency. Similarly, the OP coefficient for "encountered weeds problems" was also not-significant (-0.0038,  $p = 0.875$ ), indicated a negligible effect. However, the OP coefficient for the farmers "encountered disease problems" in their crops was statistically significant (0.4591,  $p = 0.014$ ), indicated that the farmers who encountered crop diseases chosen to apply pesticides more frequently. The findings exhibited the importance of addressing the challenges of diseases and warrants for strategies to promote effective disease management, to minimize pesticide use in agricultural production.

The results of OP analysis for farmers' cultivating different crop varieties showed a significance (0.5015,  $p = 0.014$ ) for those "cultivating solanaceae crops, indicating their propensity towards higher pesticide application frequencies. Correspondingly, the farmers "cultivating leafy vegetables" exhibited strong significant positive probabilities (0.7404,  $p = 0.001$ ), indicated their potential inclination for frequent pesticide use. Contrastingly, both farmers "cultivating root crops" (-0.1816,  $p = 0.423$ ) and those "cultivating tree crops" had a negligible effect, on pesticide use frequency. In summary, cultivating Solanaceae crops and leafy vegetables is associated with higher pesticide application, while

cultivating root crops and tree crops have minimal impact on pesticide use frequency.

### **Marginal Effects of Ordered Probit Model**

The Ordered Probit model's nonlinearity prevents direct insights into estimated variables. To improve interpretability, researchers calculated marginal effects and predicted probabilities based on the model's results. Table 3 presents these findings, offering a comprehensive overview of marginal effects and predicted probabilities.

The analysis found no significant gender effects on pesticide application probabilities across different categories. The coefficient for the "Never" category suggested a small negative effect for males, but it was not statistically significant. Additionally, no significant gender effects were observed for the probabilities of "Sometime," "Rarely," and "Usually" pesticide application. Thus, gender alone does not have a substantial impact on pesticide application probabilities in these categories.

Age groups (26-40, 40-60, and >60) did not significantly affect pesticide application probabilities across categories compared to farmers aged  $\leq 26$  years. The coefficients for these age groups showed no significant association with pesticide application (frequency) probabilities. Therefore, age alone does not significantly influence farmers' pesticide use behavior. Contrastingly, the farmers with 5-10 years of experience had a different pesticide application behavior vis-à-vis those with less than 5 years of experience. They had a significantly higher likelihood (0.3156, SE = 0.1481) of never applying pesticides, suggesting a shift towards alternative farming practices such as integrated pest management strategies. However, when examining probabilities for "Sometime", "Rarely", and "Usually", farmers with 5-10 years of experience exhibited significantly lower probabilities. This suggests they are less likely to use pesticides occasionally, rarely, or regularly compared to farmers with less than 5 years of experience. The results vividly demonstrated that the experienced farmers might apply pesticides judiciously, on need basis. The findings indicated that the experience enabled the farmers to gain more knowledge, which culminated them adapting sustainable pest management practices.

Pesticide use behavior varied with farm holding sizes. Smaller farms (2.1-3.0 acres) had more likelihood of using pesticides rarely, but not regularly. However, farm sizes with more than 3.0 acres had exhibited a tendency to apply pesticides usually, while clearly showing a negative probability for using 'never'. The results implied that the large farms had sufficient resources to procure and apply pesticides regularly to avoid pest pressure, leading to greater reliance on pesticides.

The marginal effects of OP analysis showed that the education had significant impact farmers' pesticide use behavior. Compared to those farmers had primary education alone, those had higher levels of education (both secondary and collegiate) had exhibited a tendency to never apply pesticides, while significantly avoiding the regular use of pesticides. The results of the study exhibited the imperativeness of education in the process of implementing sustainable farming practices.<sup>48,49</sup> This aligns with previous research findings that emphasized the importance of education in promoting safe pesticide use.<sup>50-53</sup>

The analysis of OP marginal probabilities reiterated that insect and weed problems had no significant effects on pesticide application frequencies, while, encountering disease problems had a significant negative tendency for never applying pesticides (-0.1785, SE = 0.0712). Farmers facing diseases were less likely to abstain from pesticide use. Farmers dealing with diseases were more inclined to apply pesticides on higher order categories. These findings showed that the disease problems were pressing the farmers to use pesticides on regular basis. Insect problems do not significantly affect pesticide application, while disease issues had a notable influence.

Cultivating Solanaceae crops had shown a significant negative tendency on never applying pesticides (-0.1974, SE = 0.0798), and more significantly positive attitude on occasional, rare, and regular use of pesticides indicated that the farmers faced frequent disease threats in their Solanaceae crops. Similarly, cultivating leafy vegetables had a significant negative effect on

never applying pesticides (-0.2727, SE = 0.0724), indicating farmers in this category were less likely to abstain from pesticide use. Also, the significant positive probabilities on occasional, rare, and regular pesticide application frequencies suggested a higher inclination for pesticide use among leafy vegetable farmers. However, cultivating root crops or tree crops did not have statistically significant effects on pesticide application probabilities. This suggested that cultivating root crops or tree crops alone did not strongly influence pesticide application behavior. Therefore, Solanaceae and leafy vegetable cultivations were associated with higher pesticide use, while cultivating root crops or tree crops had a limited impact. The results implied that the type of crop cultivated should be taken into account, while planning for any intervention to promote sustainable agricultural practices.

### Conclusion

The Ordered Probit Model has provided insight into the factors that influence farmers' decisions regarding the use of pesticides in the Trinidadian food supply chain. Gender and age did not have a significant effect on the frequency of pesticide use, emphasizing the need for more comprehensive and diversified approaches to ensure food security and sustainability. However, farm size and experience did have an impact, as larger farms and more experienced farmers demonstrated distinct pesticide application behaviours. Also, education, particularly at secondary and college levels, was found to be a major factor in reducing pesticide application frequency, which is in line with sustainability objectives. Furthermore, crop-specific trends, such as an increased use of pesticides with Solanaceae or leafy vegetables, highlight the need for tailored interventions to promote food safety and sustainably. The impact of insect and weed issues was minimal, however, the management of disease-related issues remains an important factor in reducing pesticide use. The overall conclusion of the study is that multi-disciplinary interventions that take into account the size of the farm, experience, training, and crop types should be aimed at to encourage the sustainable application of pesticides in agriculture, thus promoting food safety and the long-term sustainability of the Trinidadian food supply chain.



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