Research Article

# Adoption of Bio-Security Threats Management Practices and Food Security among Arable Farmers in South-West, Nigeria

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**Abstract** | Farmers are faced with the problem of food insecurity, which is driven by climate extreme events, soil degradation, economic instability, lack of sound agricultural policy, unstable political situation, herders-farmers crisis, and other pressing challenges. Most notably, bio-security threats, and other unobserved events ravaging the agri-food system, and causing significant loss of farm output, disruption of food supply chain, as well as loss of returns and other economic damages. This research interrogated the effect of adoption of bio-security threats management practices on arable crop farmers' food security status in South-West, Nigeria, using cross-sectional research design, with the dataset elicited from 403 farmers drawn through a multi-stage random sampling technique. Data were analyzed using frequency distribution and percentages, cross-tabulation, and food insecurity experience-based scale for the continuum categorization of farmers' food security status. Ordinal logistic regression model was applied to estimate the effect of adoption of bio-security practices and other dynamics on the farmers' levels of food security status. Findings revealed that crop farmers were aware of bio-security threats, but with low adoption of bio-security threats management practices. One-third of the farmers were also vulnerable to transitory and chronic food insecurity status. The odds ratio estimates of the ordinal logistic regression model also indicated that gender of the farmers ($p<0.05$), years of formal education ($p<0.1$), dependency ratio ($p<0.01$), farm size ($p<0.05$), adoption of bio-security ($p<0.1$), land ownership ($p<0.1$), and access to bio-security information ($p<0.1$) have significant influence on the levels of farmers' food security status in the study area.

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## Introduction

Arable farming involves cultivation of staple food crops with production life cycle of about a year, and such crops include tubers like cassava and yam, as well as cereals such maize amongst many others (Nwaobiala *et al.*, 2019). Meanwhile, cultivation of such crop is faced with some challenges; and in Nigeria, for instance, crop production, and agricultural development in general have witnessed slow growth over the years owing to the growing urbanization, rural-urban migration, and increasing population dynamics, and this has put pressure on the food production metrics which keep decreasing, and consequentially resulted to food importation (Olawuyi, 2020).

According to Ojo *et al.* (2019), food production is growing below 2%, while the population is growing at an annual rate of 2.5%, which is also in line with the Malthusian theory of population. Consequent on these, several households are faced with the challenges of food insecurity caused by climate extreme events, unsustainable production where demands exceed supply, scarcity of land, and degradation of soil.

In addition, food insecurity situation is also driven by economic instability, lack of sound agricultural policy, unstable political situation, herders-farmers crisis, and a host lot of other significant pressing challenges. Bio-security issues in farming systems are perfect examples of such challenges, which could include, pests infestation and crop diseases, incidence of weeds and other unobserved events capable of causing monumental and significant loss of farm returns and other economic damages (Oluwasusi *et al*., 2020).

All these are currently ravaging many crop farms in South-West Nigeria, and mitigating these challenges require sustainable land management and farming practices, good agricultural policies, stable economic and political environment, as well as adoption of bio-security management measures.

Adoption of bio-security measures within the context of crop plant has to do with farm management practices targeted at controlling, preventing, and minimizing the introduction and spread of new insects, weeds, diseases and pests (Duong *et al*., 2019). In fact, adoption of bio-security practices has a significant and positive impact on the financial situation of farms in many developed countries.

However, the knowledge, and/or awareness, and importantly, the use of bio-security measures in many developing countries such as Nigeria remains poorly understood because of insufficient studies, and lack of adequate attention in this direction (Oluwasusi *et al*., 2020; Mateo *et al*., 2021), and this research seeks to fill this gap, and also investigate the farmers' perceived benefits of bio-security measures, and how personal, socio-economic and farm characteristics shape the adoption of bio-security measures among arable farmers in South-West, Nigeria.

All these will enable the policy makers to understand the different dynamics influencing farmers' adoption decision and behaviour, and it will also help to put in place policy relevant action plans targeted at promoting positive and continuing adoption of bio-security measures among the farmers.

*Empirical studies*

The adoption of bio-security management practices in crop farms across many developed nations around the world have been documented by some studies (for instance, (Sanz, 2018; Tidbury *et al*., 2018; Hardy-Smith *et al*., 2019) as a huge success in terms of production outcomes and farmers well-being. Farmers are generally differentiated by varying personal and socio-economic conditions, such as age, education, religion, household size, farming experience, and indigenous knowledge on farming practices, access to extension service delivery, and access to timely information, which hitherto dictate their decision-making, economic and risk behaviours (Garforth *et al*., 2013; Oluwasusi *et al*., 2020; Mateo *et al*., 2021). More so, adoption of bio-security measures by farmers has also been influenced by several of these highlighted personal and socio-economic dynamics (Toma *et al*., 2013).

Despite the multicultural nature of many developing countries, which is favoured with a good system for managing bio-security threats and incursions, and its positive implication on the farm environment, farm families, and the economy at large (Mmbone *et al*., 2013; Duong *et al*., 2019), sadly, in Nigeria, these positive standings have been challenged by many man-made and natural occurrences such as insecurity, persistent and widening inequality gaps, as well as environmental conditions favouring the likelihood of increased bio-security incursions in terms of climate extreme events, environmental degradation and bio-security threats. This poses a serious threat to the nation's attainment of zero hunger policy target by the year 2030.

Owing to the aforementioned, this study investigated the adoption impact of bio-security practices and its effect on the arable farmers food security status in South-West, Nigeria, by specifically assessing farmers' awareness, adoption of farm bio-security threats management measures, levels of farmers' adoption, farmers perceived benefits of bio-security measures, farmers food security status, and the effect of adoption of bio-security threats management practices on the farmers food security status. The study also hypothesized that awareness of bio-security measures through proper information dissemination channel, does not influence the famers' ability to cope with bio-security threats, or minimize the risks, and does not have a significant effect on the farmers' food security status in the study area.

*Underpinning theoretical framework*

Following Duong *et al.* (2019), protection motivation theory propounded by Rogers (1975) is adopted for this study, to shed more light into human attitudes and behaviour. Notable literature (for instance, Cui *et al.*, 2016; Duong *et al.*, 2019) on behavioural change have interrogated health protection behaviours among individuals, and there are two main processes that describe the protection motivation theory, and these are: the threat appraisal process and the coping-appraisal process. The threat appraisal process has to do with people's assessment of the threat, and perceived vulnerability and consequence (Bubeck *et al.*, 2013), while the coping-appraisal process delves on the coping techniques in terms of how individuals successfully assess their approach to mitigate bio-security threats in line with the three areas associated with the coping-appraisal process: response efficacy, self-efficacy and the response costs associated with each management strategy option (Duong *et al.*, 2019).

*Description of the study area*

The study area is South-West Nigeria. It shares boundaries with Delta and Edo States in the eastern part, as well as Kogi and Kwara States in the northern hemisphere as shown in Figure 1. The state also shares boundary with the Benin Republic and Gulf of Guinea in the western and southern parts respectively (Ogunleke and Baiyegunhi, 2019). The area enjoys a tropical climate with both wet and dry seasons annually, while the major livelihood activities are agriculture and trading. There is a mild heterogeneity among the people (mostly Yoruba speaking clans with few minorities), but are largely homogeneous in nature with considerable level of social connectivity. The state enjoys a bi-modal rainfall pattern (the wet and dry seasons) and blessed with a tropical climate which supports the arable farming activities in this State.

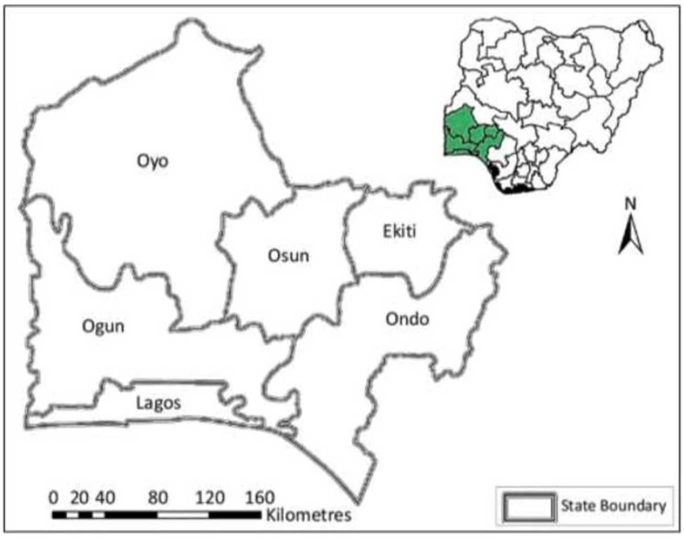


**Figure 1:** *Map of south-west, Nigeria.*
**Source:** *Ogunleke and Baiyegunhi, 2019.*

*Data and sampling procedure*

Cross-sectional data were collected from the farmers through the use of a well-structured interview schedule designed in line with the research objectives; this is in addition to the Food Insecurity Experienced-Based Scale (FIES) survey module (Ballard *et al.*, 2013; Nord *et al.*, 2016; WFP, 2020) which was also used to elicit information on farmers' food security vis-à-vis food insecurity situation in the last 3 months.

In the selection of the farmers, multistage sampling technique was employed for this study. South-western zone of Nigeria is made up of six States. In the first stage, Oyo, Osun and Ekiti States were purposely selected from these six States because of the predominant agricultural activities in across these states. Simple random selection of two agrarian Local Government Areas (LGAs) was made from each of the three states in the second stage. For the third stage, random proportionate to size sampling technique was used to select 15 villages from all the LGAs.

Given the three main caveats (that is, the level of precision, confidence level and the degree of variability) required for determining a suitable sample size for any research survey (Miaoulis and Michener, 1976), proportionality factor (random proportionate to size sampling) was also applied in the fourth stage to select the 416 representative sample used for this study. This was used because of the variation that exists in the population of the villages chosen across the study area. A detailed breakdown of the sampling and selection procedure of the respondents from the LGAs and villages are presented in Table 1.

**Table 1:** *Distribution of the sampled respondents in the study area.*

| State | LGAs | Villages | Number of respondents | Sample/ LGA | Per-centage |
|---|---|---|---|---|---|
| Oyo State | Orire | Iluju<br>Igbori<br>Tewure | 37<br>32<br>21 | 90 | 21.6 |
| | Ibarapa East | Olorunda<br>Alagbena<br>Sobaloju | 32<br>28<br>27 | 87 | 20.9 |
| Osun State | Ai-yedaade | Aba-Igbira<br>Olukotun | 35<br>31 | 66 | 15.9 |
| | Ataku-mosa East | Araromi<br>Iwara<br>Araromi | 31<br>19<br>22 | 72 | 17.3 |
| Ekiti State | Oye | Odogba<br>Itapa | 5<br>31 | 56 | 13.5 |
| | Ikole | Igboroko<br>Aba-alayan | 22<br>23 | 45 | 10.8 |
| Total | 6 | 15 | 416 | 416 | 100.0 |

**Source:** *Field survey, 2022.*

However, responses from 403 farmers were found worthy for the final analyses, due to incomplete responses in some research instruments. The research instrument was used to elicit necessary information such as farmers' personal and socio-economic characteristics, farm characteristics, farmers' access to institutional engagements, bio-security and food security information.

Further, Table 2 presents these variables, their descriptions and measurements.

*Empirical and methodological estimation*

The dataset for this research were analyzed using descriptive and inferential statistics and analytical techniques. Descriptive statistics such as frequency count, and percentage distribution were used to describe arable crop farmers' food security and adoption status. Following the categorization approach of WFP (2020), this study estimated the farmers' food security status, and categorized them into the following categories of food security status: Chronic food insecurity (CFIS), Transitory food insecurity (TFIS), Food break-even (FBE), and Food surplus (FS). In addition, composite score technique was applied for the ordinal categorization of the arable farmers into levels of adoption of bio-security practices among the arable crop farmers (Adepoju *et al*., 2011). Then, ordinal logistic regression model was used as inferential statistical tool to estimate the effect of adoption of bio-security practices and other dynamics on the levels of farmers' food security status in the study area.

*Model specification of ordinal logistic regression model*

Ordinal logistic model is also referred to as proportional odds or ordered logit model, and this represents a form of logistic regression that is used to model the change among many ranked or ordered

**Table 2:** *Description and measurement of variables.*

| Variable | Description and Measurement |
|---|---|
| Chronic-FIS | If a farmers suffers from chronic-FIS (yes = 1, 0, otherwise) |
| Transitory-FIS | If a farmer suffers from transitory-FIS (yes = 1, 0, otherwise) |
| Food break-even | If a farmer experiences food break-even (yes = 1, 0, otherwise) |
| Food surplus | If a farmer experiences food surplus (yes = 1, 0, otherwise) |
| Gender | Sex of the farmers (male = 1, 0, otherwise) |
| Age | Age of the farmers (actual number) |
| Household size | Number of persons within a household (actual number) |
| Years of formal education | Number of years spent in school (actual number in years) |
| Farm size | Size of farmland under cultivation (ha) |
| Bio-security practice adoption | Use of any bio-security measures (use = 1, 0, otherwise) |
| Dependency ratio | Number of dependents in a household-population (fraction) |
| Land ownership | If a farmer owns a personal farmland (own = 1, 0, otherwise) |
| Local level institutions | Belong to a local level institution (member = 1, 0, otherwise) |
| Access to bio-security info. | Access to bio-security information (access = 1, 0, otherwise) |
| Access to extension services | Access to extension delivery services (access = 1, 0, otherwise) |
| Awareness of bio-security | If a farmer is aware of bio-security (aware = 1, 0, otherwise) |

**Source**: *Authors' compilation, 2022* values of the response variable as a function of each unit increase in the covariate or predictor (Fagerland and Hosmer, 2017). Given an ordinal outcome having three or more categories, the odds ratio for the logistic model represents the odds of a higher category versus (as compared to) all the lower categories combined (Williams and Quiroz, 2019). Suffice it to say that, the model presents a cumulative odds ratio showing increased likelihood to the next highest category, relative to the lower categories for each unit increase in the predictor or explanatory variable. According to Williams (2021), the benefit of using ordinal logistic regression over another likely method of estimation such as multinomial regression is that one will be ignoring the ordinality of the response variable, and treating it as nominal. This could possibly lead to a loss of efficiency in estimation and increases the risk of getting insignificant results and/or distorted findings; even though, the parameter estimates may appear unbiased.

The likelihood function of the ordered logistic regression to model the effect of gender inequality (women empowerment) and other hypothesized factors on the level of food security status of the arable crop farmers, is expressed as:

$$FSST = [\Phi(0 - X_i\beta)]^{z_{i1}} [\Phi(\mu_1 - X_i\beta) - \Phi(0 - X_i\beta)]^{z_{i2}} [1 - \Phi(X_i\beta - \mu_1)]^{z_{i3}} \quad ..(1)$$

$$z_j = \begin{cases} 1, f \ldots y_i = j \\ 0, otherwise.\ for \ldots j = 0.\ 1,..2.\ and \ldots 3 \end{cases} \quad \ldots (2)$$

Where: for $i^{th}$ individual; $FSST_L$ = Levels of farmers' food security status (CFIS = 0; TFIS = 1; FBE = 2, and FS = 3). $X_i$ = a vector of hypothesized explanatory variables including adoption of bio-security measures; while the unknown parameters $\beta_i$ is to be estimated through maximum likelihood estimation procedure.

## Results and Discussion

This section presents the results of the analyses, and discusses the findings, as well as the economic implications of the findings. These are presented as follow:

*Farmers awareness of bio-security threats and adoption of bio-security practices*

The results in Table 3 revealed the distribution of arable farmers based on their awareness of bio-security threats and adoption of bio-security practices or measures adopted by the farmers in the study area. The findings indicated that majority (94.8%) of the farmers in the study area are aware of the bio-security threats, while only 5.2 percent reported unawareness.

**Table 3:** *Farmers awareness, and adoption of bio-security measures.*

| Variables | Frequency | Percentage |
|---|---|---|
| Awareness of bio-security measures | | |
| Aware | 382 | 94.8 |
| Not aware | 21 | 5.2 |
| *Adoption of bio-security measures | | |
| Wedding and clearing of farms | 399 | 99.0 |
| Physical security (fencing and guards) | 27 | 6.7 |
| Insect/rat/rodent control measure | 73 | 18.1 |
| Dipping of foot inside disinfectant pool | 26 | 6.5 |
| Disinfection of vehicles | 0 | 0.0 |
| Quarantine of new plant varieties | 33 | 8.2 |
| Restriction of unauthorized visits | 20 | 4.9 |
| Provision of protective clothing for visitors | 0 | 0.0 |
| Total | 403 | 100.0 |

**Source:** *Field survey, 2022.* *: *Multiple response.*

*Adoption of bio-security measures*

There are many bio-security measures put in place by the arable farmers in the study area, to mitigate bio-security threats on their farms, and the farmers used more than one bio-security practices or measures. Findings in Table 3 revealed that almost (99%) all the farmers were involved in weeding and clearing of bushy environment in the farms, while 18.1 percent of the farmers put in place insects, rats, and rodents control measures. Similarly, few (8.2%, 6.7% and 6.5%) of the famers were involved in quarantine of new plant varieties control measure, physical security such as fencing and the use of guards to curtail the unwanted intrusions, as well as putting in place the disinfectant pool for dipping of foot before entrance, respectively. The results also revealed that very few (4.9%) put up visible warning against unauthorized visitors to the farms. However, none of the farmers adopted disinfection of vehicles before accessing the farms, and the provision of protective clothing for the visitors coming to the farms. The implication of all these findings is that majority of the farmers adopted general bio-security practices, and few specific ones. This is clearly an indication of farmers adoption apathy, more so, failure of the farmers to adopt disinfection of vehicles and provision of protective clothing and gears could be devastating in economic terms, if the visitors unintentionally import pathogens to the farms.

*Level of adoption of bio-security measures*

The results in Table 4 revealed the levels of adoption of bio-security practices by the arable farmers in the study area. Findings indicated that 58.6 percent of the farmers fall within the low category of adoption, while few (27.8%) fall within the moderate level of adoption category, and very few (13.6%) of the respondents were found in the high level of adoption category. By implication, most of the farmers were within the lower continuum of adoption category; this does not look good for achieving healthy farm environment because bio-security threats can successfully thrive in an unhealthy environment. With this, agricultural productivity will decline, food supply chain will be badly disrupted, and increase in food prices will automatically be activated. All these are pointers of food insecurity situation among the populace.

**Table 4:** *Levels of adoption, perceived benefits of bio-security measures and farmers food security status.*

| **Variables** | **Fre-quency** | **Per-centage** |
|---|---|---|
| Levels of adoption of bio-security measures | | |
| Low | 236 | 58.6 |
| Moderate | 112 | 27.8 |
| High | 55 | 13.6 |
| *Perceived benefits of bio-security measures | | |
| Increase in farm output and food supply | 403 | 100.0 |
| Increase in income and profitability | 274 | 67.9 |
| Health environment against diseases & pathogens | 19 | 4.71 |
| To get credit access | 33 | 8.2 |
| Access to up to date information | 171 | 42.4 |
| **Food security status (categories)** | | |
| Chronic food insecurity | 124 | 30.8 |
| Transitory food insecurity | 171 | 42.4 |
| Food break-even | 65 | 16.1 |
| Food surplus | 43 | 10.7 |
| Total | 403 | 100.0 |

**Source:** *Field survey, 2022. * - Multiple response*

*Farmers perceived benefits of bio-security measures*

Adoption of agricultural technologies or risk mitigating strategies is mostly driven by the axiom of rationality in consumers' theory, and multiplicity of other factors. When the expected benefits of adoption outweigh the expected costs, adoption is embraced, and vice versa. The results shown in Table 4 indicated that arable farmers' adoption of bio-security practices in the study area was mostly (100%) driven by the perceived benefit of increase in farm output and food availability. More than two-third (67.9%) of the farmers also expressed opinion of increased income and profitability as perceived benefits of adoption of bio-security measures, while 47.4 percent of the farmers placed their expectations on achieving healthy environment against diseases and pathogens, and ultimately minimize the risks of crop pest infestation, and disease outbreak.

*Food security status of the farmers*

The results shown in Table 4 revealed the arable farmers' food security status expressed in categories, using the FAO's food insecurity experience-based scale module, as explained in the methodology section. The findings indicated that 30.8 percent of the arable farmers fell within the chronic food insecurity category, while 42.4 percent are in the transitory food insecurity status space. More so, few (16.1%) farmers were in the food break-even category, while very few (10.7%) were found in the food surplus category. The implication of this revelation is that nearly one-third of the arable crop farmers in the study area are susceptible to transitory and chronic food insecurity status, and there is a possibility for farmers' movement to a better or worse off state, given an appropriate agri-food development policy, or otherwise.

**Table 5:** *Disaggregation of farmers' food security status by bio-security adoption categories.*

| **Food security status** | **Adoption categories** | | | **Total** |
|---|---|---|---|---|
| | **Low** | **Moderate** | **High** | |
| Chronic food insecurity | 90 (38.1) | 22 (19.6) | 12 (21.8) | 124 |
| Transitory food insecurity | 98 (41.5) | 60 (53.6) | 13 (23.6) | 171 |
| Food break-even | 34 (14.4) | 12 (10.7) | 19 (34.6) | 65 |
| Food surplus | 14 (6.0) | 18 (16.1) | 11 (20.0) | 43 |
| Total | 236 | 112 | 55 | 403 |

**Source:** *Field survey, 2022. Figures in parentheses are percentage values.*

*Disaggregation of farmers' food security status by bio-security measures adoption categories*

The cross-tabulation analysis presented in Table 5 revealed the disaggregation of arable farmers' food security status by levels of bio-security adoption among the farmers. The findings indicated that 38.1 percent, 19.6 percent, and 21.8 percent of the farmers who were found within the low, moderate, and high adoption categories, respectively, were vulnerable to chronic food insecurity status. Also, 41.5 percent, 53.6 percent, and 23.6 percent of the farmers who were within the low, moderate, and high adoption categories, respectively, were vulnerable to transitory food insecurity status. Similarly, 14.4 percent, 10.7 percent, and 34.6 percent of the farmers who were in the low, moderate, and high adoption categories, respectively, were found in the food break-even class of food security status. Further, very few (6%) farmers who were in the low adoption category were found in the food surplus class (highly food secure), while 16.1 percent and 20 percent of the farmers who were in the moderate and high adoption categories, respectively, were also found in the food surplus class. The implication of the findings is that most of the sampled farmers were found in the low adoption group, and were also classified within the chronic food insecurity category. Invariably, the low adoption is perhaps responsible for low productivity on the farm, which consequently resulted to high food insecurity status.

*Effect of adoption of bio-security measures on farmers' food security status*

The results in Table 6 revealed the fitted ordinal logistic regression model (expressed in odds ratio) estimates, with the final log-likelihood value of -289.16281 and the likelihood ratio chi-squared value of 197.35 at degree of freedom of 11 with a *p-value* of 0.0000. Given all these, it suggests that the full model is significant, compared to a null model without any predictor. The model's cut-points, which are the threshold parameters, have estimated values of -1.7832, -1.9618 and 3.2901, respectively. And, this implies that although, the results appear to emanate from a single equation model, but in the real sense, there exists three equations nested in a single model (Williams, 2021). The reason for this is because the response variable (food security status) is expressed in four ranked levels or continuums.

Given the findings, the estimates revealed that gender of the farmers ($p<0.05$), years of formal education ($p<0.01$), dependency ratio ($p<0.01$), farm size ($p<0.05$), adoption of bio-security ($p<0.1$), land ownership ($p<0.1$), and access to bio-security information ($p<0.1$) have significant influence and effect on the levels of farmers' food security status in the study area. Importantly, this effect or relationships are expressed in different direction of movements.

**Table 6:** *Ordinal logit: Effect of adoption of bio-security measures on food security status.*

| Levels of food security status | Odds ratio | z- statistics | p>\|z\| |
|---|---|---|---|
| Gender | 0.8109 | 2.09** | 0.039 |
| Age | -0.0989 | -1.54 | 0.126 |
| Years of formal education | 0.1678 | 1.69* | 0.095 |
| Dependency ratio | -0.6621 | -2.69*** | 0.008 |
| Farm size | 0.2483 | 2.26** | 0.026 |
| Years of farming experience | -0.0229 | -1.28 | 0.204 |
| Adoption of bio-security measures | -0.0167 | -1.77* | 0.080 |
| Land ownership | -0.7289 | -1.74* | 0.085 |
| Membership of local level institutions | -0.0114 | -1.11 | 0.271 |
| Access to bio-security information | -0.1443 | -1.65* | 0.102 |
| Access to extension services | -0.0252 | -1.44 | 0.154 |
| /cut 1 | - 1.7832 | 0.9271 | |
| /cut 1 | - 1.9618 | 0.5338 | |
| /cut 3 | 3.2901 | 2.0374 | |
| LR chi² (11) = 197.35 | Prob>chi² | 0.0000 | |
| Log likelihood = -289.16281 | Pseudo R² | 0.2492 | |

**Source:** *Data analysis, 2022.* *** - $p<0.01$, ** - $p<0.05$, * - $p<0.1$.

More specifically, the estimate of farmers' gender indicated that the variable is a significant predictor of falling into the highest level of food security status versus the combined lower levels of food security status. *Ceteris paribus*, for every unit increase in a farmer being a male gender, there is a 0.81 point increase in the log odds of falling into the highest level of food security status versus the combined lower ranked food security status levels, given that all other variables are held constant. In line with the submission of Ovute (2019), this result suggests that male farmers appear more food secure than the female counterparts in the study area. Further, the estimate of the years of formal education also suggests that, for every unit increase in the farmers' years of formal education, there is an increase of approximately 0.17 point in the log odds of falling into the highest level of food security status versus the combined lower ranked food security status levels, all else equal. In tandem with the findings reported in Kehinde *et al.* (2021), this is as expected because higher education increases the chances of individual to perform better in their livelihood activities. Besides, education is also helpful in the uptake of modern farming systems, to increase food productivity, and the chances of being food secure.

In terms of farm size, the results revealed that, a unit increase in the size of cultivated farmland will induce an improvement in the log odds of the farmers falling into the highest continuum of food status versus the combined lower ranked food security levels, by approximately 0.25 point. Expectedly, increase in the size of cultivated farm land should translate to higher output, with positive impact on the food supply chain, and by extension increase in income, and general well-being of the farmers. This result is in line with a-priori expectations, and the submission of Sileshi *et al*., (2019) in a similar study conducted in Ethiopia.

Conversely, the findings also revealed an inverse effect of dependency ratio with farmers' food security status. In a clear term, the estimate indicated that a unit increase in dependency ratio will reduce the log odds and farmers' chances of falling into the highest level of food security status versus the combined lower ranked food security status levels, by 0.66 point. The implication of this result is that, relative to the household size, the proportion of the unemployed individuals appeared to be on the high side, and this is telling on the well-being of the household. This outcome is expected, and presents a clear message that higher dependency is parasitic in nature, and reduces the chances of farmers to be food secure. All in all, the result underscores the submission of Sani and Kemaw (2019) in their study on households' food insecurity and coping mechanism in western Ethiopia. Similarly, the finding is in tandem with Aboaba *et al*. (2020) who also reported similar findings in their study on the determinants of food security in Southwestern Nigeria.

Given farmers' adoption of bio-security measures, the estimate revealed that bio-security practices adoption has an inverse effect on the farmers food security status. This indicates that for every unit increase in the farmer's adoption of bio-security measures and practices against bio-security threats, the log odds of being in the highest class of food security versus the combined lower ranked food security status levels, decreases by 0.01 point. This is contrary to expectation, as adoption of bio-security practices is expected to induce productivity increase, and the chances of being food secure. A plausible explanation for this deviation could be as a result of the usual apathy among the farmers towards adoption of modern farming techniques and/or agricultural technologies, as emphasized by Hunecke *et al*. (2017) in their study on adoption of agricultural technologies in Central Chile.

In addition, the estimate of land ownership by the farmers revealed that, for every unit increase in the farmland held through inheritance, the log odds of the farmers to be in the highest level of food security status versus the combined lower ranked food security status levels, decreases by 0.7 point. In line with Ajayi *et al*. (2021), this is not surprising due to the prevalent land ownership type (inheritance) in the study area, where land is being passed from one generation to another; this action usually triggers fragmentation of farmland, and impedes agricultural development. In terms of access to bio-security information, the estimate also revealed that, for every unit increase in farmers' access to bio-security information, the log odds and chances of the farmers falling into the highest level of food security status versus the combined lower ranked food security status levels, decreases by 0.14 point. This is contrary to expectation, because access to agricultural information should drive positive adoption of improved farming practices and by extension leads to improved farm output, and better food security status. Meanwhile, farmers' apathy behavior can be also linked to this inverse relationship or effect, as earlier established in Hunecke *et al*. (2017) in their study on the role of social capital in farmers' adoption decisions on irrigation technology in Central Chile.

In fact, farmers local level organizations and contact with extension agents are regarded as important information channels through which farmers can seamlessly access, and benefit important livelihood information such as bio-security control measures, and sustainable farming methods. However, from the findings, it seemed like the extension service delivery is somewhat not effective in the study area, while the local level institutions also appeared like ordinary social gatherings among the farmers, given the non-significance and the inverse relationships associated with these important variables. This clearly presents a major impediment to rural and agricultural development, and also threatens the attainment of sustainable food security status among the farmers, in the long run.

**Table 7:** *Fit tests statistics for the model.*

| Null model (intercept only) | | Full model | |
|---|---|---|---|
| Log-lik intercept only | -356.138 | Log-Lik Full Model | -289.163 |
| D (389) | 394.314 | LR (11) | 197.357 |
| McFadden's $R^2$ | 0.468 | Prob > LR | 0.000 |
| ML (Cox-Snell) $R^2$ | 0.512 | McFadden's Adj. $R^2$ | 0.341 |
| McKelvey and Zavoina's $R^2$ | 0.623 | Cragg-Uhler (Nagelkerke) $R^2$ | 0.571 |
| Variance of y* | 6.418 | Variance of error | 2.308 |
| Count $R^2$ | 0.329 | Adj Count $R^2$ | 0.146 |
| AIC | 1.551 | AIC*n | 625.053 |
| BIC | -1027.182 | BIC | -11.249 |
| BIC used by Stata | 560.282 | AIC used by Stata | 625.053 |

**Source:** *Data analysis, 2022*

In conclusion, this research has established that gender of the farmers, years of formal education, dependency ratio, farm size, land ownership, and importantly, adoption of bio-security and access to bio-security information are significant predictors of the farmers' levels of food security status in the study area.

*Fit tests statistics for the model*

The Akaike's Information Criterion (AIC), Bayesian Information Criterion (BIC) and McFadden's $R^2$ are the spotlights in the fit statistics for ordered response models (Williams, 2018). Most importantly, the information measures are usually applied to gauge the relative plausibility of two or more models, and the preferred model is usually attached with a smaller value of the test statistics or a more negative value generated (Williams, 2018). Suffice it to say that, the model having a smaller AIC is preferred as the best fit model. All else equal, BIC assesses the model with a high likelihood to have generated the observed data. The values from the information measure criteria in Table 7 favour the full model, compared to the null model which has no predictor. Therefore, one can safely infer that the model fits very well.

## Conclusions and Recommendations

This study has shown a compelling indication that farmers have varying personal and socio-economic dynamics, as well as adoption of bio-security threats management practices, which have significant effect on the farmers food security status in the study area. The study had also established the significant influence of farmers access to bio-security information through proper dissemination channels for awareness in the study area. This therefore permits to assert that access to bio-security information (which defines awareness of bio-security measures) through proper information dissemination channel drives famers ability to cope with bio-security threats and minimize the bio-security risks, had a significant effect on the farmers' food security status in the study area, hence, the null hypothesis is not accepted.

Based on the research findings, the following recommendations are made:

- Since adoption of bio-security measures appeared to be low, and skewed towards a particular practice, scaling up of campaign on the need to embrace positive adoption behavior and all inclusive adoption with respect to different bio-security threats management measures is important. Proper information dissemination among the farmers should also be intensified on the benefits of adoption of different bio-security threats management practices.
- Farmers' food security situation appeared to be concentrated around chronic and transitory status. Given this observation, government and development experts need to brace up on developing a viable and efficient agricultural development policy that will drive adoption of bio-security practices among the farmers, and transform the agri-food sector positively. This will ensure maximum production, efficient distribution of food in the supply chain, and sustained food access among individuals.
- Gender was found to have a direct effect on the level of farmers' food security status, and the need is imperative to continue to promote gender-just food security policy, and adequate empowerment for all. These are central to improving food

productivity, achieving the zero hunger vision for all, having sufficient and equitable participation in decision-making process, as well as improving the living conditions of the rural people. Without ensuring all these, gender equality and rural empowerments from the social, economic, and political perspectives, as well as zero hunger vision may be difficult to achieve.

- Education is an important factor that can drive adoption of good agricultural practices. As such, human capital development in terms of farmers' education and trainings should be prioritized and promoted; these can induce positive adoption behavior in farmers.
- Since land ownership form presents an inhibiting factor to farmers' food security status, there is an urgent need for reform in the area of land acquisition and use. The land acquisition and use is a critical issue of great policy relevance in developing nations such as Nigeria. Amendment of this should capture and address the prevailing realities around the customary laws and informal land markets in Nigeria.
- As much as family labour is good to reduce cost of labour, there is a greater need to intensify information on the need for birth control. This is necessary to control large family size and high dependency ratio, negatively impacting on the households' level of food security status, given the farmers' scale of operation and the meager resources they operate with.
- Effective extension service delivery is capable of driving better food security status, and this should be given top priority by the government at all levels, as well as the non-governmental organizations. Since the findings indicated a non-significant and non-functional extension delivery system, extension services should be prioritized to allow farmers to access extension services, and maximum contacts with the extension agents who should be recruited based on expertise.

## Novelty Statement

The research provides empirical evidence of the relevance of adoption of bio-security threats management practices by crop farmers in Nigeria, towards sustainable food production and the attainment of zero hunger, which is in line with the Sustainable Development Goal 2 of the United Nations.

## Author's Contribution

**Olawuyi, Seyi Olalekan, Anjorin, Adedotun Oluwagbenga and Alao, Oluwagbenga Titus:** Conceptualized and supervised the research study. They also have equal participation in the: write-up of the manuscript's sections, analyses of the dataset, and interpretation of the results.
**Olawuyi, Tosin Dolapo, Ayinla, Rachael Ajibola and Ayinla, Rasheed Ayodele:** Developed the research instruments in line with the objectives of the study, supervised the field survey and carried out the data collection process, as well as coding of the dataset.
All authors read and approved the final manuscript for submission.

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*Ethical considerations*
This study adhered strictly to the following standard ethical practices and considerations: anonymity, informed consent, privacy, confidentiality, and professionalism, as outlined in WHO (2001) Helsinki declaration on research protocol.

*Conflict of interest*
The authors have declared no conflict of interest.

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