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RESEARCH ARTICLE

Causal Effect of Agricultural Diversification on Smallholder Farmers' Welfare Status in Nigeria

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ABSTRACT

The acceptance rate of agricultural diversification as an effective strategy to mitigate climate change shocks on smallholder farmers' welfare is growing. However, many smallholder farmers in Oyo State, Nigeria, feel that the proposed solutions to their ongoing welfare challenges lack sufficient information and guidance. Thus, this study used descriptive statistics, the Herfindahl-Hirschman index, the double hurdle model and a sample selection ordered probit regression model, to analyze the dataset elicited from 249 smallholder farmers through a multi-stage random sampling technique. These analytical techniques were applied to: describe farmers' personal and socio-economic characteristics, examine the levels of diversification in the different agricultural enterprises, determine the correlates of agricultural diversification, and investigate the causal effect of agricultural diversification and other unobserved factors on farmers' welfare status in the study area, respectively. Results showed that the average household size was five persons. Similarly, the majority engaged in diversified farming are operating at a moderate level and were classified as having a moderate welfare status. Furthermore, the double hurdle estimation revealed that age, dependency ratio, market access, food security status, years of farming experience, per capita in-

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come, and credit access significantly influenced both the decision to diversify and the extent of diversification. The sample selection ordered probit regression estimation indicated that agricultural diversification, household size, per capita income, distance to market, and years of farming experience significantly influenced farmers' welfare status. Findings also revealed the need to support smallholder farmers with policies that encourage them to diversify their farming activities to maximize their gains, experience improved life and contribute to rural development in Oyo State, Nigeria.

Keywords: Agricultural Diversification; Herfindahl Hirschman; Double Hurdle Model; Sample Selection Ordered Probit Model; Welfare Status; Nigeria

1. Introduction

Threats confronting agricultural systems include climate change. Michler and Josephson [1] opined that seasonal irregularities including but not limited to drought, high temperatures, very low humidity and precipitation are noticeable climate change impacts. Makate et al. [2] also noted that climate change would lower crop yield, deplete soil fertility and cause environmental degradation. Given the relationship between climatic and ecological conditions, smallholder farmers earning a livelihood from farming are expected to experience more challenges and risks. In addition, Hansen et al. [3] discovered and reported that risks induced by climate change directly influence the severity of poverty in many rural areas. According to Larson, Muraoka and Otsuka [4], rural areas in Africa and Nigeria are dominated by resource-poor farmers who are susceptible because they rely on rainfall, one of the climate change-controlled factors, to cultivate their crops.

The influence of climate change, particularly on rainfall, has altered farming seasons and lowered farmers' ability to predict and plan appropriately for planting and harvesting periods. For instance, prolonged droughts occasioned by the absence of rainfall have not only rendered some locations unsuitable for growing certain crops [5], but have also increased heat stress with a resultant decline in the crops harvested [6]. More often than not, smallholder farmers are compelled to sell their limited perishable produce at low prices to middlemen, which often leaves them struggling with food insecurity and variations in market forces. Furthermore, Saleem et al. [6] documented a higher vulnerability tendency that resulted in lower productivity and severe health challenges for crops and livestock grown and raised in warmer environments. In a recent development, there have been reports of terror unleashed in the agrarian community, which has increased the state of insecurity. Farmers have to pay to access their farms. Where farmers resist, they are denied access to their farms and/or inflicted with life-threatening injuries by an unidentified group of persons.

Under the renewed hope agenda, the current government has changed several provisions, including those in the agricultural sector, to accelerate the pace of agricultural productivity [7]. Establishing a feasible policy framework capable of assisting smallholder farmers to prosper using their existing resources is sacrosanct to reducing food insecurity, improving poor welfare conditions, and dousing the wave of protests recently occurring in the nation due to economic instability. The urgency to address various challenges and redress the demands of the people, particularly in the agricultural sector, has witnessed the establishment of the Agricultural Transformation Agenda (ATA) and the Agricultural Promotion Policy (APP). These policies aim to free Nigerians from hunger through the agricultural sector, promote income growth, accelerate food and nutritional security, generate employment, transform Nigeria into a key player in world food markets and increase wealth for many farmers [8, 9]. While these programs achieved some of the reasons they were established, Nigeria is still not food secure (nationally, regionally, and locally), and farmers have also registered discontent and worse welfare status with the reforms.

Nevertheless, findings from previous research [10–12] assure that agricultural systems can still meet the nutritional demand of the growing population

and improve the welfare of smallholders. Ibid believes that sufficient food production is achievable either by expanding the area of land cultivated or intensifying cultivation on the existing land [13, 14]. Again, Power [15], Campbell et al. [16] and Giovanni [17] have all cautioned that this approach is not sustainable amidst increasing urbanization coupled with demand for land from other sectors. In addition, increasing food production by expanding land-cultivated areas has been identified as the primary driver of habitat and biodiversity loss, soil and freshwater degradation, environmental pollution, and greenhouse gas emissions globally.

Earlier reforms that established different programmes aimed at revitalizing agriculture and providing smallholder farmers with knowledge and guidance to organize their farming process to earn decent welfare were underpinned by available information. An effective strategy would have been established if more had been known. Thus, understanding how critical agricultural elements and other information interact would help build the foundation of a robust policy framework to establish programmes aimed at equipping smallholder farmers with the knowledge and guidance to help them enhance their welfare status and maximize the gains of innovative strategies. For instance, economic factors, such as market demand and supply, are essential considerations for smallholder farmers before adopting an innovative approach. Geographic location and available resources are essential variables controlling the supply side of agricultural production and impacting farmers' access to vital infrastructure, markets, and other socio-economic elements. In contrast, selective choices, climate change, and population exert pressure on agricultural systems to shape or influence the demand side [18]. Although what appears effective towards improved welfare status of farmers in any farming system may be influenced by socio-economic and geographic backgrounds, it is instructive to understand initiatives, strategies, and approaches put forward to improve smallholder farmers' welfare status. According to Swarnam et al. [19], agricultural diversification is a dynamic and holistic approach to achieving economic benefits from existing farming systems and improving the adaptive capacity of agriculture. Similarly, Michler and Josephson [1] and Moraine et al. [20] reported that the agricultural diversification approach integrates livestock production and cultivation of various crops, thereby mitigating risks associated with monocropping, stabilizing income and improving the welfare condition of farmers. According to Inoni, Gani and Sabo [21], agricultural diversification also offers a viable strategy for mitigating smallholder farmers' challenges. In the words of Nguyen [22] and Mussema et al. [23], integrating crops and livestock creates synergies, while diversification into agro-processing and value-added activities increases profitability and stability. This strategy potentially ensures balanced diets, enhances food security, and better utilizes resources. Furthermore, Makate et al. [2] contend that integrating aquaculture, agroforestry, and non-farming enterprises, including agro-processing and rural tourism, establishes this strategy's versatility in enhancing its adopters' livelihoods. Since smallholder farmers are among the most vulnerable groups in society, their welfare outcomes need to be interrogated from time to time, as such investigations can guide sustainable agricultural practices and policies, promoting environmental conservation and long-term food security. Importantly, having accurate baseline information on the welfare of smallholder farmers provides an effective base for agricultural policies and support programs, which include but are not limited to interventions to improve access to resources, credit facilities, and extension services. Similarly, improving the welfare of smallholder farmers can lead to increased agricultural productivity, contributing to rural economic growth and agrarian development.

Therefore, this study aims to assess the current level of agricultural diversification and welfare among smallholder farmers, examine the factors influencing diversification choices and the extent of diversification, and evaluate the impact of diversification on farmers' welfare. The study also hypothesizes that farmers' socio-economic factors do not significantly influence the diversification choices and extent of diversification and that agricultural diversification does not positively impact smallholder farmers' welfare.

1.1. Issues Faced by Smallholder Farmers

Smallholder farmers in developing countries, including Nigeria, encounter a myriad of challenges that

hinder their productivity and overall well-being. Many smallholder farmers have restricted access to critical resources such as quality seeds, fertilizers, and irrigation facilities, and this limitation often leads to suboptimal yields and low-quality produce [24]. In addition, inconsistent land tenure policies and practices can discourage long-term investments in land improvements and sustainable farming practices, and this land insecurity often leads to reduced agricultural productivity and limits the ability of farmers to expand their operations [25]. Likewise, inadequate rural infrastructure, including poor road networks and lack of storage facilities, hampers farmers' ability to access markets and sell their produce at competitive prices. This often results in post-harvest losses and reduced income [26]. Similarly, smallholder farmers frequently lack access to reliable market information and face challenges in reaching profitable markets, while the presence of intermediaries or middlemen who often exploit uninformed farmers and reduce their profit margins, is also a significant challenge [27]. Mango et al. [28] in a related study also emphasized that limited access to credit and financial services restricts smallholder farmers' ability to invest in modern and improved farming techniques and purchase necessary inputs, thereby limiting the scale of their operations. The unpredictable weather patterns, soil degradation, and other environmental issues are other notable constraints, negatively impacting farming activities, crop yields and farmers' income. According to Binswangermkhize and Savastano [29], most farmers who are smallholders often rely on rain-fed agriculture, and given this, they are particularly vulnerable to these events. While many smallholder farmers also lack the technical know-how to adopt improved agricultural practices, the inadequate provision of extension services further compounds this issue [21], limiting farmers' capacity to increase productivity and efficiency, which invariably affects their welfare condition.

1.2. The Role of Diversification in Addressing These Challenges

Agricultural diversification offers a viable strategy to mitigate some of the challenges faced by smallholder farmers. Through diversification of agricultural activities, farmers can achieve several benefits. Diversification reduces the risk associated with relying on a single crop or farming activity. According to Inoni, Gani and Sabo [21], diversified farms can maintain income through alternative crops or livestock in the event of crop failure due to pests, diseases, or adverse weather conditions. This implies that engaging in multiple agricultural activities allows farmers to tap into different income streams. This diversification can lead to more stable and potentially higher incomes, helping farmers to better manage their finances and invest in their farms. Importantly, by growing a variety of crops and raising different livestock, smallholder farmers can ensure a more balanced and nutritious diet for their households [20]. This approach also reduces dependency on market-purchased food, enhancing food security. Diversification also enables farmers to make better use of available resources, such as land, water, and labor. For instance, integrating crop and livestock farming can create synergies, where livestock manure enhances soil fertility for crops, while it also provides opportunities for smallholder farmers to enter niche markets, such as organic produce or specialized crops [22]. Similarly, diversification into agro-processing and other value-added activities can equally increase the profitability of agricultural produce, and achieve greater economic stability, food security, and resilience to environmental and market fluctuations [23]. Also, it is important to reiterate that the concept of agricultural diversification includes both horizontal diversification, which involves growing different types of crops within a given period or area, and vertical diversification, which encompasses activities such as agro-processing and value addition. Diversification can also extend to integrating livestock, aquaculture, and agroforestry, thereby utilizing land and resources more efficiently.

2. Theoretical Perspectives on Diversification and Welfare

Several theoretical perspectives that revolve around economic theories on risk management and income stabilization provide a proper understanding of the relationship between agricultural diversification and smallholder farmers' welfare. These theories collec-

tively highlight the nature of diversification as a strategy for improving household welfare, contributing to more resilient and sustainable livelihoods through the spreading of risk, enhancing income stability, and improving resource utilization in rural areas. This study draws on these theoretical approaches to analyze the impact of agricultural diversification on the welfare of smallholder farmers. These theories as applied to this study are:

2.1. Portfolio Theory

Originating from finance, and applied in several fields, including agriculture, this theory posits that a well-diversified farm portfolio can lead to more stable and predictable returns, thereby stabilizing income and enhancing household welfare[30]. Portfolio theory has been applied to agriculture to explain diversification as a risk management strategy. Just as investors diversify their portfolios to minimize risk, farmers diversify their agricultural activities to reduce the impact of adverse events on any single income source.

2.2. Risk Aversion Theory

This theory suggests that individuals are generally risk-averse and prefer to minimize uncertainty in their income streams, and in agriculture, this translates to diversification as a means to spread risk across different crops and activities[31]. This is to say that by not relying solely on one crop or income source, farmers can protect themselves against crop failures, price drops, and other risks. This behavior is particularly relevant in the context of smallholder farmers who often operate under significant economic uncertainty.

2.3. Theory of the Farm Household and Utility

This theory integrates the production and consumption decisions of farm households. According to Barnum and Squire[32], it posits that households maximize utility by choosing a combination of activities that balance income generation with risk management and resource constraints. This is regarded as a strategy to optimize household utility by balancing the benefits of additional income against the risks and costs of engaging in new activities.

2.4. Economic Development and Structural Change Theory

This theory examines how economic development leads to changes in the structure of economies, including the agricultural sector. As economies develop, there is often a shift from traditional agriculture to more diverse and specialized forms of production, including high-value crops, livestock, and agro-processing[33]. This shift is facilitated by improvements in infrastructure such as access to markets, which in turn enhance rural welfare.

2.5. Conceptual Framework

Figure 1 illustrates a conceptual framework where agricultural diversification is expected to augment farm income mitigate the risks associated with climate vagaries and contribute to environmental and social sustainability goals. The institutional, legal and policy framework interacts to form a comprehensive arrangement that prescribes permissible operation and the outcome within its purview.

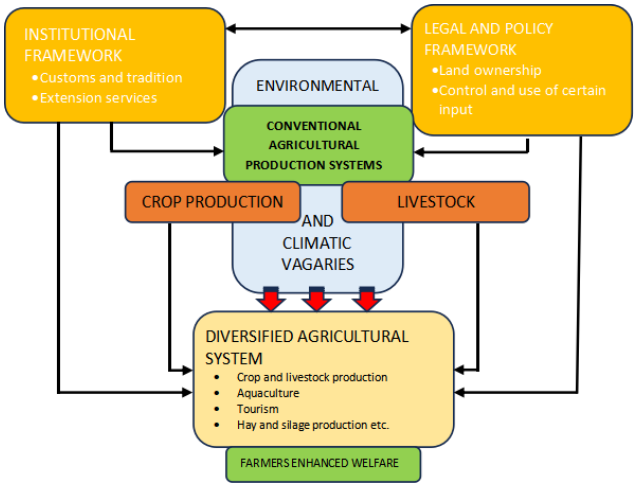

Figure 1. Conceptual framework.

Conventional agricultural production systems, being no exception to this standard, must comply with the specified guidance and regulations governing their operation. Crop and livestock are the dominant agricultural activities, practiced singularly or combined on a small scale for subsistence. However, the spectre of climate change exposes this conventional approach to unpre-

dictable weather patterns and intense climatic events that have threatened these systems, causing different degrees of destruction to already vulnerable smallholder farmers in the agrarian community.

An agricultural diversified farming system even amidst challenging climates, mitigates the devastating effects of climate change by integrating crop and livestock production synergistically and incorporating additional income-generating activities including but not limited to tourism, aquaculture, agroforestry, pasture and hay processing and by-product processing activities to enhance farmers welfare, reduce associated climatic risks, and promote the economic viability of farms and the environment.

3. Brief Empirical Review of Literature on Agricultural Diversification and Its Welfare Effect

Agricultural diversification has been widely studied across different regions of the world, with varying contexts and outcomes. Globally, diversification is recognized as a crucial strategy for enhancing agricultural sustainability and farmer resilience. In regions such as South Asia and Sub-Saharan Africa, studies have highlighted the role of diversification in mitigating risks associated with climatic variability and market fluctuations [34]. For instance, research conducted in India has shown that diversification into high-value crops, livestock, and agro-processing can significantly boost farmers' incomes and reduce poverty levels [35]. Similarly, studies in East Africa have demonstrated that diversification into horticulture and cash crops has improved smallholder farmers' livelihoods by providing access to new markets and increasing household income stability [36]. In West Africa, including Nigeria, diversification often includes a mix of traditional staple crops and high-value crops like cocoa and oil palm [36]. Research has indicated that in countries like Ghana and Nigeria, smallholder farmers practicing diversification are better positioned to cope with economic shocks and climate change impacts [24, 37]. These studies emphasized the importance of market access, infrastructure, and supportive policies in facilitating successful diversification. The welfare impacts of agricultural diversification have been explored in several empirical studies. Many of these studies focus on indicators such as income levels, food security, nutrition, and overall livelihood resilience. For example, in Southeast Asia, diversification into fish farming alongside traditional rice cultivation has been linked to improved nutritional outcomes and increased household incomes [34]. In Sub-Saharan Africa, research has highlighted the positive impacts of diversification on food security [38]. Studies conducted in Ethiopia and Niger have found that households engaged in diverse agricultural activities are less likely to experience food shortages and are better able to meet their nutritional needs, which is often attributed to the availability of a wider variety of food products and more stable income streams [39, 40]. In Nigeria, Inoni, Gani and Sabo [21] showed that farmers' age, farm income, credit access, extension contact, as well as farm size influenced farmers' diversification decisions and extent of diversification, and these factors also drive households' welfare. Likewise in northern Ghana, Baba and Abdulai [41] established the positive and significant relationship between household food security and diversification; while Danso-Abbeam et al. [38] also revealed that farmers' age, farm size, extension service and off-farm employment make significant contributions to farmers' decision to diversify and extent of diversification into crop-livestock diversification in a mixed farming system. Asante et al. [24] in their study in Ghana also revealed that off-farm income, farm size, use of tillage equipment and good road network are major determinants of farmers' decision to diversify into crop-livestock systems, while gender, credit access, extension service, market information, stable income and good road network were reported to influence farmers' extent of diversification in their study. In the study conducted by Mekuria and Mekonnen [27] in the central highlands of Ethiopia, the findings indicated that livestock holding, land rented out, and soil fertility influenced farmers' decision on crop-livestock diversity, while non-farm income, livestock holding, farmland size, land rented out, extension contact, cultivated irrigation land, soil fertility, distance to asphalt road, distance to project office, and improved seed influenced the extent to which farmers diversify crop-livestock integrated farming systems.

On the flip side, some studies even suggested that diversification into non-farm activities, such as petty trading and agro-processing, can significantly enhance income levels and reduce vulnerability to agricultural risks, and its success often depends on factors such as access to credit, education, and infrastructure. But, agricultural diversification goes beyond only crop diversification that is often considered in many related studies, hence the need for this study to bridge the gap.

4. Materials and Methods

4.1. Study Area

The study was conducted in Oyo State, which is predominantly an agrarian society situated in the southwestern part of Nigeria. Agriculture plays a vital role in the economy of the state, providing employment and livelihoods to a significant portion of the population. The state is known for its diverse agricultural activities, including the cultivation of crops such as maize, cassava, yam, and vegetables, as well as livestock farming. The agricultural sector not only contributes to the state's Gross Domestic Product (GDP) but also ensures food security and provides raw materials for agro-based industries. Other livelihood activities commonly practiced in the study area include trading, vocational activities such as carpentry, bricklaying, and crops, and livestock rearing, among many others. The state is mostly inhabited by the Yoruba ethnic group and is homogenous in nature, with few other minority ethnic groups who are spread across the state. Oyo State has 33 Local Government Areas (LGAs), of which 28 LGAs are considered rural and semi-rural, and divided into 4 distinct Agricultural Development Program (ADP) zones, namely Ibadan, Ibarapa, Ogbomoso, and Oyo ADPs [42].

4.2. Sampling Procedure and Sample Size Determination

A multistage sampling technique was used to select the sample size for this study. Oyo State is made up of 4 Agricultural Development Program (ADP) zones which are structured based on different Local Government Areas (LGAs), namely: Ibadan/Ibarapa zone with 9 LGAs, Ogbomoso zone with 5 LGAs, Oyo zone with 5 LGAs, and Saki zone with 9 LGAs. In the first stage, one-third of the LGAs in each zone were randomly selected to arrive at 10 LGAs in total. Because of the homogeneous nature of the villages in the study area, the second stage involved the random selection of 2 villages from each of the LGAs, making 20 selected villages. The study also applied a random proportionate to size sampling technique in the third stage to select the sample size for this research, owing to the variations that exist in the population of the people across the selected villages. The sample size selection process was explicitly presented in the **Table A1**.

Importantly, there are three criteria to consider in choosing a suitable sample size for any study: the level of precision, confidence level and the degree of variability. Therefore, this research selected the representative sample for this study through the validated method for sample size determination for an unknown population, using the confidence level technique of Z-score [43]. This is expressed as follows:

$$n_0 = \frac{z^2 \times p(q)}{e^2} \tag{1}$$

The followings are also defined as:

n_0 = Sample size to be estimated;

z^2 = Selected critical value of desired level of confidence or risk;

p = Estimated proportion of an attribute that is present in the population or maximum variability of the population;

$q = 1 - p$;

e = error margin.

Thus, at 0.05 error margin (95% confidence interval), the sample size was calculated as:

$$n_0 = \frac{(1.96)^2 \times 0.5(1 - 0.5)}{(0.05)^2} = 384.16 \tag{2}$$

Of this figure (384 farmers), two-thirds of this estimated value were used as the sample-size because of time and resource constraints. This translates to about 256 farmers who were used as the final representative sample for this study. However, due to incomplete information, responses from 249 farmers entered the final analyses, representing approximately a 97% response rate.

4.3. Research Design and Method of Data Collection

Cross-sectional study design was adopted for this study. The cross-sectional data were collected through the use of a well-structured interview schedule. This was administered to the respondents to elicit necessary information on their personal and socio-economic features, participation in agricultural diversification activities, and the welfare state of the farmers in the area of study.

4.4. Measurement of Diversification by Herfindahl-Hirschman Index Computation

Various methods have been developed to conceptualize the diversification or specialization of agricultural activities. Their different approaches indicate the extent of dispersion and concentration of activities in a given time and space. According to Johns, Apsara and Lachhaman [44] as well as Narmadha and Karunakaran [45], the extent of crop diversification at a given point in time may be examined by using several indices namely: Herfindahl-Hirschman Index (HI), Simpson Index (SI), Ogive Index (OI), Entropy Index (EI), and Modified Entropy Index (MEI). Prominent among the techniques is the Simpson index of diversity which is an area-based metric that assesses horizontal diversification based on the proportionate areas allocated to different enterprises, making it particularly effective for estimating crop diversification [24]. Of all, both the HI index and the Ogive index can assess "agricultural diversification in terms of revenue generated from each enterprise or domain", making both approaches suitable for assessing diversification among crop, livestock and/ or integrated crop-livestock enterprises [24, 46]. It is important to reiterate that for comparative and standardization purposes, this study applied the HI formula to estimate the Herfindahl index using the revenue shares (for each of the agricultural enterprises, namely, crop, livestock, and crop-livestock) of the total crop and/ or livestock revenue for each farmer. The resultant indices are subtracted from 1 to compute the diversification index across all three enterprises (details provided in the methodology).

Following Asante et al. [24], computation of HI starts from getting the revenue shares, which is:

$$S_k = \frac{R_k}{\sum_{k=1}^{n} R_k} \tag{3}$$

Where:

S_k = revenue share of the *k*th crop or livestock in the total revenue for a farm's crops, livestock and/ or the crop–livestock enterprises, respectively;

R_k = revenue from the *k*th crop or livestock enterprise for a sample farmer;

$\sum_{i=1}^{n} R_k$ = total farm revenue for the crops, livestock and/ or the crop–livestock enterprises, respectively;

k = 1, 2,..., n (number of enterprises involved in all farmers' farming operations).

Based on the method used by Asante et al. [24], which is also in line with the technique used by Appiah-Twumasi and Asale [46], the Herfindahl-Hirschman index was computed by taking the sum of squares of the crop and/ or livestock revenue shares of the total crop and/ or livestock revenue for each of the farmers.

The Herfindahl index is now specified as:

$$HI = \sum_{k=1}^{n} S_k^2 \tag{4}$$

The HI technique, as widely used in economic literature to gauge enterprise diversification or specialization, facilitates cross-comparison of findings, which makes it appropriate to use.

4.5. Methods of Data Analysis

Descriptive statistics such as contingency tables, frequency distributions, percentages, and mean values were used to explore the dataset and describe the respondents' personal and socio-economic characteristics. Specifically, agricultural diversification comprises of diversification into crops production, livestock production, and/ or integrated crop-livestock production mix. Therefore, to compute agricultural diversification among the farmers in the study area, this study used the Herfindahl index (HI) technique. The first step is to calculate the Herfindahl index for each of the agricultural enterprises using the revenue (which is assumed to be influenced by

quantities produced, quantities sold, prices, and transaction costs) shares of the crops and/ or livestock from the total crop and/or livestock revenue for each sample of farmers. The use of revenue was adopted for the sake of standardization, as mentioned earlier. Then, the diversification indices for each of the enterprises (crop diversification index (CDI), livestock diversification index (LDI), and the crop-livestock diversification index (CLDI)) were computed by subtracting the estimated HI for each of these enterprises from 1 (one). The resultant indices range from zero (0) to one (1), such that higher values indicate a lower extent of diversification and vice versa. When there is no diversification, it takes the value 1, and as the diversity increases, it tends to move towards 0. In other words, with an increase in diversification, the index would decrease, and vice-versa. This index takes a value of one when there is complete concentration and approaches zero when diversification is 'perfect'. According to Asante et al. (2018), a farmer is said to be diversified (1) in crops, livestock and/or integrated crop-livestock farming systems if he/ she has a CDI, LDI and CLDI > 0.5, respectively, and otherwise (0). That is, CDI = 1 – HI (for crop); LDI = 1 – HI (for livestock); CLDI (Agricultural diversification for crop-livestock mix) = 1 – HI.

Going forward, the Cragg two-step model, otherwise known as the double hurdle model (D-H model), [47] was also applied to determine the correlates (internal and external dynamics) of agricultural diversification in the study area, which explains why some farmers diversified and others did not, as well as the extent of agricultural diversification among the farmers in the study area. For this study, it is assumed that the two decisions were made in different stages, and that the same factors have different effects on these decisions. So, in the first step of the estimation process for the D-H model, the discrete decision to diversify (separately for each of the agricultural enterprises) was analyzed using the probit model, and by default, this is simultaneously followed by an estimation of the decision on the extent of diversification among the diversified sub-sample farmers using a truncated regression (tobit) model.

Similarly, the welfare index score approach was adopted to examine farmers' welfare status. This research followed the estimation approach of UNDP [48], Gautum and Andersen [49] and UN-DESA [50] to construct the farmers' welfare index score, using both economic and non-economic welfare components. Furthermore, the Sample Selection Ordered Probit Regression Model was applied to estimate the effect of agricultural diversification and other observed and unobserved factors on the levels of households' welfare in the area of study.

Also, the composite score technique was used to obtain the ordinal categorization of farmers into high, moderate and low levels of agricultural diversification and welfare status levels (using the respective indices), as previously used by Adepoju et al. [51]. The categorization was achieved using:

High category/level = Scores between maximum point (1) to (Mean + Standard Deviation) point

Moderate category/level = Scores between low and high categories

Low category/level = Scores between lowest point (0) to (Mean – Standard Deviation) point.

4.6. Model Specification and Empirical Strategies: Double Hurdle Model

The double-hurdle model introduced in 1971 by Cragg has been frequently used to model two-stage decision processes [47]. An advantage of the double-hurdle model compared with the standard univariate Tobit model is that it provides a more flexible framework to model the observed consumer behavior as a joint choice of two decisions instead of a single decision. The double-hurdle model is designed to analyze instances of an event that may or may not take place and if it takes place, takes on continuous values. For this study, a decision on farmers' involvement in agricultural diversification is made first, and then the decision on the extent of involvement in agricultural diversification activities follows. That is, the double-hurdle model was applied to investigate the factors influencing farmers' decisions to engage in agricultural diversification, and the factors driving the levels of agricultural diversification among the diversified farmers. This model is chosen because it assumes that households make two sequential decisions. Each hurdle is conditioned by the farmer's socio-economic characteristics and other observed and unob-

served factors. In estimating the double-hurdle model, a probit regression (using all observations) is followed by a truncated regression on the non-zero observations [47].

The first hurdle is then represented by:

$$d_i* = Z_i' + u_i \text{ (decision to engage in agricultural diversification (binary))} \quad (5)$$

$$y* = Xi' + v \text{(extent of involvement in agricultural diversification (index))} \quad (6)$$

$$d_i = 1 \text{ if } d* > 0 \quad d_i = 0 \text{ if } d* \leq 0 \quad (7)$$

The second hurdle closely resembles the Tobit model, which is expressed as:

$$y* = \max(y_i**, 0) \quad (8)$$

Finally, the observed variable, y_i, is determined by the interaction of both hurdles as follows:

$$y = d_i y_i* \quad (9)$$

u_i N (0, 1) v_i N (0, σ2)

If both decisions are made jointly (the Dependent Double Hurdle), the error term can be assumed to have a bivariate normal distribution defined as: (u_i, v_i) BVN (0, ψ).

According to He et al. [52], the two-stage decision nature implies that participation in agricultural diversification and consumption (extent of involvement in agricultural diversification) should be modeled jointly, partly to gain estimation efficiency.

4.7. Model Specification and Empirical strategies: Sample Selection Ordered Probit

Following De-Luca and Perotti [53], as well as Sunny et al. [54], the sample selection ordered probit regression model is expressed in two stage processes. Firstly, the outcome equation can be expressed as:

$$Y_j = \sum_{h=1}^{H} v_h 1\left(k_{h-1} < x_j\beta + u_{1j} \leq k_h\right) \quad (10)$$

Where:

Y_j = Outcome of interest (welfare status levels);

x_j = Outcome covariates (explanatory variables);

β = estimated coefficient; and

u_{1j} = a random-error term.

The observed outcome values v_1,. . .,v_H are integers such that $v_1 < v_m$ for $i<m$. κ_1,. . .,κ_{H-1} are real numbers, such that $\kappa_i < \kappa_m$ for $i < m$. κ_0 is taken as −∞ and κ_H is taken as +∞.

On the other hand, the selection equation can be expressed as:

$$S_j = 1\left(z_j\gamma + u_{2j} > 0\right) \quad (11)$$

Where:

S_j = 1 when observed *yj* and *0*, otherwise (agricultural diversification decision);

z_j = the covariates used for modeling the selection process (explanatory variables);

γ = the coefficient for the selection process;

u_{2j} = a random-error term.

Note: u_{1j}, u_{2j} have a bivariate normal distribution with mean zero and variance matrix.

4.8. Description, Measurement and A-Priori Expectations on the Variables

The **Table 1** highlights the description, unit of measurement of the variables used in the analyses, as well as the a-priori expectations which have to do with the anticipated direction of movement of the variables. To estimate the parameters of the models of Equations (5), (6), (9) and (10) for the two decisions (response variable in DH model) relating to agricultural diversification, and the estimation of the effects of agricultural diversification on the levels of farmers' welfare status (response variable in ordered probit sample selection model), a set of explanatory variables which are expected to influence the two decisions and the levels of farmers' welfare status, respectively were highlighted in **Table 1**. These variables were selected based on statistical evidence of relationship and past related empirical studies. For instance, the age of respondents which may have either a direct or inverse influence on diversification and welfare status has been reported to have non-harmonious effects in the literature [38, 40]. It is also a proxy for farming experience, and a major determinant in farming household decision making owing to the fact that older respondents have a high likelihood of having accumulated experience (years

of farming experience, noted to have a direct influence on diversification decision and welfare status), access to resources and information. All else equal, the propensity to engage in agricultural diversification is high compared to the younger population of farmers. Years of formal schooling which represent the educational status of farmers have been found to have positive effects on diversification [40]. Educated individuals are likely to be better informed about alternative crops and/or livestock adaptable to existing production conditions; thus, a positive influence on diversification decisions was anticipated.

Likewise, household size which represents the size of the family can also exert either a direct or inverse influence on diversification and welfare status [40]. While a higher household size can have a positive influence on diversification and farmers' welfare given the availability of family labour, it can also have a negative effect on household welfare, given the subsistence nature of most of the farmers. Then, distance to market is an indicator of physical access to markets and proximity to a place of economic engagement also has mixed effects on diversification [27]. Farmers closer to markets tend to diversify to meet the changing market demand for various agricultural produce especially the perishable ones. This positively affects the supply chain which may further encourage diversification and by extension welfare status among the farmers. On the other hand, greater distances from markets may actually discourage diversification and have a debilitating effect on farmers' income and general welfare status.

Frequency of extension visits typically hints at the rate at which farmers have contact with extension agents for extension services. Extension service is a potent source of information for farmers to be abreast of the latest developments in farming systems in terms of improved technologies which could induce positive diversification decisions and the extent of diversification among the farmers [21, 27]. Also, the dependency ratio, which speaks to the ratio of dependants to the number of economically active persons within the household has been reported to have a mixed effect on the extent of diversification. A greater number of dependants can induce a lower welfare status especially among resource-poor farmers and this in turn can also induce positive diversification decisions, with greater consequences on the extent of diversification, given the resource limitations [40].

In addition, food security status also exerts a mixed effects on the diversification (both decision and extent) and farmers' levels of welfare status in that food secure farmers may be induced to take more positive diversification decisions in a bid to maintain sustainable food security status, which will evidently improve farmers' levels of welfare status, and vice versa. With timely access to agricultural credit, farmers will be able to procure the needed inputs and other production resources to diversify more, and this is likely to have a positive effect on farmers' welfare status [40]. The mode of land acquisition and per capita income also have mixed effects on farmers' decisions to diversify and the extent of diversification, as well as farmers' levels of welfare. Compared to having access to a large hectare of farmland, land acquisition through inheritance always leads to fragmentation of farmland with negative consequences on farm output, which evidently discourages positive diversification decisions and the extent of diversification [38]. The spillover effects from such a situation are lower farm output which results in lower income and per capita income, given the household size, as well as poor welfare conditions reflected in a vicious cycle of poverty and deprivation. Conversely, engaging in non-agricultural activities is expected to generate non-farm income, and this could provide farmers with additional income streams that can be used to expand their farming business. Therefore, a higher non-farm income could have a mixed effect on farmers' diversification decisions and their extent as well as farmers' levels of welfare status if a wrong decision is made. This is because of the potential conflict in decision making on how to allocate resources among the available alternative income generating activities.

5. Results and Discussion

5.1. Farmers' Personal and Socio-Economic Characteristics

Table 2 presents the results from the data on the farmers' personal and socio-economic features in the

Table 1. Description and measurement of variables.

Variables	Variable Type	Measurement	A-Priori Sign
Agric. Diversification (Response)		Categories	
j_0	Non-diversified = 0	0	N/A
j_1	Low diversification (diversified = 1)	1	N/A
j_2	Moderate diversification (diversified = 1)	2	N/A
Welfare status (Response)			
j_0	Low welfare category	0	N/A
j_1	Moderate welfare category	1	N/A
j_2	High welfare category	2	N/A
Explanatory variables			
Age	Continuous	Years	+/ –
Years of formal schooling	Continuous	Numbers of years spent in school	+
Household size	Continuous	Total number of persons in the household	+/ –
Access to market	Dummy	1 if accessed, 0 if otherwise	+
Distance to market (inverse)	Continuous	Kilometer (Km)	+/ –
Frequency of extension visit	Continuous	Numbers of visits	+
Dependency ratio	Continuous	Numbers of economically dependent people	+/ –
Food security status	Dummy	1 if food secure, 0 if otherwise	+/ –
Access to credit	Dummy	1 if accessed, 0 if otherwise	+
Years of farming experience	Continuous	Numbers of years in farming	+
Mode of land acquisition	Dummy	1 if inheritance, 0 if otherwise	+/ –
Non-agric. diversification	Dummy	1 if diversified in non-farm, 0 if otherwise	+
Log of per-capita income	Continuous	Naira	+/ –

Note: N/ A—Not applicable.
Source: Authors' compilation.

study area. The findings showed that most of the respondents were male (71.9%), while the estimated mean age was 47.5 years. This points to the male dominance in agricultural activities; hence the need for policies that promote gender-just inclusion programmes that can attract female individuals to engage in agriculture and agricultural-related activities. Also, the average age suggests that the farmers were still in their active and economically viable age which can promote positive diversification decisions. The mean years of formal schooling and household size were found to be about 8 years and approximately 5 persons, respectively. The implication of this is that on average, farmers in the study area have a basic level of education which can permit them to read and write. Also, the results showed that there are at least 5 individuals in each of the farming households. The findings also indicated that in each household, there were about 3 persons who are employed. By implication, this suggests that the working members of the households can fairly cater to the responsibilities and well-being of their respective household members, so that they can be better off in terms of welfare conditions.

Table 2. Distribution of farmers' based on personal and socio-economic characteristics (n = 249).

Variables	Frequency
Gender	
Female	70 (28.1)
Male	179 (71.9)
Age-group (years)	
< 30	39 (15.7)
31–40	44 (17.7)
41–50	67 (26.9)
51–60	57 (22.9)
Above 60	42 (16.9)
Mean (47.5 years)	
Years of education (years)	
No formal education	50 (20.1)
< 6	63 (25.4)
7–12	103 (41.4)
Above 12	33 (13.3)
Mean (8.1)	
Household size group	
< 3	32 (12.9)
4–6	189 (75.9)
Above 6	28 (11.2)
Mean (4.9)	
Numbers of employed members	
< 2	187 (75.1)
3–4	60 (24.1)
Above 4	2 (0.8)
Mean (2.9)	
Agricultural Diversification	
*Crop diversification (CD)	112 (44.98)
*Livestock diversification (LD)	152 (61.04)
*Crop-Livestock diversification (CLD)	227 (91.16)

Note: Figures in parentheses are percentage values;
*-Non-mutually exclusive events.
Source: Field survey, 2023.

Given the agricultural diversification domains' values obtained, it can be deduced that each event is non-mutually exclusive in nature. The results revealed that almost 45% of the farmers concentrated on crop farming and crop diversification, while approximately 61% focused on livestock farming alone. However, about 91% of the farmers engaged in a crop-livestock diversification mix. This suggests that most of the farmers in the study area engaged in both crop production and livestock rearing, which is expected to contribute positively to the farmers' levels of welfare status.

5.2. Levels of Agricultural Diversification and Welfare

Establishing the relationship between the level of agricultural diversification and welfare status supports feasible policy formation strong enough to enhance farmers' prosperity. Thus, **Table 3** presents the results of the contingency evaluation of the respondents based on the concepts of interest in this study.

Of the 249 sampled respondents, the majority (220 respondents accounting for 88.35 per cent of the sampled population) have moderately diversified their farming activities. Furthermore, only 7 respondents representing 2.81 per cent of the total sampled respondents were found operating on a low diversified farming system, while only 22 respondents (8.84 per cent of the sample respondents) are yet to diversify their farming activities. Interestingly, we also found in **Table 3** that a higher level of agricultural diversification resulted in a higher welfare status for smallholder farmers. For instance, most of the farmers who were found operating a moderately diversified farming system have a moderate level of welfare status. The results also indicated that across all the levels of agricultural diversification classification, the majority of the farmers were found in the moderate level of welfare status. This reinforces the earlier explanation on the levels of agricultural diversification in line with the levels of welfare status among the sample farmers in the study area. This result suggests that if the farmers are adequately empowered with the required enlightenment and training, there is a good chance that many farmers would fully diversify their agricultural activities, and by extension obtain an enhanced welfare status.

It is very instructive to also state that where there is no relationship between variables (H_0) according to Torres-Reyna[55], then, the X2 (chi2) is expected to be statistically significant for the null hypothesis to be rejected; likewise, the foregoing statement also applies to the likelihood ratio test value. Thus, a statistically significant chi-square test value of $p < 0.01$ according to **Table 3** implies a differentiated association between the level of agricultural diversification and the welfare status of smallholder farmers exists in the study area. In addition, the Cramer's V value (which ranges from 0 to 1) measures the strength of association between the levels of agricultural diversification and levels of welfare status. Higher values show a strong relationship, and vice versa. Thus, the Cramer's V value of 0.21 as shown below **Table 3** reveals a weak association, and a plausible reason for this could be the moderate involvement of farmers in the diversification of their farming activities.

5.3. Correlates of Agricultural Diversification

The double hurdle estimation eases the evaluation of agricultural diversification status and the extent of diversification among the smallholder farmers in the study area. The model consists of two tiers. Tier 1 focuses on the determinants of whether a farmer engages in agricultural diversification or not, and gives an understanding of the factors that influence farmers' decisions to diversify. Tier 2 focuses on farmers who have diversified their farming system and examines the factors that influence the extent of diversification. The results from the estimation are presented in **Table 4** below.

Estimation from Tier 1 reveals the statistical significance of age at $p < 0.01$ with a coefficient of 0.025. This suggests that holding other variables constant, a unit increase in the age of the farmer is associated with a 0.025 unit increase in the probability of transitioning from a non-diversified farmer to a diversified farmer. Intuitively, the implication of this is that older farmers are more likely to engage in agricultural diversification, given their accumulated farming experience over the years. Our finding is in tandem with the result from the study by Inoni, Gani and Sabo[21], where a direct rela-

Table 3. Levels of agricultural diversification and welfare status of the respondents.

Levels of Agricultural Diversification	Levels of Welfare Status			
	Low	**Moderate**	**High**	**Total**
Non-diversified	4	15	3	22
	18.18	68.18	13.64	100.0
	10.81	8.82	7.14	8.84
Low	1	5	1	7
	14.29	71.43	14.29	100.0
	2.70	2.94	2.38	2.81
Moderate	32	150	38	220
	14.55	68.18	17.27	100.0
	86.49	88.24	90.48	88.35
Total	37	170	42	249
	14.86	68.27	16.87	100.0
	100	100.0	100.0	100.0

Note: Pearson-$chi^2(4) = 37.5380$, $Pr = 0.000$.
Likelihood-ratio $chi^2(4) = 37.7754$, $Pr = 0.000$, Cramér's $V = 0.2106$.
Source: Data analysis, 2023.

tionship between age and farmers decision to diversify was also reported, stating that experienced older farmers understand the need to diversify production to mitigate the effect of climatic variability, price shocks and total crop failure. On the contrary, our finding is in contrast with the report by Danso-Abbeam et al.[38] where older household heads were reported to be less involved in integrated crop-livestock farming owing to its multitasking nature, relative to the younger population.

From **Table 4**, the dependency ratio's coefficient is −0.120. This means that an increase in the dependency ratio decreases the likelihood of adopting agricultural diversification by 0.120 units. This effect was found to be statistically significant at ($p < 0.1$); while the negative sign of the coefficient suggests that a higher dependency ratio relative to family income might deter farmers from diversifying agricultural activities. Put differently, a high dependency ratio would likely limit the economic resources available to farmers for diversification activities. In a related study conducted in Ghana by Asante et al.[24], the study found that an increased dependency ratio negatively influences agricultural diversification, which also reinforces the finding of this study.

The **Table 4** also shows that farmers' access to the market is significant with a coefficient of 0.512. This result indicates that at ($p < 0.1$), a unit increase in farmers' accessibility to the output market increases the probability of farmers adopting agricultural diversification by 0.512 units. This result implies that proximity to market places creates a better opportunity for a farmer to engage with other farmers, make better profits and exchange ideas on the need for agricultural diversification. This finding aligns with P.K. Joshi, K. Joshi and Birthal[56] who emphasized that better market access reduces the transaction or marketing costs in South Asia, thereby enhancing easy sales of agricultural produce. P.K. Joshi, K. Joshi and Birthal[56] also reported that this assisted them in reducing the risks of possible post-harvest losses, particularly for perishable agricultural products. On the other hand, the conclusions from the study by Ibrahim et al.[57] showed that farming households that are farther away from the main markets face high costs of transportation to get their produce to the market and in such instances, they only cultivate for subsistence rather than commercial purposes. However, the study from Sichoongwe et al.[34] reported otherwise in their study conducted in Zambia where they found that an increase in distance to the market significantly increases the probability of a farmer's participation in crop diversification; this to some extent defeats the rationality principle in economics.

Farmers' food security status was found to be statistically significant at ($p < 0.1$) with a coefficient of 0.132. This evidences that an increase in farmers' food secu-

Table 4. Correlates of agricultural diversification.

	Coefficient (dy/ dx)	Std. Error	z	p > |z|
Tier 1 (Agricultural diversification decision)				
Age	0.0250	0.0098	2.55***	0.011
Years of formal schooling	0.0341	0.0232	1.47	0.142
Dependency ratio	–0.1204	0.0725	–1.66*	0.097
Access to market	0.5123	0.2963	1.73*	0.084
Frequency of extension	–0.0160	0.1132	–0.14	0.887
Food security status	0.1320	0.0729	1.81*	0.070
Mode of Land acquisition	0.2953	0.2753	1.07	0.283
Constant	–0.1795	0.6843	–0.26	0.793
Tier 2 (Extent of Agricultural Diversification)				
Age	0.0010	0.0003	3.25***	0.001
Years of formal schooling	–0.0007	0.0008	–0.92	0.355
Mode of Land acquisition	–0.0153	0.0100	–1.52	0.128
Years of farming experience	–0.0012	0.0006	–1.90*	0.057
Log of per-capita income	–0.0321	0.0090	–3.56***	0.000
Food security status	0.0316	0.0170	1.86*	0.063
Access to credit	0.0205	0.0102	2.00**	0.046
Constant	0.8395	0.1133	7.40	0.000
Sigma				
Constant	0.0592	0.0027	21.31	0.000

Wald-chi^2 (7) = 13.61; *prob > chi*^{2} = 0.0586; *, ** and *** mean 10%, 5% and 1%, respectively.
Source: Data analysis, 2023.

rity is associated with an increase of 0.132 in the likelihood of engaging in agricultural diversification among the farmers. This further suggests that farmers who are food secure have a higher propensity to diversify their agricultural activities, all things being equal. This aligns well with utility theory because farmers tend to engage in activities that return higher benefits and maximize their satisfaction. Besides, Moraine et al.[20] reported in their study conducted in Europe that diversified farms confer food security, improve dietary preference, increase household income, and reduce vulnerability to shocks. The motivation and drive to achieve these benefits can positively influence farmers' decisions to diversify their agricultural activity.

Considering the results in Tier 2 of **Table 4**, the age of the household head has a coefficient of 0.001, suggesting that a unit increase in age is associated with a 0.001 unit decrease in the predicted extent of diversification among farmers operating a diversified farming system. This effect is statistically significant ($p < 0.01$), implying that older farmers are less likely to put more effort into increasing the extent of their agricultural diversification activities as a result of aging. This finding agrees with the submission of Danso-Abbeam et al.[38] in a related study in Ghana.

Years of farming experience revealed a negative coefficient of –0.0012, implying that a unit increase in farming experience results in a 0.0012 unit decrease in the predicted extent of diversification among the farmers operating a diversified farming system, and this effect is marginally significant ($p < 0.1$). Therefore, the result implies that experienced farmers are less likely to engage in additional diversified agricultural activities as they may be found directing their attention to a limited range of agricultural activities. This result negates the findings of Ashfaq et al.[58] who noted in Pakistan that years of farming experience positively and significantly influenced the extent of diversification among the farmers.

At ($p < 0.01$), the coefficient of –0.0321 associated with per capita income indicates that a percentage change (increase) in per capita income resulted in a decrease of 0.0321 units in the predicted extent of diversification among farmers operating a diversified farming system. This could imply that a higher per capita income

could slightly narrow the range of agricultural diversification activities among farmers operating a diversified farming system. This finding is in contrast to what Asante et al.[24] reported in their study in Ghana where the authors explained that farmers' perception of assured stable income through diversification was found to be positive and highly significant in determining the continuous diversification decision.

The positive coefficient of 0.0316 associated with farmers' food security status is statistically significant at ($p < 0.1$), suggesting that being food secure positively and statistically influenced the predicted extent of diversification among farmers operating a diversified farming system by 0.0316 units. This implies that improved gains (in terms of being food secure) from agricultural diversification are likely to inspire farmers to further diversify their farming operations, aiming for better returns. Consistent with Moraine et al.[20], diversification is often driven by food security and income enhancement, thus, motivating farmers to expand more on their agricultural activities.

The results also indicated that access to credit positively and significantly ($p < 0.05$) influenced the predicted extent of agricultural diversification among farmers operating a diversified farming system by 0.0205 units. Compared to farmers without credit access, the result hints that those farmers who accessed credit indeed have a comparative advantage in terms of farmers' engagement and extent of engagement in a broader range of agricultural diversification activities. This result is as expected, and tallies with the findings of Mango et al.[28] and Danso-Abbeam et al.[38] in their separate studies conducted in Ghana and Malawi, respectively, where they observed that access to supply-side policy instruments such as agricultural credit facilities assisted farmers to diversify more than those without it. To diversify agricultural production into crops and livestock, a farmer requires financial liquidity to purchase additional land and other inputs (e.g., labor) and equipment for crop cultivation. Thus, the availability of finance to farmers in the form of cash or input supply could hasten the process and extent of diversification among the farmers.

Importantly, the estimation produced the residual standard deviation (sigma—δ) which represents the variability of the unobserved factors affecting the extent of diversification among farmers operating a diversified farming system. The value of 0.059 shown in **Table 4** implies that the observed values in the dataset are spread around the predicted values with a standard deviation of approximately 0.059. This value provides information about the unobserved heterogeneity (5.9%) not accounted for by the model, which may not present any significant issue or distortion to the findings. Then, the post-estimation test—Wald chi^2 (7) returns a value of 13.61 and a Prob > chi^2 of 0.0586 which is statistically significant at the 5% probability level. This is an indication that the estimates from the fitted D-H model appear consistent and reliable.

5.4. Effect of Agricultural Diversification on the Levels of Farmers' Welfare Status

Initiatives, schemes and/or innovative approaches prescribed for farmers' adoption should have the capacity to enhance farmers' welfare and livelihood. Thus, this section presents the influence of important farmers and farm-level attributes, including agricultural diversification impacts on farmers' levels of welfare amidst challenging environments. This was achieved by evaluating a sample selection ordered probit regression model as presented in **Table 5**, which requires the inclusion of at least one distinctive variable in the explanatory variables specified for the selection equation (that is, agricultural diversification decision) different from the explanatory variables specified for the outcome equation (levels of welfare status)[59].

Therefore, the distinctive variable (frequency of extension contacts) fitted in the selection equation (participation in agricultural diversification) serves as a control variable for unobservable factors such as farmers' innate abilities and farmers' knowledge that may bias the effect of farmers' involvement in agricultural diversification. This variable is expected to influence farmers' decision on agricultural diversification directly but should not directly influence the outcome (levels of welfare status). The estimation results are presented in **Table 5** below.

Table 5. Effect of agricultural diversification on the levels of farmers' welfare status.

Variables	Coefficient	Std. Error	z	p > |z|
Levels of welfare status (Outcome)				
Agricultural diversification	0.2029	0.0841	2.41**	0.016
Age	0.0053	0.0056	0.96	0.339
Years of formal schooling	0.0145	0.0160	0.91	0.363
Household size	–0.1431	0.0696	–2.05**	0.040
Dependency ratio	–0.0430	0.0533	–0.81	0.419
Log of per capita income	–0.6154	0.2181	–2.82***	0.005
Distance to market (inverse)	1.0883	0.4167	2.61***	0.009
Non-agric. livelihood diversification	0.0944	0.3575	0.26	0.792
Years of farming experience	0.6898	0.3877	1.78*	0.075
Selection (participation decision)				
Years of formal schooling	0.0291	0.0227	1.28	0.199
Log of per capita income	0.6216	0.2846	2.18**	0.029
Frequency of extension visits	0.0172	0.0104	1.66*	0.097
Non-agric. livelihood diversification	–0.0709	0.1092	–0.65	0.516
Constant	–6.5164	3.4798	–1.87	0.061
aux_lvl_welf (cut-points for welfare levels)				
_cut1	–7.4164	2.7227	–2.72***	0.006
_cut2	–6.5176	2.7159	–2.40**	0.016
rho - ρ (correction term)	–0.0289	0.0145	–1.98**	0.047

Note: Log likelihood = –333.467;Wald-chi^2 (13) = 28.15.
Likelihood ratio test for rho = 0: *chi^2*(1) = 2.94; *Prob>=chi^2* = 0.0866.
*, ** and *** mean 10%, 5% and 1% respectively.
Source: Data analysis, 2023.

Inferring from **Table 5**, the log-likelihood value of –333.467, Wald-chi2 value of 28.15 at df-13, and prob > chi2 of 0.0086 affirm a statistically significant probability level at 5 percent. This implies that the fitted model is reliable and mirrors the survey dataset. The values –7.4164 and –6.5176 associated with the two cut-points in **Table 5** are the threshold parameters and are statistically significant at 1 percent and 5 percent ($p < 0.01$, $p < 0.05$) probability levels, respectively. According to Ender [60], these threshold parameters indicate the existence of two different equations in the fitted model, but the results appear like a single model equation because of how the dependent variable is ordered (levels of farmers' welfare status). In particular, the cut-points or thresholds define the boundaries between the three welfare statuses, which permit the designation of individuals to the appropriate classification of welfare (low, moderate and high) based on their predicted latent scores from the ordered probit regression model.

In **Table 5**, agricultural diversification, household size, per capita income, proximity to market (expressed as an inverse value of the distance to market), and years of farming experience contributed significantly to the levels of welfare status in the study area. Other variables (age, years of formal education, dependency ratio and livelihood diversification in non-agricultural activities) appeared as non-significant factors.

The coefficient for agricultural diversification is positive and statistically significant (0.2029, $p < 0.05$). This result hints that more positive decisions made on agricultural diversification by farmers lead to a significant increase in the odds of moving to a higher welfare status category. This result is expected, and it implies positive decisions on agricultural diversification have a welfare-enhancing effect. This finding is in tandem with a-priori expectation, and agrees with Mango et al. [28] in their related study conducted in Malawi where the authors reported that farmers' diversification has a direct effect on the farmers' food security status (a proxy of welfare). The authors went on to emphasize that individuals with higher diversification intensities are less food insecure compared to those with relatively lower diversifi-

cation intensities. Similarly, Tankari, Glatzel and Demmler[61] noted in a related study carried out in Niger that diversification had a negative impact on the poverty gap (a proxy for welfare). This is to say that diversification reduces the poverty gap among the farmers, and those who diversify benefit from diversification decisions in terms of reducing or closing the poverty gap more than those farmers who did not diversify.

An increase in household size was discovered to significantly decrease the odds of moving to a higher welfare status category (–0.1431, $p < 0.05$). This tips that farmers having large members size tend to have lower welfare status. All things being equal, the chances of farmers moving to a higher welfare status are very slim, given the burden of responsibilities associated with a large family size. This finding corroborates Tankari, Glatzel and Demmler's[61] findings where it was reported that larger household sizes in Niger increased the probability of being poor owing to a higher dependency rate.

A strong and significant association (–0.6154, $p < 0.05$) that increases the odds of moving a farmer to a higher level of welfare status was also observed for a higher percentage change in per capita income. This result suggests that higher income levels are a crucial determinant of improved welfare status among the farmers. This result agrees with the findings of Asante et al.[24] in their study in Ghana where the authors observed that farmers' perception of generating stable income through diversification was positive and significant in driving a continuous diversification process which by extension has a welfare-increasing effect.

As revealed in **Table 5**, an increase in distance to the market (inverse value of the distance to market) directly and significantly affects the farmers' welfare level, and this increases the odds of moving to a higher level of welfare status (1.0883, $p < 0.05$). The implication of this is that farmers closer to the markets tend to have better welfare status. In addition, this hints that market proximity and investment opportunities can positively impact farmers' welfare status. While agricultural diversification has been established to significantly influence the levels of farmers' welfare status in this study, Mekuria and Mekonnen[27] in their study conducted in Ethiopia emphasized proximity to the market as a motivating factor for agricultural diversification, which implicitly affects farmers' welfare status. This is because shorter distances (high proximity) between the farmers' residence and/or farm gate and the market favor agricultural diversification compared to those residing far away from the market, who, by their proximity, have a lower propensity to engage fully in agricultural diversification activities; apparently, this has a consequential effect on farmers' welfare status. For the years of farming experience, the variable showed a direct and statistically significant effect on the levels of farmers' welfare status (0.6898, $p < 0.1$). All things being equal, an increase in years of farming experience increases the odds of moving to higher levels of welfare status. This is expected because years of farming experience is a human capital resource which drives growth and development in individuals.

In the selection (participation decision) part of **Table 5**, years of formal schooling and participation in non-agricultural livelihood activities did not show any statistically significant effects on the likelihood of being selected into the sample. This posed no problem to the model. However, per capita income and frequency of extension contacts have significant effects on the selection equation. The positive effects of per capita income and frequency of extension contacts suggest that both variables are likely to induce positive selection bias in the model. That is, farmers with higher percentage change in income and those with more contacts with extension personnel are more likely to be selected into the sample.

The reality surrounding this suspicion is revealed by the statistical significance of the selection correction term—rho (ρ), which mitigates any potential bias and ensures valid inference of the fitted model. From the results, the correction factor showing the correlation between the error terms in the two equations (selection and the outcome equations) is –0.0289, and statistically significant at $p < 0.05$. This implies that the correlation or self-selection bias in the model is very weak. According to Certo et al.[62], this might not be unconnected with the estimation that observed a strong exclusion restriction and model identification caveats required for the model. Further, based on the submission of Baiyegunhi, Hassan and Ortman[63], the negative correction factor—

rho (ρ), which is significantly different from zero, also reinforces the likely presence of selection bias from the unobservable factors.

The results also revealed a likelihood-ratio test for rho(ρ) = 0, which also rejects the null hypothesis at the 5% ($p < 0.05$) probability level. In the context of a sample selection model, the auxiliary equation in the third panel, often referred to as the "Auxiliary Level Equation" or simply "Auxiliary Equation" also plays a specific role. It defines the thresholds (cut-points) that divide the ordinal dependent variable (levels of welfare) into its different ordinal categories (low, moderate and high), helping to determine how individuals are categorized based on their predicted welfare latent scores. Summarily, factors that significantly impact the levels of farmers' welfare status include agricultural diversification, household size, per capita income, distance to market and years of farming experience, while other factors such as age, years of schooling, dependency ratio, and participation in non-agricultural activities did not show any significant effects on the levels of farmers' welfare status in the study area.

6. Conclusions

The impact of agricultural diversification on smallholder farmers' levels of welfare status is multidimensional and driven by the interplay of economic, social and institutional factors. Evidence from the findings affirmed that agricultural diversification holds significant potential to enhance the well-being of smallholder farmers in diverse ways in the study area. The findings revealed that higher levels of agricultural diversification translate to a higher level of welfare status of the smallholder farmers, and most of the farmers who operated at a moderate level of agricultural diversification were found to be at a moderate level of welfare status. This implies that by embracing diversified farming systems, empowering the farmers according to their needs, and instituting pro-smallholder farmers supportive policies, smallholder farmers' livelihoods could be improved, enhanced to be resilient to shocks, and contribute to sustainable rural development. This will ultimately lead to a more equitable and prosperous agricultural sector, as well as improved welfare conditions. The study also showed that farmers' welfare status is driven by agricultural diversification, household size, per capita income, distance to market and years of farming experience.

7. Policy Recommendations

Promotion and incentivizing agricultural diversification based on local needs (context-specific), which considers the farmers' needs and preferences should be given attention, while policies that promote seamless access to credit and extension services, as well as market access, should also be developed. These factors were found to play critical roles in facilitating farmers' adoption of diversified farming systems and enhancing their welfare outcomes. Another crucial aspect is the need to invest in farmers' education and training programs which should focus on sustainable farming practices leveraging an active extension services delivery system to enhance farmers' skills and knowledge. Investment in rural infrastructure development, including a good road network and market facilities should be given priority, this could improve connectivity and market access to transport agricultural products, reduce transaction costs, and reduce the risks of post-harvest losses, particularly for perishable agricultural products. There is also the need to integrate climate-smart agriculture practices into agricultural diversification strategies, including conservation agriculture, as well as other sustainable land management practices. These practices are resilient to climate variability and are gateways to achieving better food security status. Another important aspect is that household size was shown to have an indirect influence on smallholder farmers' welfare status, hence, the urgent need for a mass enlightenment campaign against uncontrolled procreation that increases household size without any economic contribution to the rural farming household. This may help to control the likely financial burden that prevents smallholder farmers from fully diversifying their farming operations, and which has also impacted negatively on their welfare status.

Author Contributions

Conceptualization: A.K.J., S.O.O. and M.O.G.; Data curation: S.O.O. and T.A.B.; Methodology: S.O.O. and A.K.J.; Data analysis: S.O.O.; Writing—original draft prepara-

tion, review and editing: A.K.J., S.O.O., T.A.B. and M.O.G.; Supervision: S.O.O. All authors have read and agreed to the published version of the manuscript.

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Institutional Review Board Statement

The study was approved by the Research Ethics and the Postgraduate Research Committees, Department of Agricultural Economics, Faculty of Agricultural Sciences, Ladoke Akintola University of Technology, Ogbomoso, Nigeria.

Informed Consent Statement

Written informed consent has been obtained from the research subjects during the field survey, and to publish this paper in line with all standard ethical considerations as highlighted in the Helsinki's declaration on research protocols, which are: "anonymity, informed consent, privacy, confidentiality, and professionalism".

Data Availability Statement

The dataset for this research is available on request.

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Conflicts of Interest

The authors declare no conflict of interest.

Appendix A

Table A1. Sample size selection procedure.

Oyo State ADP Zones	Number of LGAs Selected in Each ADP—First Stage	Number of Villages Selected in Each LGA—Second Stage	Number of Respondents Selected (Proportionate to Size)—Third Stage
Ibadan/Ibarapa	3	6	69
Ogbomoso	2	4	60
Oyo	2	4	51
Saki	3	6	76
Total	**10**	**20**	**256**

Note: 249 responses were found suitable for the final analyses.
Source: Field survey, 2023.

References

[1] Michler, J.D., Josephson, A.L., 2017. To specialize or diversify: agricultural diversity and poverty dynamics in Ethiopia. World Development. 89, 214–226.

[2] Makate, C., Wang, R., Makate, M., et al., 2016. Crop diversification and livelihoods of smallholder farmers in Zimbabwe: Adaptive management for environmental change. Springer Plus. 5(1), 1135.

[3] Hansen, J., Hellin, J., Rosenstock, T., et al., 2019. Climate risk management and rural poverty reduction. Agricultural Systems. 172, 28–46.

[4] Larson, D.F., Muraoka, R., Otsuka, K., 2020. Rural Development Strategies and Africa's Small Farms. In: Gomez y Paloma, S., Riesgo, L., Louhichi, K. (eds.). The Role of Smallholder Farms in Food and Nutrition Security. Springer, Cham: Switzerland. pp. 45–77. DOI: https://doi.org/10.1007/978-3-030-42148-9_4

[5] Balogun, T.A., Samson, S.A., 2023. Sustainable maize crop production in Owena Basin, Nigeria. Asian Journal of Agricultural Extension, Economics & Sociology. 41(10), 613–633. DOI: https://doi.org/10.9734/AJAEES/2023/v41i102206

[6] Saleem, A., Anwar, S., Nawaz, T., et al., 2024. Securing a sustainable future: the climate change threat to agriculture, food security, and sustainable development goals. Journal of Umm Al-Qura Univ. Applied Sciences. 1–17. DOI:

https://doi.org/10.1007/s43994-024-00177-3

[7] Federal Ministry of Communications, Innovation and Digital Economy (FMCIDE), 2023. Accelerating our collective prosperity through technical efficiency: A strategic plan. Available from: https://fmcide.gov.ng/wp-content/uploads/2023/11/blueprint.pdf

[8] Crisis Group, 2021. Ending Nigeria's Herder-Farmer Crisis: The Livestock Reform Plan. Crisis Group Africa Report no. 302, 4 May 2021.

[9] Shaibu, U., 2023. Agricultural Sector Policy Periods and Growth Pattern in Nigeria (1960–2020): Implications on Agricultural Performance. IntechOpen: Zagreb, Croatia. pp. 1–13. DOI: https://doi.org/10.5772/intechopen.111382

[10] Herrero, M., Thornton, P.K., Mason-D'Croz, D., et al., 2020. Innovation can accelerate the transition towards a sustainable food system. Nature Food. 1, 266–272. DOI: https://doi.org/10.1038/s43016-020-0074-1

[11] Bhat, R., 2022. Emerging trends and sustainability challenges in the global agri-food sector. In: Bhat, R. (ed.). Future Foods. Academic Press: Burlington, MA, USA. pp. 1–21. DOI: https://doi.org/10.1016/B978-0-323-91001-9.00041-4

[12] Bizikova, L., Jungcurt, S., McDougal, K., et al., 2020. How can agricultural interventions enhance contribution to food security and SDG 2.1? Global Food Security. 26, 100450. DOI: https://doi.org/10.1016/j.gfs.2020.100450

[13] Cohen, B., 2006. Urbanization in developing countries: Current trends, future projections, and key challenges for sustainability. Technology in Society. 28, 63–80.

[14] Totin, E., Segnon, A., Schut, M., et al., 2018. Institutional perspectives of climate-smart agriculture: A systematic literature review. Sustainability. 10(6), 1990.

[15] Power, A.G., 2010. Ecosystem services and agriculture: Tradeoffs and synergies. Philosophical Transactions of the Royal Society B-biological Sciences. 365, 2959–2971.

[16] Campbell, B.M., Beare, D.J., Bennett, E. M., et al., 2017. Agriculture production as a major driver of the Earth system exceeding planetary boundaries. Ecology and Society. 22(4), 8.

[17] Giovanni, T., 2020. Agricultural diversification promotes multiple ecosystem services without compromising yield. Science Advances. 6, eaba1715. DOI: https://doi.org/10.1126/sciadv.aba1715

[18] Xueqing H., Wolfgang, W., Yi, Z., et al., 2022. Integrating agricultural diversification in China's major policies. Trends in Ecology and Evolution. 37(10), 819–822. DOI: https://doi.org/10.1016/j.tree.2022.07.002

[19] Swarnam, T.P., Velmurugan, A., Ravisankar, N., et al., 2018. Diversification of island agriculture—A viable strategy for adaptation to climate change. In: Sivaperuman, C., Velmurugan, A., Singh, A.K. (eds.). Biodiversity and Climate Change Adaptation in Tropical Islands. Academic Press: Berkeley, CA, USA. pp. 553–575. DOI: https://doi.org/10.1016/B978-0-12-813064-3.00020-X

[20] Moraine, M., Duru, M., Nicholas, P., et al., 2014. Farming system design for innovative crop–livestock integration in Europe. Animal. 8(8), 1204–1217. DOI: https://doi.org/10.1017/S1751731114001189

[21] Inoni, O.E., Gani B.S., Sabo, E., 2021. Drivers of crop diversification: Evidence from smallholder farmers in Delta State Nigeria. Acta Universitatis Agriculturae et Silviculturae Mendelianae Brunensis. 69(1), 59–70.

[22] Nguyen, H.Q., 2017. Analyzing the economies of crop diversification in rural Vietnam using an input distance function. Agricultural Systems. 153, 148–156.

[23] Mussema, R., Kassa, B., Alemu, D., et al., 2015. Determinants of crop diversification in Ethiopia: Evidence from Oromia region. Ethiopian Journal of Agricultural Sciences. 25(2), 65–76.

[24] Asante, B.O., Villano, R.A., Patrick, I.W., et al., 2018. Determinants of farm diversification in integrated crop-livestock farming systems in Ghana. Renewable Agriculture and Food System. 33(2), 131–149.

[25] Lowder, S.K., Skoet, J., Raney, T., 2016. The number, size, and distribution of farms, smallholder farms, and family farms worldwide. World Development. 87, 16–29.

[26] Burchfield, E.K., de la Poterie, A.T., 2018. Determinants of crop diversification in rice dominated Sri Lankan agricultural systems. Journal of Rural Studies. 61, 206–215.

[27] Mekuria, W., Mekonnen, K., 2018. Determinants of crop-livestock diversification in the mixed farming systems: Evidence from Central highlands of Ethiopia. Agriculture and Food Security. 7, 60. DOI: https://doi.org/10.1186/s40066-018-0212-2

[28] Mango, N., Makate, C., Mapemba, L., et al., 2018. The role of crop diversification in improving household food security in central Malawi. Agriculture and Food Security. 7(7), 1–10. DOI: https://doi.org//10.1186/s40066-018-0160-x

[29] Binswanger-mkhize, H.P., Savastano, S., 2017. Agricultural intensification: The status in six African countries. Food Policy. 67, 26–40. DOI: https://doi.org/10.1016/j.foodpol.2016.09.021

[30] Paut, R., Sabatier, R., Tchamitchian, M., 2019. Reducing risk through crop diversification: An application of portfolio theory to diversified horticul-

tural systems. Agricultural Systems. 168, 123–130. DOI: https://doi.org/10.1016/j.agsy.2018.11.002

[31] Spiegel, A. Britz, W., Finger, R., 2021. Risk, risk aversion, and agricultural technology adoption—A novel valuation method based on real options and inverse stochastic dominance, Q Open. 1(2), 1–26. DOI: https://doi.org/10.1093/qopen/qoab016

[32] Barnum, H.N., Squire, L., 1979. An econometric application of the theory of the farm-household. Journal of Development Economics. 6(1), 79–102. DOI: https://doi.org/10.1016/0304-3878(79)90037-3

[33] Mann, S., 2021. Synthesizing knowledge about structural change in agriculture: The integration of disciplines and aggregation levels. Agriculture. 11(7), 601. DOI: https://doi.org/10.3390/agriculture11070601

[34] Sichoongwe, K., Mapemba, L., Ng'ong'ola, D., et al., 2014. The determinants and extent of crop diversification among smallholder farmers: A case study of Southern Province, Zambia. MaSSP Working Paper 5. Washington, DC, USA: International Food Policy Research Institute (IFPRI). pp. 1–14. Available from: http://ebrary.ifpri.org/cdm/ref/collection/p15738coll2/id/128183

[35] Rao, P., Birthal, P.S., Joshi, P.K., et al., 2004. Agricultural diversification in India and role of urbanization. MTID DISCUSSION PAPER NO. 77. Washington, DC, USA: International Food Policy Research Institute. pp. 1–71. Available from: http://www.ifpri.org

[36] Waha, K., van Wijk, M.T., Fritz, S., et al., 2018. Agricultural diversification as an important strategy for achieving food security in Africa. Global Change Biology. 24(8), 3390–3400. DOI: https://doi.org/10.1111/gcb.14158

[37] Ohunyeye, F., Joseph, O., Omonona, S., et al., 2020. Effect of economic and agricultural diversification on the economic growth in Nigeria. Agricultural Science Digest. 40(1), 34–38.

[38] Danso-Abbeam, G.D., Dagunga, G., Ehiakpor, D., et al., 2021. Crop-livestock diversification in the mixed farming systems: Implication on food security in Northern Ghana. Agriculture and Food Security. 10(35), 1–14. DOI: https://doi.org/10.1186/s40066-021-00319-4

[39] Asfaw, S., Pallante, G., Palma, A., 2018. Diversification strategies and adaptation deficit: Evidence from rural communities in Niger. World Development. 101, 219–234. DOI: https://doi.org/10.1016/j.worlddev.2017.09

[40] Gebiso, T., Ketema, M., Shumetie, A., et al., 2023. Crop diversification level and its determinants in Ethiopia. Cogent Food & Agriculture. 9(2), 1–19. DOI: https://doi.org/10.1080/23311932.2023.2278924

[41] Baba, A.R., Abdulai, A., 2020. Determinants of crop diversification and its effects on household food security in northern Ghana. Journal of Economic Theory and Practice. 20(2), 227–245. DOI: https://doi.org/10.1177/0976747920936818

[42] Oyo State Government, 2022. About Oyo State. Available from: https://oyostate.gov.ng/about-oyo-state/

[43] Shete, A., Shete, A., Dube, S., et al., 2020. Sample size calculation in bio-statistics with special reference to unknown population. International Journal for Innovative Research in Multidisciplinary Field. 6(7), 236–238.

[44] Johns, T.G., Apsara, K.P., Lachhaman, T., 2022. Handout on crop diversification index measurements: Essentials for sustainable livelihood of farm households. AgriCos e-Newsletter, Open Access Multidisciplinary Online Magazine. 3(10), 76–79. Available from: www.agricosemagazine.com

[45] Narmadha, N., Karunakaran, K.R., 2022. Agricultural Diversification in Tamil Nadu—An Economic analysis. Economic Affairs. 67(3), 183–188.

[46] Appiah-Twumasi, M., Asale, M.A., 2024. Crop diversification and farm household food and nutrition security in Northern Ghana. Environment, Development and Sustainability. 26, 157–185. DOI: https://doi.org/10.1007/s10668-022-02703-x

[47] Cragg, J., 1971. Some statistical models for limited dependent variables with application to the demand for durable goods. Econometrica. 39, 829–844.

[48] UNDP, 2014. Human Development Report 2014 (Technical Note). 2014 Report, 24 July 2014. Available from: https://www.undp.org/sites/g/files/zskgke326/files/migration/bz/Human-Development-Report-2014.pdf

[49] Gautum, Y., Andersen, P., 2016. Rural livelihood diversification and household well-being: Insights from Humla, Nepal. Journal of Rural Studies. 44, 239–249. DOI: https://doi.org/10.1016/j.jrurstud.2016.02.001

[50] UN-DESA, 2020. HLPF 2020 Session: Protecting and Advancing Human Wellbeing and Ending Poverty. 7 July 2020. Available from: https://sustainabledevelopment.un.org/content/documents/26482HLPF_Advancing_human_well being_BN_FINAL_1July2020.pdf

[51] Adepoju, A.A., Oni, O.A., Omonona, B.T., et al., 2011. Social capital and rural farming households welfare in South-West Nigeria. World Rural Observations. 3(3), 150–161.

[52] He, S., Fletcher, S.M., Chinnan, M.S., et al., 2004. Factors affecting school students' consumption of peanut butter sandwiches. Journal of Food Distribution Research. 35(1), 112–117.

[53] De-Luca, G.D., Perotti, V., 2011. Estimation of ordered response models with sample selection. Stata Journal. 11(2), 213–239. Available from: https://www.stata-journal.com/article.html?article=st0226

[54] Sunny, F.A., Fu, L., Rahman, M.S., et al., 2022. What influences Bangladeshi Boro rice farmers' adoption decisions of recommended fertilizer doses: A case study on Dinajpur district. PLoS ONE. 17(6), e0269611. DOI: https://doi.org/10.1371/journal.pone.0269611

[55] Torres-Reyna, O., 2007. Getting started in data analysis using Stata (v. 6.0). Princeton University: Princeton, NJ, USA. pp. 1–63. Available from: http://dss.princeton.edu/training/

[56] Joshi, P.K., Joshi, L., Birthal, P.S., 2006. Diversification and its impact on smallholders: Evidence from a study on vegetable production. Agricultural Economics Research Review. 19, 219–236.

[57] Ibrahim, H., Rahman, S.A., Envulus, E.E., et al., 2009. Income and crop diversification among farming households in a rural area of North Central Nigeria. Journal of Tropical Agriculture, Food, Environment and Extension. 8(2), 84–89.

[58] Ashfaq, M., Hassan, S., Naseer, Z.M., et al., 2008. Factors affecting farm diversification in rice-wheat. Pakistan Journal of Agricultural Sciences. 45(3), 45–47.

[59] Blundell, R., Costa-Dias, M., 2000. Evaluation Methods for Non-Experimental Data. Fiscal Studies. 21(4), 427–468.

[60] Ender, P., 2005. Applied Categorical and Non-normal Data Analysis: Ordered Logit and Probit Models. Course Notes Education 231C. Available from: http://www.philender.com/courses/categorical/notes2/ologit.html

[61] Tankari, M.R., Glatzel, K., Demmler, K., 2019. Crop diversification and poverty reduction: The role of access to road in Niger. Proceedings of the 6th African Conference of Agricultural Economists; Abuja, Nigeria; 23–26 September 2019. pp. 1–19. DOI: https://doi.org/10.22004/ag.econ.295774

[62] Certo, T., John, R., Busenbark, J., et al., 2016. Sample selection bias and heckman models in strategic management research. Strategic Management Journal. 37, 2639–2657. DOI: https://doi.org/10.1002/smj.2475

[63] Baiyegunhi, L.J.S., Hassan, M.B., Ortmann, G.F., 2018. Impact of Integrated Striga Management (ISM) technology on maize productivity in northern Nigeria: A treatment effect approach. African Journal of Science, Technology, Innovation and Development. 10(3), 335–344. DOI: https://doi.org/10.1080/20421338.2018.1463645