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Determinants of Pesticide Use in Food Crop Production in Southeastern Nigeria

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Abstract: The present study examines pesticide use in producing multiple food crops (i.e., rice, yam, and cassava) and identifies the range of socio-economic factors influencing pesticide use by 400 farmers from Ebonyi and Anambra states of Southeastern Nigeria using a Tobit model. Results reveal that 68% of the farmers grew at least two food crops. Overall, 41% of the farmers applied pesticides in at least one food crop, whereas 70% of the farmers producing both rice and yam applied pesticides. Pesticide use rates and costs vary significantly amongst farmers producing different food crops and crop combinations. Pesticide use rate is highest for producing yam followed by cassava estimated at 1.52 L/ha costing Naira 1677.97 per ha and 1.37 L/ha costing Naira 1514.96 per ha. Similarly, pesticide use rate is highest for the farmers that produce both yam and cassava followed by farmers that produce both rice and cassava. The inverse farm size–pesticide use rate exists in the study areas, i.e., the pesticide use rate is highest for the small farmers ($p < 0.01$). Farmers seem to treat pesticides as substitutes for labor and ploughing services, indicated by the significant positive influence of labor wage and ploughing price on pesticide use. Increases in yam price significantly increase pesticide use. Rice production significantly increases pesticide use, whereas cassava production significantly reduces pesticide use. Male farmers use significantly more pesticides. Farming experience is significantly positively related to pesticide use. Policy recommendations include land reform policies aimed at increasing farm operation size and investment in programmes to promote cassava production to reduce pesticide use in food crop production in Southeastern Nigeria.

Keywords: pesticide use; food crop production; socio-economic determinants; Tobit model; Southeastern Nigeria

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1. Introduction

Pesticide, a damage control input to safeguard from insects and other pests, is considered to improve nutrition in food, and its use is assumed an economic, labour-saving, and efficient tool for pest management [1]. Furthermore, pesticide is believed to improve competitive advantage in agriculture [2]. This is because pesticide use is deemed essential for retaining current production and yield levels, as well as maintaining a high-quality standard of life [2]. There is a widespread acceptance that the use of modern agricultural technologies has led to a sharp increase in pesticide use, along with other modern inputs, in the developing economies [3–5]. However, there is a widespread claim that pesticides are harmful to human health and the environment [6,7]. The environmental and social impact of pesticide use in the USA alone is estimated at USD 10 billion per year [7]. An estimated 1–5 million farm workers suffer from pesticide poisoning every year, and at least 20,000 die annually from exposure, mostly in developing countries [8].

Both Asia and Latin America experienced dramatic increases in agricultural productivity due to rapid and widespread adoption of Green Revolution (GR) technologies, which incorporate widespread use of modern agricultural inputs and agro-chemicals [9]. However, Sub-Saharan Africa (SSA) did not or could not participate in this drive for GR technologies of the 1970s–1980s, and therefore could not gain from the application of modern agricultural inputs and agro-chemicals [10]. In fact, the low use of modern inputs, including pesticides, is assumed to be the norm in SSA agriculture, which led to the setting up of policy directives and programs such as the Comprehensive Africa Agriculture Development Program (CAADP), Abuja Declaration and Malabo Declaration [10].

Nigeria, the largest economy in Africa, is largely dependent on its agricultural sector for the supply of raw materials, food, and foreign exchange, and employs over 70% of the labor force [11]. Small-scale semi-subsistence farmers comprising more than 70 million farmers/rural citizens [11] also dominate the sector. The agricultural sector is characterized by low level of productivity and modern technology adoption [12,13].

Cassava and yam are the main staple food crops in Nigeria with a wide range of industrial and commercial uses as well [14]. The country is one of the leading producers of cassava and yam in the world, supplying more than 68% of global yam production [15,16]. However, over the past two decades, rice has also been introduced as a major staple food crop in Nigeria, growing at an annual rate of 14% from 1990 onward [17]. Manyong et al. [18] noted that the major constraints on improving agriculture in Nigeria is the subsistence production system, the low level of modern technology adoption, land fragmentation, and crop failure, which increases production risk. Lack of the use of damage control inputs, e.g., pesticides, further increases the risk of crop losses. This is because about 20–40% of potential food produced is lost to insects and other pests in Africa [19].

Explaining variation in pesticide use intensity at the farm level is quite complex and not well explored in the literature [20]. A limited number of studies are available that examine various aspects and/or determinants of pesticide use at the farm level in Africa [10,19,21–24]. Sheahan and Barrett [10] utilized a large-scale multi-country nationally representative dataset generated through the Living Standard Measurement Study-Integrated Surveys on Agriculture (LSMS-ISA) with 22,565 households and 62,387 plots from six countries (Ethiopia, Malawi, Niger, Nigeria, Tanzania and Uganda) collected during 2010–2012. The project aimed to investigate the broader question of the current level of modern input use in agriculture, which also includes the use of agro-chemicals. One of their main conclusions is that although modern input use may be relatively low in aggregate, it is not equally low across six countries, particularly regarding the use of inorganic fertilizers and agro-chemicals [10]. Anang and Amikuzuno [19], using a sample of 300 rice farmers from Northern Ghana, reported that a number of socio-economic factors influence farmers' decision to choose pesticides. Adeniyi et al. [21], using a sample of 100 cocoa farmers from Osun State, Nigeria, noted that pesticide price is an important determinant of pesticide use. Oesterlund et al. [23], using a sample of 317 small-scale farmers in Uganda, concluded that the farmers do not use the most dangerous WHO Class 1a and 1b pesticides but mostly use WHO Class II pesticides, and have poor knowledge of the level of toxicity and poor protection practices. Mwatawala and Yeyeye [22], using a sample of 91 tomato farmers from Morogoro region in Tanzania, noted that the farmers are generally aware of the laws, environment, and consumer health, but could not name a single act, and only 21% of them used the correct dose of pesticides. Idris et al. [24], using a sample of 50 cocoa farmers from Ogun State, Nigeria, noted that most of the farmers applied fungicides because of the black pod disease. It is clear from the aforementioned brief review that the studies were mainly conducted on a single crop (e.g., cocoa, tomato, and rice) with limited sample sizes, and Sheahan and Barrett [10] did not provide any detailed information on the factors influencing agro-chemical use. In addition, none has examined the use of pesticides on major food staples, i.e., yam and cassava, in Africa in general and Nigeria in particular.

Given this backdrop, the present study examines the influence of a range of price and socio-economic factors on pesticide use in producing multiple food crops (rice, yam, and cassava) by using a survey data of 400 farm households from two states (Ebonyi and Anambra) of South-eastern Nigeria. Our specific contributions to the existing literature are as follows: (a) We have examined the extent of pesticide use by type and/or combinations of food crops produced by the farmer, which may provide further insight into whether pesticide use varies across cropping portfolio; (b) We have tested the farm-size and pesticide use relationship; and (c) We have incorporated a wide range of variables including prices, socio-economic factors, and variables representing commercial motive of the farmers to explain pesticide use at the farm level, which are not seen commonly in the literature. However, we could not use agroecological, climatic, land elevation, and/or political-economic variables applied by Rahman [25] and Galt [20] because of a lack of information in these areas, which are also important in explaining the complexities of pesticide use in crops.

The paper is organised as follows. Section 2 presents the analytical framework, the description of the study area, data, and the empirical model. Section 3 presents the results. Section 4 provides conclusions and draws policy implications.

2. Methodology

2.1. Theoretical Framework

The study utilizes a farm production model based on the profit maximizing behaviour of the farmers adopted by Rahman [4,25,26]. Consider a model with two variable input vectors: pesticides, H, and 'other inputs', X, and one fixed input of land, L, to produce n number of crops ($i = 1 \ldots n$), in which L_i is land area allocated to the ith crop.

Farmer j maximizes total profits:

$$\sum_{i=1}^{n} p_i Q_{ij} - w^Q H_j - w^O X_j$$

$$s.t. Q_{ij} = f(H_{ij}, X_{ij}, L_{ij}, S_j) for\ all\ i = 1, 2, \ldots n \tag{1}$$

$$and \sum_{i=1}^{n} L_{ij} \leq L_j \tag{2}$$

$$\text{Where } H_j = H_{1j} + \ldots + H_{nj}$$

$$\text{And } X_j = X_{1j} + \ldots + X_{nj}$$

The first order conditions lead to the corresponding demand functions for pesticides (H_j) and for 'other inputs' (X_j) for individual crops:

$$H_j = H_j\ (w^Q, w^O, p_1 \ldots p_n, L_{1j} \ldots, L_{nj}, S_j) \tag{3}$$

$$X_j = X_j\ (w^Q, w^O, p_1 \ldots p_n, L_{1j} \ldots, L_{nj}, S_j) \tag{4}$$

in which p's and w's are output and input prices, respectively.

We can aggregate the pesticide demand functions of individual crops (Q_j) as follows:

$$H'_j = H'_j\ (w^Q, w^O, p_1 \ldots p_n, L_{1j} \ldots, L_{nj}, S_j) \tag{5}$$

in which H'_j = aggregate pesticide demand.

The assumption of the separability of inputs (pesticide on one hand, and all 'other inputs' on the other) enables the pesticide demand equation to be estimated separately [4,25,26].

2.2. Study Area and the Data

A multi-stage sampling procedure was utilized for this study. First, two states, Ebonyi and Anambra, from Southeastern Nigeria were purposively selected. Then, three local government areas (LGAs) from each state were selected randomly based on the cell structure developed by the Agricultural Development Program. Then, 10 communities/villages from each LGA were chosen randomly. Finally, a simple random sampling procedure was applied to choose farmers from these communities. Using the total number of farm households in each village as the sample frame, the sample size (n) of households was determined [27]:

$$n = \frac{Nz^2 p(1-p)}{Nd^2 + z^2 p(1-p)} \tag{6}$$

in which n = sample size, N = total number of farm households, z = confidence level (at 95% level z = 1.96); p = estimated population proportion (0.5, this maximizes the sample size), and d = error limit of 5% (0.05).

The required total sample size by applying the sampling formula in Equation (6) is 450. However, due to difficulty of data collection in developing countries and usability of the returned questionnaires, a reserve of 33% sample was added. As such, 600 questionnaires were distributed (300 in each state with 30 in each community), of which 290 from Ebonyi and 190 from Anambra states were returned. However, complete information was available in only 249 and 141 questionnaires from Ebonyi and Anambra, respectively. Therefore, the final sample size stands at 400 households. Details on input and output data for each of the three major food crops (i.e., cassava, yam, and rice) by the farmers were recorded separately. In addition, key demographic and socio-economic information from each of the farm households were also collected. The field survey was very intensive and carried out during the months of October and November 2011. The questionnaire was pre-tested and modified as required prior to final administration. Farmers were asked to provide details of their production activities, level of inputs used, and outputs produced individually for each of the major food crops covering the crop year 2010–2011 based on their recall. Therefore, all quantity and price data used in the analysis are actual data provided by the farmers specific to each crop produced. The co-author and two research assistants who are the final year agricultural undergraduate students were used for collecting primary data. The co-author trained the research assistants on the questionnaire and survey methodology prior to data collection.

2.3. The Empirical Model

Since not all farmers use pesticides in their production process, meaning that the dependent variable is censored at zero, the Tobit model provides a suitable method for estimating the pesticide demand equation in this case, as it allows for zero use of inputs [4,25,26].

The stochastic model underlying Tobit may be expressed as follows:

$$H'_j{}^* = H'_j{}^*(w^Q, w^O, p_1 \ldots p_n, L_{1j} \ldots, L_{nj}, S_j) + u_j \tag{7}$$

$H'_j{}^*$ is a latent variable such that:

$$H'_j = H'^*_j \quad if \;\; H'_j > 0 = 0 \; if \; H'_j \leq 0, j = 1,\ 2,\ \ldots\ldots m \tag{8}$$

in which the disturbances u_j are an error term and are independent and identically distributed as $N(0, \sigma^2)$. The econometric software STATA V. 10 (StataCorp., College Station, TX, USA) was used for the analysis.

2.4. Variables

The dependent variable in the econometric model is the total amount of pesticides (measured in litres of concentrated pre-prepared form as purchased from the market) applied to each of the three major food crops (i.e., rice, yam, and cassava). Brief details of the type of pesticides used in these three major food crops are presented in Section 3. We did not include the price of pesticides because of the unavailability of correct information, although Rahman [4] reported the correct negative impact of own price of pesticides on its demand.

The variables included in the pesticide demand function were: (a) input prices—weighted average prices of inorganic fertilizers applied to each of the three food crops, weighted average of the wages of labour used in each of the three food crops, and weighted average per unit cost of ploughing services used (this is mainly the cost of labour used exclusively for land preparation) in each of the three food crops; (b) output prices—price of rice, price of yam, and price of cassava; (c) total amount of manure applied to all three crops; (d) a set of socio-economic characteristics that includes total farm operation size, experience of the farmer, average education of the farmer, average family size of the household, amount of agricultural credit, share of land rented in for cultivation, number of extension contacts, and distance to nearest agricultural extension office; (e) dummy variable to represent gender of the farmer; (f) share of rice area; (g) share of cassava area; and (h) two variables representing motives (i.e., high profit and high yield) behind adopting modern inputs and technologies (i.e., use of high yielding varieties of seed, inorganic fertilizers and pesticides) were included in the model, since adoption of modern technology influence pesticide use [4,25]. Table 1 presents the definition, measurement, and summary statistics of all the variables used in the econometric model. The choice of these variables was based on the literature and justification thereof [4,10,19–21,25,26].

Table 1. Definition, measurement, and summary statistics of the variables.

Variables	Definition	Mean	Standard Deviation
Dependent variable			
Quantity of pesticide use per farm	kg/L	1.02	1.82
Output price			
Rice	Naira per kg	51.83	2.54
Yam	Naira per kg	50.00	5.47
Cassava	Naira per kg	14.41	2.76
Input price			
Labor wage	Naira per person-day	712.81	167.09
Ploughing price	Naira per ploughing-day	1168.03	402.41
Fertilizer price	Naira per kg	411.24	437.28
Socio-economic factors			
Gender of the farmer	Dummy (if male = 1, 0 otherwise)	80.75	
Share of rice area	Proportion of total cultivated area	0.19	0.30
Share of cassava area	Propoortion of total cultivated area	0.48	0.32
Manure	Kg	127.40	176.80
Farm size	Ha	1.27	1.11
Family size	Number of persons	3.88	1.91
Farming experience	Years	19.78	13.62
Education of the farmer	Completed years of schooling	7.84	4.73
Share of rented in land	Proportion of operated area rented in	0.26	0.67
Distance to extension office	Km	3.64	3.56
Extension contact	Number	0.15	0.56
Training	Number of days	0.10	0.34
Agricultural credit	Naira	5885.40	29208.13
Revealed motive			
High profit	Weighted rank of high yield as the motive (Number)	0.85	0.27
High yield	Weighted rank of high profit as the motive (Number)	0.53	0.41
Number of observations		400	

Note: Exchange Rate: GBP1.00 = Naira 200.00.

All price variables used in this study were reported by the farmers for purchase of inputs and sale of outputs. For the family-supplied inputs, such as family labour, the market wage paid by the farmers was imputed. Ploughing price, which is mainly the cost of labour used exclusively for land preparation, was treated as a separate variable, because wages varied for this operation as compared to the wages paid for other farming operations. Again, for family-supplied labour for this operation, corresponding market wage was imputed.

The share of rice area and the share of cassava area were included in the pesticide demand function. This is because although both are staple food crops, rice is mainly destined for the market and provide an indication of the level of commercialization in food production, which is not commonly seen in the literature. Finally, two variables representing motivation behind using modern agricultural inputs were included to check their independent influence on pesticide use, reflecting commercialization motive of the farmers. Farmers were asked about the motivation for making their crop choice decision and to rank each of the motives (e.g., high yield and high profit) on a five-point Likert scale (i.e., 1 for least important motive and 5 for most important motive). The variables are the weighted average rank values of the motives.

2.5. Variance Analyses

The study also used other forms of analysis. First, a One Way Analysis of Variance (ANOVA), was planned to be utilised to examine existence of systematic variation in pesticide use rates and cost of pesticide use per ha across various categories of classification, e.g., by crop combinations and by farm size categories. The underlying assumption in conducting ANOVA is that the population of farmers from which the sample was drawn who were producing major food crops and applying pesticides in their farming operations is normally distributed. Although, the graphical plots of the pesticide use rate and cost of pesticide used per ha for each crop in a histrogram with normal curve imposed showed an approximate normal distribution with a few outliers, the Levene's test for the Homogeneity of Variance showed that the variances are significantly different. An additional Brown-Forsythe's robust test for the equality of means showed that the means between categories are significantly different. Nevertheless, due to some concerns of the robustness of Brown-Forsythe test in the literature, we have also conducted the non-parametric Kruskal-Wallis test to identify systematic differences across categories (details of the test results were presented in the bottom panel of Tables 3 and 4 below). The SPSS V. 24 (IBM Corporation, Armonk, NY, USA) was used to conduct cross tabulation and variance analyses.

2.6. Multicollinearity

In a regression analysis with multiple variables, multicollinearity can be a problem [20]. Therefore, it is important to check existence of collinearity amongst variables used in the econometric model. Pairwise correlation tests were conducted for all the variables used in the model. Results showed that although less than 50% of the variables are significantly correlated, all the correlation coefficients were under 0.4, except correlation between total farm size and rice price ($r = 0.53$, $p < 0.05$) and education and farming experience ($r = -0.55$, $p < 0.05$). A general rule of thumb of the presence of serious multicollinearity is to have correlation coefficient in excess of 0.6 for more than two variables [28]. Therefore, multicollinearity is not an issue in this study.

3. Results and Discussion

Farmers in the study areas spray their farms with pesticides to protect their crops from attacks by pests and disease. For example, rice farmers protect their crops against pest and diseases like borers, army worm, and blast diseases. Yam farmers protect against beetle and yam nematode, and cassava farmers protect against mosaic disease and mealy bugs [29,30]. The pesticides used by the farmers were Oriyzo-plus, Dithane M-45, Round-up, Saro set and Dexate, Attacke, Bordeaux, No-pest, and Benlate. The pesticides in the study areas were sold to farmers in concentrated pre-prepared form in litres, who were then advised to dilute these further before applying them to the crop. This makes it difficult to determine the final quality and strength of the pesticide used. Also, the price of pesticides depends on from where the farmer purchased them. Price of pesticides is most expensive in their local market and relatively cheaper if they can buy from the ADP office. The major constraints in the use of pesticides identified in this study are the quality of those sold at the local market, their availability when needed, and knowledge of how best to apply them. The Recommended Pesticide Rates (RPR) of most pesticides, such as Dithane M-45, is 1 L/ha or Benlate is 1.5 L/ha; they are to be dissolved in 500 L of water before being sprayed [31]. We have used actual amount of these concentrated pre-prepared pesticides applied to each individual crop as reported by the farmers.

3.1. Socio-Economic Characteristics of the Farmers

Basic information about the socio-economic characteristics of the farmers is presented in Table 1. About 80.75% of the farmers are male, and 73.50% and 35.75%% of the farmers produced yam and rice along with cassava, which establishes the level of diversity in food crop production in the study area. The average farm size is small and is estimated at 1.27 ha. Family size is under four persons per household, and average farming experience is 19.78 years. The average level of education of the farmer is above primary level, estimated at 7.84 years of completed schooling. About 26% of the farmers are tenants or part-tenants. The number of contacts with extension and training is low, estimated at 0.15 and 0.10 times with large standard deviation, and the distance to nearest agricultural extension office is 3.64 km. The amount of agricultural credit per farm is Naira 5885.4 with very large standard deviation. High profit is the main motive behind using modern inputs (including pesticides), followed by high yield as the second most important motive.

3.2. Level and Extent of Pesticide Use by Major Food Crops

The level and extent of pesticide use for each major food crop is presented in Table 2. It is clear that only about one third of the total farmers produced rice, whereas cassava is the most common food crop produced by more than four-fifth of the total farmers. However, the crop area under rice is the highest, followed by almost equal operational area for yam and cassava. About half of the total rice farmers applied pesticides, and a third of total yam farmers applied pesticides, whereas only one-fifth of the total cassava farmers applied pesticides. Overall, only 41% of the total farmers applied pesticides in any of their food crops (Table 2). This figure is, however, higher than 33% and 16.3% for Nigeria and for the 6 African countries combined, respectively, as reported by Sheahan and Barrett [10]. The pesticide use rate reported in column 5 is for all the farmers (i.e., pesticide users and non-users) that produce each major food crop, which shows the overall level of pesticide use in the study areas. Figures in parenthesis are the standard deviation of the mean use rate, which shows considerable level of variability in pesticide use rates. It is clear from Table 2 that the pesticide use rate is highest for yam, followed by cassava. As a result, the cost of pesticide use per ha is also highest for yam production followed by cassava. This is because yam is mainly destined for the market, whereas cassava is mainly for consumption. Overall pesticide use rate is 1.42 L/ha costing Naira 1555.28 per ha.

Table 2. Extent of pesticide use by major food crops.

Food Crops	Percent of Total Farmers (%)	Area under Crop (ha)	Percent of Farmers Applied Pesticides (%)	Overall Pesticide Use Rate (L/ha)	Overall Value of Pesticide Use (N/ha)
Rice	35.80	1.04 (0.83)	50.35	1.189 (1.64)	1335.93 (1909.94)
Yam	73.50	0.59 (0.38)	32.30	1.518 (2.56)	1677.97 (2815.40)
Cassava	86.00	0.58 (0.34)	26.20	1.373 (2.78)	1514.96 (3033.27)
Overall	100.00	1.27 (1.11)	41.00	1.420 (2.32)	1555.28 (2504.01)
Number of observations	400		164	400	400

Note: Figures in parenthesis are standard deviations.

3.3. Level and Extent of Pesticide Use by Crop Combinations

The extent of diversity in food crop production is presented in Table 3, which demonstrates that farmers actually grow multiple food crops with seven combinations. The proportion of single crop growers is very low. For example, 18% of the farmers produced 'only cassava' with lowest average farm size of only 0.53 ha, whereas the proportion of 'only rice' or 'only yam' producers are even lower but with relatively larger farm sizes. This implies that small farms with their tiny farm size can afford only two crops, whereas large farms seem to grow all three crops due to command over a larger cultivated area [14]. Not only the proportion of farmers vary by cropping portfolio, but also the average farm-size varies significantly by crop combinations (Table 3). The average farm-size is largest for the farmers who produces all three crops under consideration.

Use of pesticides in crops is dependent upon pest infestations, prevalence of diseases, and the type of crops grown [4,25]. Table 3 presents information on the extent and magnitude of pesticide use in different crop combinations identified above. As expected, the proportion of farmers applying pesticides varies based on cropping portfolio. The highest proportion of the farmers who produced both rice and yam have used pesticides followed by farmers who produced both rice and cassava. In contrast, only 25.0% of the 'only cassava' producers used pesticides, although it is the main staple crop of the economy. Adeniyi et al. [21] reported that 70% of the cocoa farmers in Nigeria used pesticides, which is a commercial product. Similarly, Anang and Amikuzuno [19] noted that 72.67% of the rice farmers in Uganda applied pesticides. These results are very close to our estimate for crops that are mainly destined for the market (Table 3).

Significant variation exists with respect to pesticide use rate, as well as cost of pesticide use per ha in the study area as confirmed by the Kruskal-Wallis test results reported at the bottom panel of Table 3. The highest rate of pesticide use is by those who produced both yam and cassava followed by those who produced both rice and cassava. When asked about whether the farmer applied enough amount of pesticides, 75.6% of the pesticide users replied that they have used enough pesticides to their crops.

Table 3. Extent of pesticide use in multiple food crops.

Producer Categories	Percent of Total Farmers (%)	Farm Operation Size (ha)	Percent of Farmers Applied Pesticides (%)	Overall Pesticide Use Rate (L/ha)	Overall Value of Pesticide Use (N/ha)
Only rice producer	6.25	0.79 (0.69)	60.00	0.944 (0.901)	960.80 (939.37)
Only yam producer	5.25	0.68 (0.56)	61.90	2.29 (2.22)	2377.78 (2272.87)
Only cassava producer	18.00	0.53 (0.29)	25.00	1.039 (2.148)	1093.29 (2228.12)
Rice and yam producer	2.50	1.20 (0.62)	70.00	2.298 (1.92)	2555.93 (2236.09)
Rice and cassava producer	2.25	1.24 (1.25)	66.67	2.783 (3.20)	2858.33 (3204.96)
Yam and cassava producer	41.00	0.99 (0.58)	35.37	1.784 (2.836)	1967.23 (3070.89)
Rice, yam and cassava producer	24.75	2.54 (1.31)	47.47	0.819 (1.28)	965.76 (1547.10)
Overall	100.00	1.27 (1.11)	41.00	1.420 (2.32)	1555.48 (2504.01)
Levene's test of homogeneity of variance		19.105 ***		12.669 ***	12.873 ***
Brown-Forsythe's robust test of equality of means		52.966 ***		3.947 ***	3.927 ***
Kruskal-Wallis test		188.421 ***		17.139 ***	16.167 ***
Number of observations	400		164	400	400

Note: *** Significant at 1% level ($p < 0.01$); Figures in parenthesis are standard deviations.

3.4. Farm-Size and Pesticide Use Relationship

Farm operation size is an important factor that affects productivity in developing country agriculture, and the debate on size-productivity relationships is mixed in the literature. In general, an inverse relationship between farm-size and productivity is prominent in areas where farming practice is labor intensive [32]. This is because the high level of labor costs deter large farms from using hired labor to optimal levels [32]. However, with an increased use of modern agricultural inputs, the inverse size-productivity relationship has been weakened in recent times (Niroula and Thapa,2005).

We test the nature of relationship between farm-size and pesticide use. In this study, farmers were categorized into three main farm-size categories: small farms (cultivating land between 0.10 and 2.00 ha), medium sized farms (cultivating land between 2.01 and 3.00 ha), and large farms (cultivating land $\geq$ 3.01 ha). Table 4 presents the level and extent of pesticide use by farm-size categories. The sample is dominated by small-scale farms, which confirms the prevalence of small-scale subsistence farmers in Nigeria as reported in the literature [11]. However, medium and large sized farms are also present in the data (Table 4). As expected, the proportion of farmers applying pesticides within each farm-size category varies where highest proportion of the large-farms applied pesticides. However, when the actual level of pesticide use rate was considered, it is evident that the small-farms applied significantly higher amount of pesticides estimated (Table 4). The Kruskal-Wallis test results, reported at the bottom of the Table 4, statistically confirm that an inverse farm-size–pesticide use rate exists in the study area, which has important policy implication. Sheahan and Barrett [10] also noted that inverse relationship consistently exists between farm and/or plot size and level of input use in Sub-Saharan Africa (SSA), which conforms to our results.

Table 4. Extent of pesticide use by farm size categories.

Producer Categories	Percent of Total Farmers (%)	Farm Operation Size (ha)	Percent of Farmers Applied Pesticides (%)	Overall Pesticide Use Rate (L/ha)	Overall Value of Pesticide Use (N/ha)
Small farms	81.00	0.82 (0.45)	41.98	1.164 (2.49)	1788.70 (2676.25)
Medium farms	10.75	2.54 (0.24)	25.58	0.334 (0.712)	383.30 (769.49)
Large farms	8.25	4.04 (1.01)	51.52	0.642 (1.03)	792.10 (1453.11)
Overall	100.00	1.27 (1.11)	41.00	1.420 (2.32)	1555.48 (2504.21)
Levene's test of homogeneity of variance		18.402 ***		30.087 ***	28.033 ***
Brown-Forsythe's robust test of equality of means		379.366 ***		33.322 ***	25.056 ***
Kruskal-Wallis test		187.126 ***		9.096 ***	8.914 ***
Number of observations	400		164	400	400

Note: *** Significant at 1% level ($p < 0.01$); Figures in parentheses are standard deviations.

3.5. Determinants of Pesticide Use in Food Crops

Prior to reporting the results, we reported a series of hypothesis tests conducted to justify inclusion of these diverse set of regressors in the pesticide demand model. The results are presented in Table 5. The first test was to confirm whether the full model is superior to the model without these variables. The Chi-square test result reported at the bottom of Table 5 confirms that all these variables jointly explain changes in pesticide demand by the farmers ($p < 0.01$). In other words, the full model is superior to the model with only the intercept term. Next, four tests were conducted to check the individual influences of output and input prices and socio-economic factors on pesticide demand, which are strongly rejected at 1% level of significance (Table 4).

Table 6 presents the parameter estimates of the pesticide demand function using Equations (7) and (8) using Tobit regression procedure. Among the output prices, pesticide demand is significantly positively influenced by a rise in yam price. A 1 Naira rise in yam price will increase pesticide demand by 0.10 kg. Rahman [4,25,26] also reported significant positive influence of output prices (e.g., rice, jute, and pulses) on pesticide demand in Bangladesh.

Farmers treat pesticides as substitutes for labor and ploughing services as indicated by the significant positive signs on the coefficients on labor wage and ploughing price. This means that an increase in labor wage will induce farmers to use more pesticides to save on intercultural operation cost of labor, as reported by Rahman [25,26] for Bangladeshi farmers. In contrast, Adeniyi et al. [21] noted significantly negative influence of labor wage on pesticide use in cocoa farms in Nigeria, implying that farmers treat labor as complements. Similarly, an increase in ploughing price will lead to an increase in pesticide use so that the farmers can save on number of ploughings (Table 6). The relative influence of labor wage increase on pesticide use is three times higher than the rise in ploughing price—that is, a 1 Naira increase in labor wage will increase pesticide use by 0.0042 kg, whereas a 1 Naira increase in ploughing price will increase pesticide use by only 0.0014 kg. There is no significant influence of organic manure on pesticide use, although Rahman [26] noted significantly positive influence of manure use on wheat production in Bangladesh.

Educated farmers seem to use fewer pesticides, but the influence is not statistically significant. Adeniyi et al. [21] and Idris et al. [24] also did not find any influence of education on pesticide use in cocoa farms in Nigeria. Galt [20] noted that taking agricultural classes greatly reduces pesticide use in vegetable farming in Costa Rica. In contrast, Rahman [25,26] noted significantly positive influence of education on pesticide use in Bangladesh. However, Idris et al. [24], Rahman [4], and Dasgupta et al. [33] did not find any significant influence of education on pesticide use in Bangladesh. The implication is that the influence of education on pesticide use is somewhat mixed in the literature.

The share of rice area significantly increases pesticide use. A one percent increase in area under rice will increase pesticide use by 2.46 L, which is very high. The implication is that on one hand, according to conventional wisdom, farmers are applying more pesticides to crops that are sold to the market for cash, but on the other hand, rice is also increasingly becoming a staple crop in the Nigerian economy, and farmers are applying pesticides in order to safeguard from yield risk. Sheahan and Barrett [10] also noted that contrary to expectation, pesticide use is not only confined to horticultural or cash crops but that pesticides have also been applied to plots containing mostly grains in SSA. However, it is highly encouraging to note that share of area under cassava significantly reduces pesticide use. A one percent increase in area under cassava will reduce pesticide use by 2.21 L, which is substantial. Cassava is one of the most popular staple crop in Nigeria, and the results showed that farmers tend not to use too much pesticides for this crop.

Farm size, however, shows a negative influence on the demand for pesticide use, but the coefficient is not statistically significant. Anang and Amikuzuno [19] observed significant influence of farm size on pesticide use in rice farms in Northern Ghana, whereas Adeniyi et al. [21] and Idris et al. [24] did not find any significant influence of farm size on pesticide use in cocoa production in Nigeria. Galt [20] also did not find any influence of land ownership on pesticide use, but ownership of the parcel of land significantly reduces pesticide use in vegetable farming in Costa Rica. Rahman [4] also noted significantly positive influence of cultivated areas under modern rice, potatoes, spices, vegetables, and cotton on pesticide demand in Bangladesh. There is no influence of tenurial status on pesticide use.

The amount of agricultural credit does not have any influence on pesticide use, whereas Rahman [4] reported significant influence of agricultural loan on pesticide use in Bangladesh. Similarly, Galt [20] also noted significant influence of credit on vegetable farming in Costa Rica. However, Sheahan, and Barrett [10] noted that few households use credit to purchase modern inputs in SSA which seem to conform with our results.

Experienced farmers use significantly more pesticides, also noted by Idris et al. [24] and Rahman [26]. However, Adeniyi et al. [21] and Anang and Amikuzuno [19] did not find any influence of experience or age of the farmer on pesticide use. Male farmers use significantly more pesticides as compared to female farmers, which confirms that there are gender differences in the decision to apply modern inputs as highlighted by Sheahan and Barrett [10].

Agricultural extension services do not play any significant role in pesticide use, as indicated by a lack of significance of the coefficients on training, extension contact, and distance to extension services variables (Table 6). In contrast, Anang and Amikuzuno [19] noted significantly positive influence of extension contacts on pesticide use in rice farms in Northern Ghana.

Table 5. Hypothesis tests.

Test	**Parameter Restrictions**	***F*-Statistic**	**Degrees of Freedom (v_1, v_2)**	**Decision**
No influence of output prices on pesticide use	H_0: $\beta_1 = \beta_2 = \beta_3 = 0$	3.63 ***	(3379)	Reject H_0: Output prices jointly exert significant influence on pesticide use
No influence of input prices on pesticide use	H_0: $\beta_4 = \beta_5 = \beta_6 = 0$	4.42 ***	(4379)	Reject H_0: Input prices jointly exert significant influence on pesticide use
No influence of the type of crop cultivated on pesticide use	H_0: $\gamma_1 = 0$	11.01 ***	(2379)	Reject H_0: Type of crops cultivated jointly exert significant influence on pesticide use

Table 5. *Cont.*

Test	Parameter Restrictions	*F*-Statistic	Degrees of Freedom (v_1, v_2)	Decision
No influence of socio-economic factors on pesticide use	H_0: $\gamma_3 = \gamma_4 = .. = \gamma_{13} = 0$	4.03 ***	(10, 379)	Reject H_0: Socio-economic factors jointly exert significant influence on pesticide use

Note: *** Significant at 1% level ($p < 0.01$).

Table 6. Determinants of pesticide use in producing food crops.

Variables	Dependent Variable: Amount of Pesticide Use Rate per Farm		
	Parameter	Coefficient	*t*-Ratio
Constant	α_0	−10.0774 **	−2.26
Output price			
Rice	β_1	−0.1034	−1.42
Yam	β_2	0.1144 ***	3.02
Cassava	β_3	0.0469	0.62
Input price			
Labor wage	β_3	0.0038 ***	2.68
Ploughing price	β_4	0.0017 ***	3.52
Fertilizer price	β_5	−0.0002	−0.43
Socio-economic factors			
Gender of the farmer	γ_1	1.0827 *	1.86
Share of rice area	γ_2	2.4647 ***	3.32
Share of cassava area [a]	γ_3	−2.2102 ***	−2.92
Farm size	γ_4	−0.2561	−1.08
Family size	γ_5	0.1593	1.41
Years of farming experience	γ_6	0.0644 ***	3.38
Education of the farmers	γ_7	−0.0756	−1.54
Share of land rented in	γ_8	0.3647	1.23
Distance to extension office	γ_9	−0.0431	−0.71
Extension contact	γ_{10}	0.3705	1.05
Training	γ_{11}	−0.0180	−0.03
Agricultural credit	γ_{12}	0.0001	1.38
Manure	γ_{13}	−0.0010	−0.93
Revealed motives			
High profit	δ_1	0.5555	0.96
High yield	δ_2	0.8695	1.14
Model diagnostics			
Log-likelihood		−506.20	
Chi-square statistic (21 df)		154.66 ***	
Left censored observations		236	
Uncensored observations		164	
Total number of observations		400	

Note: *** Significant at 1% level ($p < 0.01$), ** significant at 5% level ($p < 0.05$), * significant at 10% level ($p < 0.10$); [a] = this coefficient is from a separate model fitted by replacing the share of rice area with the share of cassava area in order to avoid high multicollinearity between share of rice and cassava areas.

4. Conclusions and Policy Implications

The principal aim of this study was to examine the level and extent of pesticide use in multiple food crops and identify the influence of prices and socio-economic factors on the pesticide demand of a sample of 400 farms from two states (Ebonyi and Anambra) from Southeastern Nigeria. Farmers produce multiple food crops, as proven by the fact that 68% of the farmers produced at least two food crops. Results show that pesticide use is strongly influenced by a host of price and socio-economic factors of the farmer and the farming household, with varied effects. Although the overall proportion of farmers applying pesticides is relatively low, estimated at 41%, there is a wide variation in the proportion of farmers using pesticides in various food crops and crop combinations.

Significant variation also exists with respect to pesticide use rates and cost of pesticides per ha amongst farmers producing various crops and crop combinations.

Pesticide use rate and cost per ha is highest for the farmers producing yam followed by cassava, and for those who produced both yam and cassava followed by rice and cassava. Farmers treat pesticides as substitutes for labor and ploughing services. The implication is that a rise in labor wage and ploughing price will induce a significant rise in pesticide use mainly to reduce the amount of labor for various farm operations and ploughing activities. On the other hand, an increase in the price of yam, which is desirable for increasing income of the farmers, would lead to a significant increase in pesticide use. Nevertheless, since actual pesticide use rate is relatively low in Nigeria, the level of increase in pesticide use relative to a rise in yam price will not be very large.

Inverse farm size–pesticide use rate exists in the study areas, i.e., the pesticide use rate is highest for the small farmers ($p < 0.01$), estimated at 1.16 L/ha costing Naira 1788.70 per ha. The pesticide use rate is relatively higher for a crop that is mainly produced for the market but which is also a staple crop of the economy. This was confirmed econometrically by significant influence of the share of rice area on pesticide use. In contrast, production of cassava uses significantly fewer pesticides. Significant gender differences exist with respect to pesticide use as male farmers use significantly higher pesticides. Farming experience significantly increases pesticide use.

The following policy implications can be drawn from the results of this study. First, land reform policies aimed at increasing the farm operation size of individual farmers could lead to a reduction in pesticide use. Galt [20] also noted that land reform with local backing could reduce pesticide use in vegetable farming in Costa Rica. Second, investment in programmes to promote expansion of cassava, e.g., Cassava Plus project, will significantly reduce pesticide use in major staple food crop production, as was also noted by Galt [20] for vegetable farming in Costa Rica. Third, policies to encourage female farmers to engage in farming are likely to reduce pesticide use in food production.

Although the effective implementation of these policies is challenging, a significant reduction in pesticide use is important for sustaining the agricultural sector, as well as for safeguarding the farming population, which is a worthwhile goal to pursue.

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