

**Economic Efficiency and Adoption Dynamics of Pesticide Use in Cowpea (*Vigna unguiculata*) Production: Evidence from Ondo State, Nigeria**

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**Abstract**

Pesticide use remains a critical input in cowpea (*Vigna unguiculata*) production, particularly in pest-prone regions such as Southern Nigeria, where yield losses due to insect infestations are a persistent challenge. Despite its growing importance, empirical evidence on the economic efficiency and adoption dynamics of pesticide use in cowpea systems remains limited, especially in emerging production zones like Ondo State. This study fills this gap by investigating the economic efficiency and adoption dynamics of pesticide use in cowpea production in Ondo State, Nigeria. Using a multistage sampling technique, data were collected from 160 farmers, comprising 104 pesticide users and 56 non-users. Analytical tools included descriptive statistics, a damage control production function, budgetary analysis, and logistic regression. The results reveal that pesticide use significantly increased cowpea yield and net returns, with adopters reporting higher mean income and a higher return on investment (ROI) than non-adopters. However, resource-use efficiency analysis showed that the marginal value product (MVP) of pesticide inputs was often lower than the marginal factor cost (MFC), indicating overapplication. Price elasticity estimates showed a high responsiveness of demand to pesticide prices, particularly for Cymbush and Deltamethrin. Logistic regression analysis identified age, education, income level, access to extension, and credit as significant predictors of pesticide adoption. These findings underscore the dual challenge of improving pesticide efficiency while expanding equitable adoption. Policy interventions should prioritize farmer education, affordable access to inputs, improved market linkages, and institutional support to promote both economically efficient and environmentally sustainable pesticide use in cowpea farming.

**Keywords:** Cowpea production, economic analysis, pesticides, productivity, pest management, Nigeria

**1. Introduction**

Cowpea (*Vigna unguiculata*), often referred to as the “poor man’s meat” due to its high protein content, plays a vital role in sub-Saharan Africa's agricultural economy and food systems (Ikhajiagbe et al., 2022; Nounagnon et al., 2024; Nwagboso et al., 2024). It is a climate-resilient crop well-suited to semi-arid and tropical environments, particularly in West Africa, where Nigeria is the leading global producer, accounting for more than 40% of global output (Nwagboso et al., 2024). Despite its agronomic advantages and economic value, cowpea production remains significantly constrained by pest infestations, especially insect pests that damage the crop from field to storage, often resulting in devastating yield losses (Oyewale &

Bamaiyi, 2013; Oso & Ashafa, 2020; Anago et al., 2021). In extreme cases, uncontrolled pest infestations can reduce yields by 80–100% (Togola et al., 2023). In response to this challenge, chemical pesticides have become a dominant strategy in pest control among farmers, especially where other options, such as biological or cultural practices, are limited in scalability or efficiency. The growing adoption of synthetic pesticides, however, has generated new challenges in the literature (Matowo et al., 2020; Warra & Prasad, 2020; Demi & Sicchia, 2021; Srinivasan et al., 2022; Ngegba et al., 2022). While their efficacy in pest suppression and yield enhancement is well-documented, their economic rationality, particularly in resource-constrained settings, remains contested. Pesticides often account for a significant share of input costs for smallholder farmers. This raises essential questions about whether pesticide use actually translates to increased profitability when costs are taken into account (Onuwa, 2022). Additionally, indiscriminate or sub-optimal application, driven by limited access to extension services and poor knowledge of integrated pest management (IPM), can result in economic inefficiencies, environmental degradation, and adverse health effects (Tudi et al., 2021; Khan et al., 2023).

Nigeria's southern states, including Ondo State, offer a unique agro-ecological and socio-economic context for studying pesticide use in cowpea production (Muoghalu & Akanwa, 2021; Alo, 2020). Unlike the traditionally cowpea-dominant northern regions, the southern belt represents an emerging frontier in cowpea cultivation (Saka et al., 2018). Farmers in these areas are increasingly drawn to cowpea due to its short growth cycle, nitrogen-fixing capacity, and income-generating potential. However, these farmers often face limited access to certified pesticides, extension services, and input subsidies, which complicates rational decision-making around pesticide use (Adesina et al., 2021). These contextual differences make Ondo State an ideal case study for examining the economics of pesticide use in cowpea production, particularly in terms of both profitability and the behavioural factors influencing adoption. Despite the importance of pesticides in ensuring cowpea yield stability, the literature on pesticide use in cowpea production in Nigeria has been narrowly focused. Much of the existing research focuses on agronomic performance, varietal trials, or general productivity trends, without delving into the microeconomic dynamics of input use and profitability (Anago et al., 2021; Sani & Joseph, 2023). Few studies (e.g., Asfaw et al., 2009; Singbo et al., 2015; Sheahan et al., 2017) explicitly model the economic efficiency of pesticide use, i.e., the relationships among input costs, output yields, and revenue. Even fewer (e.g., Dinpanah et al., 2019; Salifu et al., 2020; Moussa et al., 2021) explore the socio-economic and institutional variables that influence the decision to adopt or forgo pesticide use altogether. This gap in empirical evidence is particularly significant given the increasing pressure to promote sustainable, cost-effective farming practices amid rising pesticide prices and environmental concerns (Coulibaly & Lowenberg-DeBoer, 2002).

Furthermore, while there has been a gradual shift toward integrated pest management (IPM) in research discourse, adoption at the farm level remains low in Nigeria (Togola et al., 2023). Smallholder farmers continue to rely predominantly on chemical pesticides such as Deltamethrin and Cymbush due to their perceived reliability and ease of use. However, the price elasticity of demand for these products remains poorly understood, especially in local markets where price volatility, accessibility, and knowledge asymmetries prevail. Understanding how sensitive farmers are to pesticide prices offers critical insights into input responsiveness, subsidy design, and sustainable intensification policies (Nwagboso et al.,

2024). From an economic standpoint, assessing the marginal productivity and profitability of pesticide use is crucial for both farmers and policymakers. Models such as the Cobb-Douglas production function or the more nuanced Damage Control Model developed by Lichtenberg and Zilberman provide valuable frameworks for disentangling yield gains attributable to pesticides from those due to other inputs (Dent & Binks, 2020). By estimating marginal value products (MVPs) and comparing them with marginal factor costs (MFCs), researchers can assess whether pesticides are being used efficiently or whether there is overuse or underuse (Durham & Mizik, 2021). Such insights are vital for the rational allocation of limited farm resources and the development of cost-effective extension programs. Additionally, the decision to adopt pesticide use is not merely economic; it is shaped by a complex interplay of demographic, socio-economic, institutional, and psychological factors. Logistic regression models are particularly effective in capturing this multidimensional decision-making process (Das, 2021). Factors such as farmer education, experience, access to credit, membership in cooperative societies, and exposure to extension services have all been shown to influence technology adoption rates in agriculture (Sani & Joseph, 2023). However, region-specific analyses that account for local contexts are lacking, especially in southern Nigeria. This study seeks to fill these gaps by providing a comprehensive evaluation of the economic efficiency and adoption dynamics of pesticide use in cowpea production in Ondo State, Nigeria. Using a combination of the damage control model, price elasticity estimation, budgetary analysis, and logistic regression techniques, the study addresses four core objectives:

1. To evaluate the marginal productivity and resource use efficiency of pesticide application in cowpea farming.
2. To estimate the price elasticity of demand for key pesticide types used by farmers in the study area.
3. To assess the financial returns (profitability) derived from pesticide use among adopters compared to non-adopters.
4. To identify the socio-economic and institutional factors influencing the adoption of pesticide use among cowpea farmers in the area.

The study contributes to the broader discourse on sustainable agricultural intensification by integrating microeconomic efficiency analysis with behavioural adoption modelling. Its findings have practical implications for improving farmer decision-making, optimising input use, and designing targeted agricultural support policies. By grounding the analysis in empirical data from a geographically underrepresented region, the study also contributes to rebalancing the geographical bias in cowpea research, which has historically focused on northern Nigeria (Mohammed et al., 2021). Ultimately, the findings are expected to inform agricultural policymakers, Development practitioners, and agribusiness stakeholders on how best to support efficient, economically viable, and environmentally sustainable pest management strategies in cowpea production systems across sub-Saharan Africa.

## **2. Materials and Methods**

### **2.1 Study Area**

The study was conducted in Ondo State, located in the southwestern region of Nigeria. Ondo State lies between latitudes 5°45' and 7°52' N, and longitudes 4°20' and 6°05' E. The state

comprises 18 local government areas (LGAs), with agriculture serving as a major livelihood for the predominantly rural population. The region experiences a bimodal rainfall pattern, with annual precipitation ranging from 1,200 to 2,000 mm, supporting the cultivation of food crops including cassava, maize, yams, and cowpea. Ondo State presents an emerging cowpea production zone due to its increasingly favourable agroecological and market conditions.

## **2.2 Research Design**

The study adopted a descriptive survey design to evaluate the economic efficiency and adoption dynamics of pesticide use in cowpea production. The approach enabled the collection of cross-sectional data from a diverse group of cowpea farmers with and without pesticide experience, thereby enabling comparative and inferential statistical analyses.

## **2.3 Population and Sampling Procedure**

The target population for this study comprised all active cowpea farmers residing in Ondo State, Nigeria. A multi-stage sampling technique was adopted to select the respondents. In the first stage, six Local Government Areas (LGAs) were purposively selected based on their prominence in cowpea production. State agricultural extension records guided this purposive selection, and prior reconnaissance surveys indicated high cowpea cropping intensity in these LGAs. In the second stage, two farming communities were randomly selected from each of the selected LGAs using a simple random sampling technique, resulting in a total of 12 communities. Within these communities, lists of registered cowpea farmers were obtained through local farmer associations and cooperative registers, which served as the sampling frame. The final stage involved the random selection of individual respondents from these lists using a probability proportionate to size (PPS) approach to reflect the distribution of cowpea farmers across communities. A total of 160 respondents were selected for the study. These were stratified into two groups to allow for comparative analysis between pesticide adopters and non-adopters. Of the total sample, 104 respondents were identified as pesticide users, while 56 were non-users. This stratification was essential for addressing the study's core objective of analyzing both the economic efficiency and the adoption dynamics of pesticide use in cowpea production.

## **2.4 Data Source and Data Collection**

The study employed primary data as its main source of empirical information. Data were collected using a well-structured, interviewer-administered questionnaire. The instrument was designed to capture both qualitative and quantitative dimensions of cowpea production, pesticide use behaviour, and socio-economic characteristics of the respondents. To ensure content validity, the questionnaire was developed in consultation with agricultural extension officers, farm economists, and local agronomists familiar with cowpea production in the area. A pre-test was conducted on a sample of 20 farmers from a non-selected LGA to evaluate the instrument's clarity, reliability, and cultural appropriateness. Based on the feedback, adjustments were made to improve question framing and sequencing. Data collection was conducted over 4 weeks by trained enumerators fluent in both English and Yoruba, the dominant local language in the study area. Enumerators received orientation on ethical considerations, data confidentiality, and culturally sensitive engagement strategies. All completed questionnaires were reviewed for completeness and consistency before data entry and analysis.

## 2.5 Analytical Framework

A combination of descriptive and econometric tools was used to meet the study’s objectives.

### 2.5.1 Damage Control and Pesticide Demand Functions

To evaluate the marginal productivity of pesticide use and its responsiveness to price changes, this study employed the logistic specification of the damage control production model, originally developed by Lichtenberg and Zilberman (1986). This approach distinguishes between traditional input-output relationships and the abatement role of inputs, such as pesticides, which mitigate yield loss rather than directly increasing output.

The generalized multi-factor production function is specified as:

$$Q = f(Z_1, Z_2, Z_3, \dots, Z_n) + U \dots \dots \dots (1)$$

where Q denotes the observed output (in kg/ha),  $Z_1, \dots, Z_n$  represent conventional production inputs (e.g., land, labour, seed, fertilizer), and U is a stochastic error term. However, as Lichtenberg and Zilberman argue, damage control agents such as pesticides do not directly produce output but instead reduce damage caused by pest pressure. This conceptualization draws from Feder (1979), who posited that:

$$Y = \pi - D \dots \dots \dots (2)$$

Here, Y is the actual output realized,  $\pi$  represents the potential (undamaged) output, and D is the yield loss attributed to pest activity. Rational farmers apply pesticides to minimize DDD, thereby increasing Y. If X denotes the quantity of pesticide applied, and  $\psi(X)$  is the proportion of pest damage mitigated, the realized output can be expressed as:

$$Y = \pi - D[1 - \psi X] + \varepsilon \dots \dots \dots (3)$$

This formulation establishes an indirect, damage-abating role of pesticides rather than a direct productive one.

In this framework, the Lichtenberg–Zilberman (LZ) model treats output Q as a function of productive inputs and pest pressure:

$$Q = f(Z, B) \dots \dots \dots (4)$$

where Z denotes conventional inputs and BBB the prevailing pest level. Pest pressure B is further defined as a function of pesticide use:

$$B = B(X, B_0) \dots \dots \dots (5)$$

Here, X represents the quantity of pesticide applied, and  $B_0$  is the uncontrolled pest level in the absence of pesticide intervention.

Lichtenberg and Zilberman propose a functional form that integrates the abatement effect of pesticides via a transformation function G(X), yielding the following modified Cobb-Douglas specification:

$$Q = \alpha Z^\beta [G(X)]^\gamma \dots\dots\dots(6)$$

In this model:

- Q: observed cowpea output (kg/ha),
- $\alpha$ : intercept,
- Z: vector of productive inputs,
- X: pesticide use (liters/ha),
- $\beta, \gamma$ : output elasticities of Z and G(X), respectively,
- G(X): abatement function with  $0 < G(X) < 1$ .

Expanding the production function explicitly, we obtain:

$$Q = \alpha_0 + \beta_1 Z_1 + \beta_2 Z_2 + \dots \beta_4 Z_4 + G(X) + \mu \dots\dots\dots(7)$$

where:

- Z<sub>1</sub>: farm size (ha),
- Z<sub>2</sub>: fertilizer applied (kg/ha),
- Z<sub>3</sub>: labor input (person-days),
- Z<sub>4</sub>: quantity of cowpea seed (kg/ha),
- X: pesticide use (liters/ha),
- $\mu$ : stochastic error term.

To capture the functional relationship between pesticide application and pest control efficacy, a logistic function is assumed for G(X):

$$G(X) = \frac{1}{1 + \exp(\mu - \sigma X)} \dots\dots\dots(8)$$

Substituting Equation (8) into Equation (7), the final logistic specification of the damage control model becomes:

$$Q = \alpha + Z^\beta - \gamma \ln[1 + \exp(\mu - \sigma X)]^{-1} \dots\dots\dots(9)$$

This formulation captures both the diminishing returns to pesticide use and its nonlinear impact on yield protection.

To assess the responsiveness of pesticide use to economic incentives, the corresponding pesticide demand function was derived from the farmer's profit-maximization behaviour:

$$X = \frac{\mu}{\sigma} + \frac{1}{\sigma} \ln \left[ \frac{PQ}{W} - \frac{1}{\gamma\sigma} \right] \dots\dots\dots(10)$$

which simplifies to:

$$X = a_0 + a_1 \ln \left[ \frac{PQ}{W} - \frac{1}{\gamma\sigma} \right] \dots\dots\dots(11)$$

where:

- P: farmgate price of cowpea (N/kg),

Q: output (kg/ha),

W: unit cost of pesticide (N/liter),

$$a_0 = \frac{\mu}{\sigma} + \frac{1}{\sigma},$$

$$a_1 = \frac{1}{\sigma}.$$

Assuming that  $\frac{1}{\sigma}$  If it is sufficiently small, the pesticide demand function approximates a linear function of the price-cost ratio  $PQ/W$ , capturing the price elasticity of pesticide demand.

Finally, to estimate the Marginal Value Product (MVP) of pesticide use, the Marginal Physical Product (MPP) was computed as:

$$MVP = MPP \times P \dots\dots\dots(12)$$

and the MVP was obtained via:

$$MPP = \gamma\alpha X^{\gamma-1} \dots\dots\dots(13)$$

These estimates are critical for assessing resource-use efficiency. If the MVP of pesticide use exceeds its marginal cost, the input is underutilized; if it is below that level, the input is overutilized. Thus, this specification enables a robust empirical analysis of both economic efficiency and adoption behaviour in cowpea production.

**2.5.2 Estimating Price Elasticity of Pesticide Demand**

To estimate the responsiveness of farmers' pesticide use to changes in pesticide prices, a price-elasticity-of-demand model was employed. In agricultural economics, understanding the elasticity of demand for inputs, such as pesticides, is crucial for evaluating how price fluctuations affect farm-level resource allocation decisions. This study adopts a double-log (log-linear) functional form for the demand equation, which is well-suited for elasticity estimation because its coefficients are directly interpretable as elasticities. The model is specified as:

$$\log X_i = \beta_0 + \beta_1 \log P_i + \epsilon_i \dots\dots\dots (14)$$

Where:

$\log X_i$  = logarithm of the quantity of pesticide type i used (in liters per hectare),

$\log P_i$  = logarithm of the market price of pesticide type i (in Naira per liter),

$\beta_0$  = constant term,

$\beta_1$  = price elasticity coefficient for pesticide i,

$\epsilon_i$  = error term, assumed to be normally distributed with zero mean and constant variance.

The key parameter of interest is  $\beta_1$ , which measures the price elasticity of demand. It captures the percentage change in pesticide use associated with a one percent change in price, holding other factors constant.

Interpretation of Elasticity Coefficient:

If  $|\beta_1| > 1$ , demand is elastic, indicating farmers significantly reduce pesticide use when prices rise.

If  $|\beta_1| < 1$ , demand is inelastic, suggesting that pesticide use is less price-sensitive, often because it is perceived as necessary to mitigate crop loss.

If  $|\beta_1| = 1$ , demand is unitary elastic.

This analysis provides insight into how price signals affect farmers' input behaviour and has practical implications for input subsidy policy, market regulation, and integrated pest management adoption strategies.

Model Estimation and Data Considerations: Separate regressions were conducted for different pesticide types commonly used in cowpea production (e.g., Deltamethrin, Cypermethrin, Lambda-cyhalothrin), allowing for comparison across chemical classes. The dependent variable  $X_i$  was measured as the quantity of each pesticide type applied per hectare. Prices were obtained from local agrochemical input markets and cross-validated with farmers' reported purchase prices during the same production season to enhance accuracy. To ensure robustness of the model, all continuous variables were log-transformed and checked for linearity in the log space. Multicollinearity was assessed, and heteroscedasticity-consistent standard errors were used to correct for violations of the classical linear regression assumptions. The estimated elasticity coefficients offer a quantitative measure of farmers' input responsiveness and serve as a basis for evaluating the potential impact of price fluctuations, supply shocks, or policy interventions on pesticide use behaviour.

### 2.5.3 Budgetary Analytical Model

To evaluate the profitability derived from pesticide application in cowpea production, a budgetary analytical model was employed. This model estimates the net financial benefit of pesticide use by comparing the additional revenue generated through pest control to the associated control costs. The specification follows the framework presented by the Entomological Society of Canada (1988) and, as adapted by Tijani (2006), for crop protection studies in developing agricultural systems.

The model is formally expressed as:

$$N = \left[ \left( \frac{1}{100+I} \right) (Q)(P) \right] - \left[ (PC)(L) \left( \frac{1}{100+I} \right) (Q) \right] \dots\dots\dots (15)$$

where:

I = Efficacy (Percentage increase in marketable yield resulting from pest control measures.)

Q = yield in Kg<sup>-1</sup>

P = price of cowpea in N Kg<sup>-1</sup>

PC = pest control cost (pesticide plus application cost per hectare)

L = Application frequency per farming season

N = Net returns of cowpea farmers (gross margin per treated hectare to farmers derived from pest control in NHa<sup>-1</sup>)

The first term  $\left(\frac{I}{100+I} Q \cdot P\right)$  estimates the incremental revenue from pest control, reflecting the share of total yield attributable to pesticide efficacy. The second term  $(PC)(L)\left(\frac{I}{100+I}\right)(Q)$  estimates the **cost** of achieving that yield gain, based on application frequency and cost intensity. This model isolates the net economic benefit of pesticide use by capturing both the physical effect of yield improvement and the financial cost incurred to achieve it. It is particularly useful for distinguishing between technically effective but economically inefficient pest control practices and those that offer genuine financial advantages to smallholder farmers. To complement this estimation, descriptive summary statistics were used to compare mean net returns between pesticide adopters and non-adopters. Additionally, an independent-samples t-test was used to assess the statistical significance of differences in profitability between the two groups.

#### 2.5.4 Logistic Regression Model

The study investigated the adoption of pesticides in cowpea production in the study area using a logit model. This model was employed to analyze the factors influencing a farmer's decision to adopt pesticides. Using logistic regression, the study quantitatively assessed the effects of various factors on respondents' decisions to adopt pesticides. This analytical approach facilitated an examination of the relationship between the dependent variable (pesticide adoption) and the independent variables. Thus, the logistic regression model used was specified as in equation (16):

$$\log\left(\frac{P_i}{1-P_i}\right) = \alpha + \beta_1 x_1 + \beta_2 x_2 \dots + \beta_{11} x_{11} + \theta_i \dots\dots\dots(16)$$

where:

$\log\left(\frac{P_i}{1-P_i}\right)$  = Logit or log of odds ratio

P<sub>i</sub> = Adoption of pesticides for cowpea protection

1 - P<sub>i</sub> = Non-adoption of pesticides for cowpea protection

$\alpha$	= Constant term
$\beta_1 \dots \beta_6$	= Model parameters to be estimated
$\theta_i$	= Error term
$X_1$	= Farming Experience (years)
$X_2$	= Household size (number of persons in a household)
$X_3$	= Education (number of years of formal schooling)
$X_4$	= Gender (binary variable, 1 = male, 0 = Female)
$X_5$	= Age (years)
$X_6$	= Household income (Naira)
$X_7$	= Labour availability (binary variable, 1 = if Yes, 0= if No)
$X_8$	= Access to credit (Yes = 1 and No = 0)
$X_9$	= Access to market information (Yes = 1 and No = 0)
$X_{10}$	= Access to extension agents (Yes = 1 and No = 0)
$X_{11}$	= Cost of Pesticides (Naira)

### 3. Results and Discussion

#### 3.1 Socioeconomic Characteristics of Pesticide Users and Non-Users

The socio-economic profile of the respondents is presented in Table 1. According to the Table, pesticide use was significantly skewed toward male farmers, with 74% of users being male compared to 83.9% of non-users. This pattern is consistent with prior findings that agricultural input adoption is often gendered, with women facing more systemic barriers to accessing agrochemicals due to limited control over land, capital, and extension services (FAO, 2011; Ma and Zheng, 2022; Bello, 2025). Although women constituted 26% of users, their representation among non-users was notably lower (16.1%), suggesting persistent gender gaps in agro-input access. The average age of pesticide users (42.4 years) was higher than that of non-users (37.6 years), implying that more experienced or older farmers are more inclined to adopt pesticides. Younger farmers (under 30) made up 19.2% of users but 33.9% of non-users, possibly due to either risk aversion or limited financial resources to invest in pest control technologies. These findings align with empirical evidence that age may influence technology adoption through experience, access to capital, and risk tolerance (Olutumise et al., 2020; Adelakun and Olayemi, 2022; Sarmah, 2023). Married farmers dominated both the user (72.1%) and non-user (82.1%) groups, indicating that cowpea farming is often a household-based livelihood strategy. The average household size of users (3.99) was slightly larger than that of non-users

(3.48), suggesting that labour availability within the household may positively influence pesticide use. Larger household sizes potentially allow for more internal labour allocation, reducing the cost of application and increasing input efficiency (Oduntan et al., 2016; Azeez et al., 2018). A clear difference emerged in farming experience: 63.5% of pesticide users had over 10 years of farming experience, while 82.1% of non-users had less than 10 years. This finding underscores the role of experience and technical know-how in the adoption of pesticides, consistent with assertions that experienced farmers are better positioned to assess risk, perceive pest pressure, and evaluate the economic returns of input investments (Bello, 2025).

The majority of pesticide users had secondary education (73%), compared to 50% of non-users. Conversely, 33.9% of non-users had only primary education, and none had tertiary education. This suggests that higher levels of education are positively correlated with pesticide adoption, likely due to improved access to information, comprehension of extension messages, and better resource management skills, factors documented as critical for agricultural technology adoption in Southern Nigeria (Azeez et al., 2018; Bello, 2025). While cowpea farm sizes were generally small for both groups, users had slightly smaller average holdings (0.5 ha) than non-users (0.7 ha), indicating that pesticide adoption is not necessarily driven by farm size. However, the distribution shows that non-users were more represented in farms larger than 1 hectare. Regarding income, users had a marginally higher mean income (₦1,068,846) than non-users (₦1,047,142), although non-users were more clustered in the lower-income brackets. This suggests that income variability alone may not explain adoption, but access to pesticide subsidies or credit facilities could still mediate adoption decisions.

**Table 1: Distribution by Socioeconomic Characteristics of the Cowpea Farmers**

Variable	Users		Non-users	
	Frequency	Percent	Frequency	Percent
<b>Gender</b>				
Female	27	26.0	9	16.1
Male	77	74.0	47	83.9
<b>Age</b>				
<30	20	19.2	19	33.9
31-40	27	26.0	19	33.9
41 – 50	28	26.9	9	16.1
51 – 60	19	18.3	9	16.1
>60	10	9.6	-	-
Mean	42.4		37.6	
SD	12.6		10.2	
<b>Marital status</b>				
Single	20	19.2	10	17.9
Married	75	72.1	46	82.1

Divorced	3	2.9	-	-
Widowed	6	5.8	-	-
<b>Household size</b>				
1 - 3	29	27.9	19	33.9
4 – 5	75	72.1	37	66.1
Mean	3.99		3.48	
SD	1.24		0.79	
<b>Farming experience</b>				
< 10	38	36.5	46	82.1
11 – 15	56	53.9	10	17.9
> 15	10	9.6	-	-
Mean	12.6		9.0	
SD	5.9		1.9	
<b>Level of Education</b>				
No formal education	10	9.6	-	-
Primary school education	9	8.7	19	33.9
Secondary school education	76	73.0	28	50.0
Tertiary education	9	8.7	9	16.1
<b>Cowpea Farm Size</b>				
≤ 0.5	85	81.7	47	83.9
0.6 – 1.0	19	18.3	-	-
> 1.0	-	-	9	16.1
Mean	0.5		0.7	
SD	0.3		0.6	
<b>Income (₹)</b>				
< 200,000	19	18.3	28	50.0
200,001 – 500,000	18	17.3	-	-
500,001 – 1,000,000	19	18.3	-	-
1,000,001 – 1,500,000	8	7.7	1	1.8
1,500,001 – 2,000,000	35	33.7	22	39.3
> 2,000,000	5	4.8	5	8.9
Mean	1,068,846.2		1,047,142.9	
SD	697,695.7		1,082,914.8	
Total	<b>104</b>	<b>100.0</b>	<b>56</b>	<b>100.0</b>

### 3.2 Production Function and Marginal Value Products from the Usage of Pesticides in Controlling Pests in Cowpea Production

#### 3.2.1 Marginal Value Products from the Usage of Pesticides in Controlling Pests in Cowpea Production

Table 2 displays the logistic production function coefficients estimating the effects of inputs on cowpea production, with emphasis on pesticide use. The model's R-squared value of 0.895 indicates that 89.5% of the production variation is explained, and the highly significant F-value (212.19) confirms the model's overall significance. Key inputs, such as farm size, cowpea seeds, fertilizers, and pesticides, positively contributed to output. However, labour had a negative coefficient, indicating potential inefficiencies or diminishing returns when excessive

labour is applied. Farm size had the strongest positive impact (0.44), significant at the 1% level, affirming its critical role in increasing output, likely due to economies of scale, as also reported by Omolehin et al. (2011). Fertilizer's coefficient (0.032), significant at the 5% level, showed a smaller but significant positive effect, consistent with findings by Praneetvatakul et al. (2002), reflecting improved soil fertility. Labour showed a significant negative effect (-0.328), possibly due to overuse or inefficiencies in cowpea farming. This contrasts with findings by Praneetvatakul et al. (2002) and Omolehin et al. (2011). Cowpea seeds (coefficient 0.195, significant at 5%) positively affected output, highlighting the importance of adequate seeding, aligning with Omonona et al. (2010), Omolehin et al. (2011), and Oduntan et al. (2016). Pesticides had a positive coefficient (0.092), significant at the 5% level, indicating that effective pest control enhances yield. This aligns with Zalkuwi et al. (2014) and Azeez et al. (2018).

**Table 2: Factors Affecting Cowpea Production in Ondo State**

Variable	Code	Coefficient	Std. Error	T-value	P-value
Farm size	Z <sub>1</sub>	0.439***	0.071	6.24	0.000
Fertilizer	Z <sub>2</sub>	0.032**	0.015	2.16	0.031
Labour	Z <sub>3</sub>	-0.328***	0.0097	-3.39	0.001
Cowpea seed	Z <sub>4</sub>	0.195**	0.089	2.18	0.029
Pesticide	X	0.092**	0.046	2.01	0.044
Constant	α <sub>0</sub>	2.017	0.438	4.605	0.000
R-square	0.895				
F-value	212.191***				

Source: Computed from Field Survey Data, 2014

\*\*\*  $p < 0.01$ , \*\*  $p < 0.05$ , \*  $p < 0.10$

### 3.2.2 Estimated Marginal Product of Pesticides

Table 3 reports the estimated marginal physical product (MPP) and marginal value product (MVP) of pesticides in cowpea production. These estimates help evaluate the economic efficiency of pesticide use. The MPP was 0.199, indicating that each additional litre of pesticide increases cowpea yield by about 0.199 kg/ha. This places production in Stage II (Diminishing Returns), where output continues to rise with more input, but at a decreasing rate. The MVP was estimated at ₦208.98, representing the additional revenue from applying an extra litre of pesticide. However, the MVP/MFC ratio was 0.101, far below 1. This suggests pesticides are overutilized, as the cost of an additional litre outweighs the revenue it generates. Although pesticides increase yield, excessive use leads to inefficiency. This result underscores the need for cowpea farmers to optimize pesticide application. Integrated pest management (IPM), which combines chemical and non-chemical methods, may offer a more cost-effective and sustainable approach, improving profitability while reducing unnecessary input costs.

**Table 3: Estimated Marginal Product of Pesticides**

Logistic estimate	Description	Coefficient
MPP	$G \cdot \frac{\bar{Q}}{\bar{X}}$	0.199
MVP	$MPP \cdot P_q$	208.982
MVP/MFC (Resource Use Efficiency)	$MVP/P_g$	0.101

Source: Computed from Field Survey Data, 2024

### 3.3 Demand Functions and Price Elasticity of Demand for the Different Pesticides Used for Cowpea Production

#### 3.3.1 Estimation of the Demand Functions for Pesticides

Table 4 presents the estimated demand functions for various pesticides used in cowpea production, showing how quantity demanded responds to changes in the revenue-to-pesticide cost ratio. All coefficients were positive and statistically significant, indicating that an increase in this ratio is associated with increased demand for pesticides. For Cymbush, the coefficient was 2.081, and the adjusted R-squared value of 0.59 indicated that the model explains 59% of the variation in demand. Karrate/Cypermethrin showed a coefficient of 1.632 and an adjusted R-squared of 0.47, also indicating a significant positive relationship. Shapper Plus had a coefficient of 1.971 and the highest explanatory power among all pesticides, with an adjusted R-squared of 0.72. Uppercott demonstrated a smaller but still positive coefficient of 1.207, with an adjusted R-squared of 0.55. Carbaryl had the highest coefficient, 2.671, suggesting the strongest influence of price changes on its demand, with an adjusted R-squared of 0.61. Finally, Deltamethrin showed a coefficient of 1.777 and an adjusted R-squared of 0.66. The findings show that cowpea farmers respond positively to economic incentives across all pesticides. The variability in coefficient magnitude and explanatory power suggests differences in farmer preferences, likely driven by perceived effectiveness, cost, or availability. The null hypothesis, that the revenue-to-pesticide cost ratio does not affect pesticide demand, was rejected at the 5% level of significance for all pesticides. These results align with the studies of Tijani and Oshotimehin (2007) and Omolehin et al. (2011), who also found that price dynamics significantly influence pesticide use.

**Table 4: Estimated Demand Functions for Different Pesticides**

Pesticide used	Cymbush	Karrate/Cypermethrin	Shapper Plus	Uppercott	Carbaryl	Deltamethrin
Constant	-1.897	1.387	-2.384	-3.012	-2.173	-1.592
Coefficient of the ratio of revenue per hectare	2.081	1.632	1.971	1.207	2.671	1.777

<b>and the price of pesticide</b>						
<b>Std. Error</b>	0.335	0.749	0.581	0.600	1.225	0.756
<b>P-value</b>	0.000	0.029	0.001	0.044	0.029	0.017
<b>R-square</b>	0.61	0.51	0.75	0.59	0.64	0.69
<b>Adj. R-square</b>	0.59	0.47	0.72	0.55	0.61	0.66

Source: Computed from Field Survey Data, 2024

### 3.3.2 Pesticides Demand Elasticity Estimates

Table 5 presents the price elasticity of demand (PED) estimates for various pesticides used in cowpea farming, calculated at their mean values. These elasticity values reflect how responsive farmers are to price changes for each pesticide. Deltamethrin had the highest elasticity at 5.340, indicating extreme sensitivity; each 1% price increase leads to a 5.34% drop in demand. This suggests farmers quickly reduce usage when prices rise, likely due to available substitutes or budget constraints. Cymbush also showed high elasticity (4.164), suggesting a significant reduction in demand in response to price increases. Carbaryl followed with an elasticity of 3.529, indicating strong responsiveness, possibly due to the availability of alternatives or its price relative to perceived effectiveness. Uppercott had an elasticity of 2.610, again showing high sensitivity to price fluctuations. Karrate/Cypermethrine exhibited moderate elasticity (1.674), meaning demand is still elastic but less so than the pesticides above. Shapper Plus, with an elasticity of 1.052, was just above the unitary elasticity threshold, suggesting that demand is relatively balanced—price increases lead to nearly equal proportional declines in demand. All pesticides studied exhibited elastic demand (elasticity > 1), indicating that cowpea farmers are generally highly responsive to price changes. This behaviour suggests that price is a major factor influencing pesticide choice, likely due to budget constraints, perceived effectiveness, or the availability of substitutes.

**Table 5: Pesticides Demand Elasticity Estimates**

<b>Pesticide used</b>	<b>Elasticity at means</b>
<b>Cymbush</b>	4.164
<b>Karrate/Cypermethrine</b>	1.674
<b>Shapper plus</b>	1.052
<b>Uppercott</b>	2.610
<b>Carbaryl</b>	3.529
<b>Deltamethrin</b>	5.340

Source: Computed from Field Survey Data, 2024

## 3.4 Financial Returns (Profitability) from Pesticide Usage in Cowpea Production

### 3.4.1 Estimation of the Financial Returns (Profitability) of Cowpea Production

Table 6 presents a detailed profitability analysis comparing pesticide users and non-users in cowpea production. Fixed costs for pesticide users amounted to ₦47,780.69 (17.61% of total production cost), with knapsack sprayers as the highest-cost item at ₦26,826.92 (9.89%). Non-users had slightly lower fixed costs at ₦40,685.71 (15.75%), also incurring significant knapsack sprayer expenses (₦21,250.00). This suggests equipment use remains important across both groups, but is more pronounced among pesticide users. Variable costs were ₦223,487.78 (82.39%) for users and ₦217,635.93 (84.25%) for non-users. Labour accounted for both groups' variable expenses: ₦106,311.98 (39.19%) for users and ₦99,728.10 (38.61%) for non-users. Pesticide users spent ₦5,590.10 (2.06%) on pesticides, while non-users relied more on herbicides, spending ₦17,116.96 (6.63%). The total production cost was slightly higher for users (₦260,835.07) than for non-users (₦248,386.20). However, users produced higher yields (546.15 kg/ha at ₦2,117.31/kg), resulting in ₦1,156,368.86 in revenue. Non-users had lower yields (477.86 kg/ha at ₦2,005.36/kg), generating ₦958,281.40. The differences in yield and price per kg suggest pesticide use contributes to enhanced productivity and better market returns. Gross margin for users stood at ₦932,881.08, surpassing the ₦740,645.40 of non-users. Net profit followed a similar trend, ₦895,533.79 for users and ₦709,895.20 for non-users. This indicates that, despite marginally higher costs, pesticide users earn considerably more. The Return on Investment (ROI) for pesticide users was 3.43, meaning that every ₦1 invested returns ₦3.43. For non-users, ROI was 2.86, still profitable, but comparatively lower. Overall, pesticide use in cowpea farming results in higher profitability, greater returns, and improved yield, validating findings by Aboki & Yuguda (2013), Mohammed & Mohammed (2014), and Asogwa et al. (2021), who similarly reported that cowpea returns more than double the investment. The results support the financial viability of pesticide use as a strategic investment in enhancing productivity and income in cowpea farming.

**Table 6: Distribution of Respondents by the Costs and Financial Returns**

s/n	Cost Items	Users		Non-users	
		Mean value (₦)	Percent	Mean value (₦)	Percent
<b>Depreciation cost on fixed items</b>					
	Cutlass	1921.00	0.71	1253.57	0.49
	Hoe	1378.92	0.51	1253.57	0.49
	Shovel	8653.85	3.19	10500.00	4.06
	Wheelbarrow	9000.00	3.32	6428.57	2.49

	Knapsack sprayer	26826.92	9.89	21250.00	8.23
<b>A</b>	<b>Total Fixed Cost (TFC)</b>	<b>47780.69</b>	<b>17.61</b>	<b>40685.71</b>	<b>15.75</b>
	Variable Items				
	Labour cost on pesticide applications	1122.50	0.41	-	-
	Labour cost on other activities	106311.98	39.19	99728.10	38.61
	Pesticide	5590.10	2.06	-	-
	Herbicide	11147.60	4.11	17116.96	6.63
	Fertilizer	16836.54	6.21	12982.14	5.03
	Transportation	10341.68	3.81	9829.02	3.80
	Land rent	10347.00	3.81	10294.00	3.98
	Tractor rent/hire	21800.00	8.04	30007.14	11.62
	Shelling machine rent	3932.69	1.45	4821.43	1.87
	Planting materials/seeds	36057.69	13.29	32857.14	12.72
<b>B</b>	<b>Total Variable Cost (TVC)</b>	<b>223487.78</b>	<b>82.39</b>	<b>217635.93</b>	<b>84.25</b>
<b>C</b>	<b>Total Cost of Production (TCP)</b>	<b>260,835.07</b>	<b>100.00</b>	<b>248,386.20</b>	<b>100.00</b>
	= A + B				
	<b>Revenue Information</b>				
	Yield (kg/ha)	546.15		477.86	
	Unit price (₦)	2117.31		2005.36	
<b>D</b>	<b>Total Revenue (TR)</b>	<b>1156368.86</b>		<b>958281.40</b>	
	<b>Gross Margin (D – B)</b>	<b>932881.08</b>		<b>740645.40</b>	
	<b>Profit (D – C)</b>	<b>895,533.79</b>		<b>709,895.2</b>	
	<b>Return on investment (ROI) = D/C</b>	<b>3.43</b>		<b>2.86</b>	

Source: Computed from the Field Survey Data, 2024

### 3.4.2 Estimation of the Profitability Analyses of Cowpea Production Due to Pesticide Usage

Table 7 presents the profitability estimates for cowpea production attributable to pesticide use, based on equation (15). The analysis revealed a 331% average increase in marketable yield from pesticide application, underscoring its effectiveness in controlling pest infestations and boosting productivity. The average pest control cost was ₦1,000.37 per hectare, reflecting the financial investment required for pesticide application. With an average treated area of 0.5 hectares, consistent with regional smallholder farming practices, the cost remains relatively

modest compared to the returns achieved. Importantly, the average net return from pesticide use was ₦49,595.53 per hectare, representing the profit gained after deducting pesticide-related expenses. This substantial figure confirms that pesticide use not only covers pest control costs but also significantly increases overall profitability. The findings affirm that pesticide use in cowpea farming leads to significantly higher yields and economic gains. Effective pest control enables better crop quality and marketability, making pesticide application a financially viable and beneficial practice for small-scale cowpea farmers in the region.

**Table 7: Results of Profitability Analysis of Cowpea Production Due to Pesticide Usage**

**Usage**

Estimate	I (%)	I/100+I	Q (tons/ha)	P (₦)	L (nos.)	PC (₦)	N (₦)
Average	330.56	0.768	0.55	120117.31	2.54	1049.04	49595.53

Source: Computed from Field Survey Data, 2024

I = Efficacy (Percentage increase in marketable yield resulting from pest control measures.)

Q = yield in Kg<sup>-1</sup>

P = price of cowpea in N Kg<sup>-1</sup>

PC = pest control cost (pesticide plus application cost per hectare)

L = Application frequency per farming season

N = Net returns of cowpea farmers (gross margin per treated hectare to farmers derived from pest control in NHa<sup>-1</sup>)

**3.5 Determinants of the Level of Adoption of Pesticide Use in Cowpea Production**

Table 8 presents the results of a logistic regression analysis identifying the determinants of pesticide adoption among cowpea farmers. The model’s fit was confirmed through a log-likelihood value of -33.395 and a significant LR Chi-square (140.39), suggesting strong predictive power. A pseudo-R-squared value of 0.678 indicates that the model explains approximately 67.8% of the variation in pesticide adoption, suggesting a robust model.

Farming experience emerged as a highly significant positive determinant at the 1% level. The coefficient indicated that each additional year of farming experience increased the likelihood of adoption by 70.2%, with an odds ratio of 2.018, suggesting experienced farmers are more confident in pesticide use. This supports findings by Liu et al. (2018) and Ward et al. (2018), who also reported a positive correlation between experience and technology adoption. Education was positively associated with adoption at a 1% level of significance. An odds ratio of 1.108 indicated that each additional year of education raised the odds of adoption by 10.8%. Educated farmers better understand pesticide usage, risk management, and application techniques. These findings align with Liu et al. (2018), Ward et al. (2018), and Olutumise et al.

(2020). Gender had a negative coefficient and was significant at the 1% level, indicating that male farmers are 13.4% less likely to adopt pesticide use than females. The odds ratio of 0.875 supports this, potentially reflecting gendered differences in access to resources or decision-making roles within households. This aligns with the findings of Afolyan et al. (2024) and Bello et al. (2025).

Age negatively influenced adoption, with a significant effect at the 1% level. A coefficient of  $-0.126$  and an odds ratio of 0.882 suggest that each additional year reduces the likelihood of adoption by 11.8%. Older farmers may be less open to change or risk, consistent with the findings of Bashir et al. (2018) and Oladoyin et al. (2025). Household income had a small but positive effect, with a coefficient of  $3.13e-06$ . Although the odds ratio ( $\sim 1.000003$ ) suggests a marginal increase, higher income slightly increases the likelihood of adoption by easing the affordability of inputs. Credit access was a strong positive factor, significant at the 1% level. The odds ratio of 1.453 shows that access to credit increases the likelihood of adoption by 45.3%, likely due to improved purchasing power for inputs. Access to market information, significant at the 5% level, increased the odds of adoption by 11.7% (odds ratio 1.117). Information empowers farmers to make profitable input decisions (Ilesanmi et al., 2024; Bello, 2025). Finally, pesticide cost negatively influenced adoption at the 5% level. A coefficient of  $-0.427$  and an odds ratio of 0.652 indicate that higher pesticide costs reduce adoption by 34.8%, likely due to affordability concerns.

**Table 8: Determinants of Level of Adoption**

<b>Independent variables</b>	<b>Coefficient</b>	<b>Odds Ratio</b>	<b>Std. Error</b>	<b>P-value</b>
<b>Constant</b>	-1.407	0.245	0.292	0.000
<b>Farming Experience</b>	0.702***	2.018	0.142	0.000
<b>Household size</b>	0.111	1.117	0.098	0.254
<b>Education</b>	0.103***	1.108	0.030	0.001
<b>Sex</b>	-0.134***	0.875	0.031	0.000
<b>Age</b>	-0.126***	0.882	0.028	0.000
<b>Household income</b>	$3.13e-06$ ***	1.000	$7.07e-07$	0.000
<b>Labour availability</b>	0.003	1.003	0.211	0.541
<b>Credit access</b>	0.374***	1.454	0.078	0.000
<b>Access to market information</b>	0.111**	1.117	0.055	0.044
<b>Extension agent</b>	-0.129	0.879	0.231	0.205
<b>Cost of Pesticides</b>	-0.427**	0.652	0.192	0.027
<b>Log likelihood</b>	-33.395			
<b>LR chi2 (11)</b>	140.39***			

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<b>Pseudo R<sup>2</sup></b>	0.678
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Source: Computed from Field Survey Data, 2024

\*\*\*  $p < 0.01$ , \*\*  $p < 0.05$ , \* $p < 0.10$ 

#### 4. Conclusion and Practical Recommendations

This study examined the economic efficiency and adoption dynamics of pesticide use in cowpea (*Vigna unguiculata*) production in Ondo State, Nigeria, focusing on marginal productivity, demand elasticity, profitability, and the socio-economic drivers of adoption. The findings confirm that pesticide use significantly enhances cowpea productivity and profitability, though the benefits depend on efficient input management. Farm-level production analysis revealed that pesticide use, alongside farm size and seed quantity, plays a critical role in determining yield outcomes. However, evidence of overapplication, as indicated by the marginal value product–marginal factor cost ratios, underscores the need for precision in pesticide use. Similarly, high price elasticities suggest that farmers are highly responsive to fluctuations in pesticide costs, with potential implications for use intensity and yield stability when prices rise. Profitability analysis showed that pesticide adopters consistently outperformed non-users in terms of yield, income, and return on investment. These results reinforce the economic rationale for promoting pesticide use, provided that cost-effectiveness and environmental considerations are balanced. Adoption behaviour was significantly influenced by gender, education, income, and access to extension and credit. In view of the study's findings on the economic efficiency and behavioural determinants of pesticide use in cowpea production, the following targeted policy and institutional recommendations are proposed. The study revealed that farmers are highly sensitive to pesticide prices, especially for commonly used products such as Cymbush and Deltamethrin. To sustain the economic benefits of pesticide use without exacerbating financial strain, government agencies should introduce targeted subsidies for key pesticide formulations. This intervention would mitigate cost-related disincentives and stabilize adoption levels among smallholder cowpea farmers. Also, given the strong influence of income and access to credit on pesticide adoption, public and private financial institutions should develop inclusive credit schemes tailored to smallholder farmers. These schemes should offer low interest rates and flexible repayment plans to enhance farmers' capacity to invest in productivity-enhancing inputs, such as pesticides. Access to reliable information was a critical driver of pesticide adoption. Thus, expanding agricultural extension services, with a focus on pesticide safety, efficiency, and sustainable pest management, will improve farmers' decision-making. Integrating digital platforms into extension delivery could further increase outreach and reduce knowledge gaps. Lastly, high price elasticity indicates vulnerability to price volatility. To reduce disruptions in pesticide use, the government should collaborate with input suppliers to implement price stabilization mechanisms and ensure consistent pesticide availability through well-regulated local distribution networks.

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