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# CONSERVATION AGRICULTURAL PRACTICES: DETERMINANTS AND EFFECTS ON SOIL HEALTH FOR SUSTAINABLE PRODUCTION IN NORTHERN GHANA

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## ABSTRACT

**Research background**: The threat from climate change remains a major concern especially for developing economies like Ghana. Hence, agricultural practices that are environmentally friendly and improves soil health are very necessary for building resilience.
**Purpose of the article:** The present study investigated the determinants of conservation agricultural practices in northern Ghana as well as the effect of these practices on soil health for sustainable production.
**Methods:** Using cross-sectional data collected by the International food policy research institute from 1284 households, a multivariate probit model was first performed to identify the determinants of conservation agricultural practices while the inverse probability weighted regression adjustment was employed to establish the effect of conservation agricultural practices on soil health.
**Findings & value added:** Results from the multivariate probit model showed that socioeconomic and institutional factors as well as different household-specific factors, influence farmer's decisions to engage in various conservation agricultural practices. Crop rotation, fallowing, contour ploughing or pit planting and manure application were found to have a positive effect on soil health through improved resilience to soil erosion. The study concludes that conservation agricultural practices will be useful in Ghana's quest of achieving zero hunger since the conservation agricultural practices ensure that food is produced for the present generations without compromising the soil health for further productions. Hence, the current Ghanaian government's flagship programme dubbed 'planting for food and jobs' should include conservation agriculture as a priority module in its framework so that households could both increase their output while maintaining the quality of the soil.

**Key words:** conservation agriculture; inverse probability weighted regression adjustment; multivariate probit; soil health
**JEL:** Q00; Q01; Q12

## INTRODUCTION

Conservation agriculture (CA) is defined as a series of sound land husbandry practices which minimize soil disturbance, improve organic matter and soil cover, and use of crop rotations and associations to reduce impact of pests and diseases *(***Nyanga *et al.*, 2020; Kassam *et al.*, 2009**). The concept of conservation agriculture is hinged on three main practices which protect the productive base of agriculture. These include; minimum soil disturbance, perpetual organic cover (using crop residues or living cover crops) and crop rotation (**Michler *et al.*, 2019; Nyanga *et al.*, 2020).** According to **FAO (2010)**, conservation agricultural technology is a concept for resource-saving agricultural crop production that strives to attain acceptable and sustainable productivity and profits, as well as conserving the natural environment**.** Many empirical evidence suggest, that conservation agriculture is particularly important for most developing agrarian economies like Ghana where a significant proportion of the population depend on it for their livelihood. For instance, **Michler *et al.* (2019)** asserts, that agriculture and food security are threatened by climate change in Sub-Saharan Africa and hence, conservation agricultural practices which are also said to be climate smart helps to increase productivity, ensures resilience to climate shocks and reduces negative externalities. Climate smart agricultural practices simultaneously and sustainably increase productivity and resilience (adaptation), reduces or mitigates the emission of greenhouse gases as well as helps in achieving food security (**Nyanga *et al.*, 2020)**. Since conservation agriculture improves soil organic matter and improves the vegetation cover through planning of cover crops or planting trees, it lessens the impact of climate change while improving soil health (**Nyanga *et al.*, 2020)**. According to **Nyanga *et al.* (2020)**, conservation agricultural practices provide substantial ecosystem services that play a key role in sustaining the livelihoods of smallholder farmers, particularly in the rural communities. WHO (2005) defined ecosystem services as the conditions and processes through which natural ecosystems and the species that sustain them are maintained in order to benefit human life through one or more of provisioning (food, water, wood), maintenance (soil quality, air quality), regulatory (pest and disease control and pollination) as well as supportive services to the soil biodiversity. **Nyanga *et al.* (2020)** pointed out, that conservation agricultural practices are aimed at increasing crop yields while enhancing environmental sustainability by leveraging several ecosystem services such as supporting (soil formation, nutrient cycling, and primary production), regulating (climate and water regulation), and provisioning (food security) ecosystem services. Also, **Ikazaki *et al.* (2018)** investigated the role of conservation agricultural practices on soil conservation in the Sudan Savanna and found practices relating to minimum soil disturbance and vegetation cover to be of high relevance for soil and water conservation. They however failed to include crop rotation in their study with the reason that it was not practical in their study area, Burkina Faso.

Despite the enormous potential benefits of conservation agricultural practices as outlined in the literature, most conservation agricultural practices in Sub-Saharan Africa are driven by donors, civil society groups and Non-Governmental Organizations (NGOs) **(Nyanga *et al.*, 2020)**. **Steiner-Asiedu *et al.* (2017)** stressed that there are two basic ways to achieve sustainable farming systems; either by moving from Low External Input Agriculture (LEIA) to Low External Input and Sustainable Agriculture (LEISA) or by moving from High External Input Agriculture (HEIA) to High External Input and Sustainable Agriculture (HEISA). One inconsistent policy discourse in most developing countries are often attempts that seek to move from LEIA to HEIA through the use of chemical inputs to attain short term goals instead of plans to move from LEISA to HEISA (**Steiner-Asiedu *et al.*, 2017)**. Hence conservation agricultural practices are one of a typical LEISA and when combined with some level of chemical inputs will result in HEISA which will help in sustainable development. Thus, the emphasis should be to move from LEIA to LEISA and subsequently to HEISA where sustainability is given priority as compared to the later.

Also, one critical area of concern to farmers and agronomists is soil health. Soil health is simply the continued capacity of soil to function as a vital living ecosystem that sustains plants, animals, and humans. The idea of health is to highlight, that the soil is "living and not sick" (i.e. it is not eroded or degraded). The multi-purpose use of land and its maintenance usually disturb the soil, compromising its ability for sustain future production. Ploughing and disking as methods of tillage systems (so-called conventional tillage) in the humid regions reduce soil organic matter and upsurge the erosion process, leading to chemical, physical, and biological changes in the soil features that expand the reliance on external inputs and therefore increasing production costs, causing environmental effects (**Cardoso *et al.*, 2013**). In contrast, less soil-disturbance methods of production like minimum-tillage and organic farming are much more dependent on biological processes for sustainability (**Kaschuk *et al.*, 2010**). The definition of soil quality cannot be one for all types of soil and soil-use as opined by **Sojka and Upchurch (1999).** As a result, pointers of soil quality must be selected according to soil use and management, soil features and environmental conditions **(Cardoso *et al.*, 2013**). Hence given the potential for conservation agricultural practices, it is expedient to expect that CA practices will help to improve soil health which calls for a study such as this. The objective of this study is therefore to identify the determinants of conservation agricultural practices as well as estimate its effect on soil health in northern Ghana where the soils are relatively infertile compared to soils in the south. The results could inform agricultural development policies in the country towards the achievement of production systems that supports productivity of the present without compromising the potential of same soil to provide for the future generation.

***Overview of some Conservation Agricultural Practices in northern Ghana***

There are varying conservation agricultural practices at different parts of the world but irrespective of wherever it may be, it encompasses the three areas; minimum soil disturbance, soil cover and crop rotation **(Nyanga *et al.* 2020)**.

Crop rotation is the system of farming where by a farmer cultivates more than one type of crop on the same piece of land in a sequence. Hence, the farmer could grow legumes in parcel A, cereals in parcel B and roots and tubers in parcel C in the first farming season (i.e. legumes-cereals-roots and tubers sequence) but changes the sequence in the following season by farming cereals in parcel A, roots and tubers in parcel B and legumes in the parcel C (i.e. cereals-roots and tubers-legumes sequence). In this system, the integration of legumes will help to improve the nitrogen content of the soil for the cereal production in the subsequent season while the roots and tubers will help improve soil aeration for legumes also in the subsequent season. The practice also helps to ensure that not only one nutrient is continually used in the soil by varying the crop types on the piece of land. Crop rotation is also said to improve soil quality and farm output (**Chongtham *et al.* 2016; Donkoh, 2019**).

Fallowing is the practice by which farmer allows a piece of land to rest for a given period in order for it to regain its fertility. Fallowing enhances microbial activities in the soil such that the soil regains its fertility for increased productivity. Excessive cultivation on the same piece of land could be hazardous, as it could lead to leaching and degradation of the land. Fallowing also helps to improve the vegetation cover since all forms of shrubs and grasses could spring-up in the period for which the land is left fallow. **Liu *et al.* (2013)** indicated, that fallowing provides supportive ecosystem services such as biofuel supplies and microbial activities which are required for sustainable agro-ecosystem management.

Contour Ploughing or Pit planting is a sustainable water conservation technique used to conserve soil in most dryland areas like many parts of northern Ghana where the study was undertaken. Contour ploughing or pit planting is one in which ditches are dug along the contour to stop water from running down the slope and causing erosion along sloping land. Contours are constructed to shorten the slope length and change the direction of runoff flow for the purpose of storing water, preventing scouring and combating drought and soil erosion. When it is done by ploughing it is called contour ploughing but in most areas of Sub-Saharan Africa it is often planting pits. Pits or ditches of required sizes are excavated along contour (**Critchley, 1991**). The excavated top soil is disposed on the upper side of the slope and kept for refilling. A typical exam of pit planting is the Zai technology in which small planting pits of about 20-30cm in width, 10-20cm deep, and filled with manure. The pits are spaced 70-80cm apart resulting in about 10 000 holes per hectare. Hence, Zai technology refers to small planting pits in which organic matter (manure, compost, or dry biomass) is buried before planting the seed in those pits (**Danso-Abbeam *et al.*, 2019; Mottis *et al.* 2013**).

Manure Application is the art of applying manure (animal dung, droppings or compost) to the soil to increase the nutrient level of the soil for crop cultivation. **Sharma and Reynnells (2018)** stated, that manure application can provide nutrients to soils, improving soil fertility and crop production. Manure application could be applied either by broadcasting or side placement which does not disturb the soil, improves the structure of the soil, thereby conserving the soil.

Agroforestry is one of the major ways of improving the vegetation cover as well as a key option for sequestering carbon on agricultural lands which helps to mitigate the impact of climate change (**Schoeneberger, 2009**). It is the practice of growing trees or shrubs alongside crops. **Donkoh (2019)** opined, that the goal of agroforestry is to create diverse, ecologically sound and sustainable use of land and the benefits of agroforestry ranges from productivity, environmental to socioeconomic benefits. The environmental benefits can be classified into carbon sequestration, biodiversity conservation, soil enrichment and air and water quality improvement (**Jose, 2009).** Previous studies have confirmed that agroforestry has the potential to positively influence food security, adaptation and mitigation to climate (**Mbow *et al.*, 2013; Donkoh, 2019)**.

## DATA AND METHODS

### *Data Source and Study Area*

The study used secondary data obtained from the International Food Policy Research Institute (IFPRI) under the Ghana Africa Research in Sustainable Intensification for the Next Generation (Africa RISING) 2015 baseline survey. The data was collected over 1284 households across the three northern regions (i.e. 222 households from the Upper East, 447 from the Upper West and 615 from the Northern region). The data from the Upper East Region was collected from the Bongo, Kassena Nankana East and Talensi-Nabdam disticts, that of the Upper West Region was collected from Wa West, Wa East and Nandowli districts while that of the Northern Region was taken from the Tolon/Kumbungu, Savelugu and West Mamprusi districts.

Northern Ghana account for about half the total land surface of Ghana but least developed. These regions lie roughly north of the Lower Black Volta River, which together with its tributaries, the White Volta, Red Volta, Oti river and Daka river, drain the area. Northern Ghana shares international boundaries with the Burkina Faso to the North, Togo to the east and Cote D'Ivoire to the lower southwest.

The climate in Northern Ghana is relatively dry, with a single rainy season that begins in May and ends in October. The amount of rainfall recorded annually varies between 750 mm and 1050 mm. The dry season starts in November and ends in March/April with maximum temperatures occurring towards the end of the dry season (March-April) and minimum temperatures in December and January. Agriculture is the mainstay of households and a majority of them engage in the cultivation of crops such as cereals, legumes, roots and tubers. Some households rear livestock and poultry while others engage in fishing especially those around the Volta basin.

### *Conceptual framework*

The conceptual framework for this study is based on the system approach for building soil health and productivity by **Al-Kaisi (2015).** The system approach shows the mechanisms under which healthy soils are developed and maintained in order to ensure productive and sustainable agriculture (**Al-Kaisi, 2017**). As it is indicated in Figure 1, conservation agricultural practices are expected to offer a system service through increase in organic matter, which will also increase the aggregate stability of the soil and thus increase water storage. These services will independently help build a healthy soil which is resilient to land degradation or soil erosion.

### *Theoretical framework and estimation techniques*

The study derived its theoretical underpinnings from the random utility theoretical framework. According to this theory, a system thinking rational farmer is expected to evaluate the net benefits that could be derived from a given conservation practice against his opportunity cost for not engaging in such practice. By "a system thinking rational farmer", we imply that farmers do not only decide on adopting to a given practice based on short term goals but also long-term sustainable benefits. Hence, a household will decide to engage in a given conservation agricultural practice if the perceived utility or net benefits are significantly greater. For instance, if we assume $U_{i0}$ to denote the utility for not practicing CA and $U_{i1}$ is the utility for practicing CA, then a farmer will practice CA if $U_{i1} - U_{i0} > 0$. The utility, though not directly observed can be expressed as a function of household characteristics, socio-economic activities and institutional factors expressed as Eq. 1.

$$U_i = \beta_i X_i + \varepsilon_i \qquad (1)$$

Where: $X_i$ is a vector explanatory variables, $\beta_i$ is a vector of parameters to be estimated and $\varepsilon_i$ is the error term assumed to have zero mean and constant variance.

The multivariate probit and the inverse probability weighted regression adjustment models were then applied to estimate the determinants of CA practices as well as the effect of these practices on soil health respectively.

The multivariate probit model was employed to identify the determinants of conservation agricultural practices in northern Ghana. The reason for the choice of model is because the various CA practices are correlated binary outcomes (**Greene, 2002**).

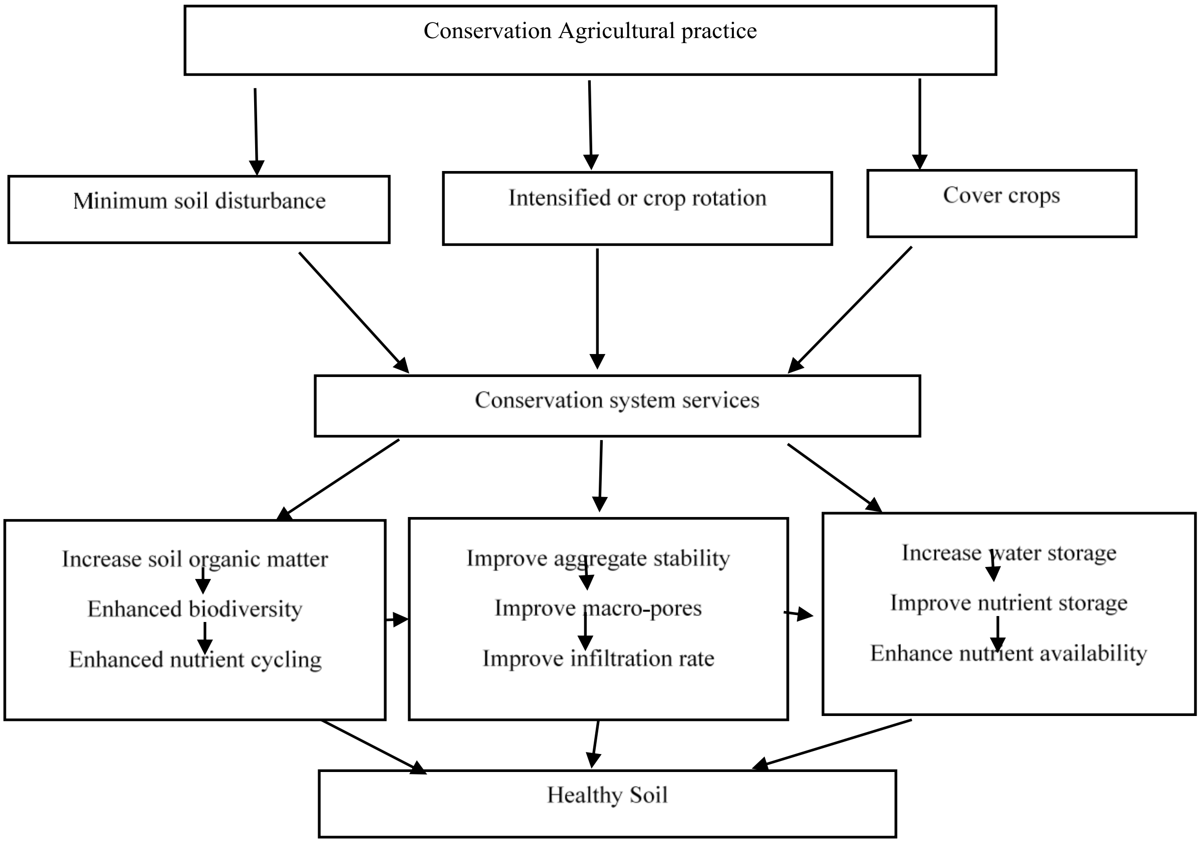


**Figure 1**: System approach for building soil health and productivity (Adapted from **Al-Kaisi, 2015**)

Following **Danso-Abbeam and Baiyegunhi (2017)** and **Donkoh *et al.* (2019)** a penta-variate probit model with five CA practices as dependent variables (Crop rotation, Fallowing, Contour ploughing or pit planting, manure application and agroforestry) could be expressed as Eq. 2.

$$y^*_{i,m} = X_{i,m} b_m + e_{i,m} \quad (2)$$

Where: $m = 1,2, \dots 5$ (i.e. the five conservation practices considered in this study), $y^*$ is the latent variable that drives household choice for a given CA practice, X is a vector of explanatory variables defined in Table 1 while e is the disturbance term.

$y^*_{i,m} = 1$ if $y^*_{i,m} > 0$ and 0, if otherwise. Since the conservation practices in this study is five, the tetra-choric correlation between the error terms could be expressed as Eq. 3.

$$\begin{pmatrix} e_1 \\ e_2 \\ e_3 \\ e_4 \\ e_5 \end{pmatrix} \Bigg| x_1 + x_2 + \cdots x_{13} \approx N \begin{bmatrix} 1 & \rho_{12} & \rho_{13} & \rho_{14} & \rho_{15} \\ \rho_{21} & 1 & \rho_{23} & \rho_{24} & \rho_{25} \\ \rho_{31} & \rho_{32} & 1 & \rho_{34} & \rho_{35} \\ \rho_{41} & \rho_{42} & \rho_{43} & 1 & \rho_{45} \\ \rho_{51} & \rho_{52} & \rho_{53} & \rho_{54} & 1 \end{bmatrix} \quad (3)$$

Where: $\rho$ is the pairwise correlation coefficient of the error terms with regards to any two of the estimated CA practices in the model. The correlation between the stochastic components of different CA practices are shown by the off-diagonal elements in the variance-covariance matrix (**Danso-Abbeam and Baiyegunhi, 2017**)

The effect of the various CA practices on soil health was estimated using the Inverse Probability Weighted Regression Adjustment (IPWRA). This is because, IPWRA has the ability to account for potentially biased estimates (ATT) that might emanate from propensity score models in the presence of misspecification (**Wooldridge, 2007**). Hence, IPWRA can ensure consistent results as it permits the treatment and the outcome model to account for misspecification due to its double-robust property. Here, soil health has been defined as 1 if the household agricultural soil is healthy (i.e. if their soils are not susceptible to erosion) and 0 if otherwise. **Imbens and Wooldridge (2009)** stated, that estimating the average treatment effect on the treated (ATT) involves a two-step process. Hence given the outcome equation (Eq.4).

$$Y_i = \alpha_i + \beta_i x_i + e_i \quad (4)$$

the propensity score is first generated from the selection equation as $ps = p(x; y)$ and in the second step, a linear regression is employed to estimate the propensity scores as $p(\alpha_0; \beta_0)$ and $p(\alpha_1; \beta_1)$ using inverse probability least squares on the binary outcome. The inverse probability least squares is expressed as Eq. 5-6.

$$\text{Min}_{\alpha_0,\beta_0} \sum_i^N (Y_i - \alpha_0 - \beta_0 x_i)/p(x,y) \quad (5)$$

if soil health is 0 for the ith household and

$$\text{Min}_{\alpha_1,\beta_1} \sum_i^N (Y_i - \alpha_1 - \beta_1 x_i)/p(x,y) \quad (6)$$

if soil health is 1 for the ith household.

Hence the ATT is then computed as the difference between Equation 5 and 6, expressed as Equation 7.

$$ATT = \frac{1}{N_w}\sum_i^{N_w}[(\hat{\alpha_1} - \hat{\alpha_0}) - (\hat{\beta_1} - \hat{\beta_0})x_i] \quad (7)$$

Where: $(\hat{\alpha_1} - \hat{\alpha_0})$, are the estimated inverse probability weighted estimates for the treated group of the *i*th household and $(\hat{\beta_1} - \hat{\beta_0})$ are the estimated inverse probability weighted estimates for the control group. Finally, $N_w$ is the total number of treated households.

## RESULTS AND DISCUSSION

### *Summary statistics of Household socioeconomic and institutional variables*

The results (Table 1) of the study showed that about 42% of the arable soils were reported by to be healthy (i.e. said to be resilient to soil erosion). With the household specific factors considered in this study, the average age of the household head in the study area was approximately 48 years which is well within the active labour force usually engaged in agricultural production. The respondents were made up of approximately 84% male headed households which indicates male dominance in the study area. About 95% of the household heads were married and about 99% of them indicating that agriculture was their main occupation. The average farm size that was recorded from the survey is approximately 4 acres (about 1.6 Ha) which implies that most of the respondents were smallholder farmers.

There was less participation in surface and ground water irrigation by the respondents in the study area. Only about 1% of the respondents supported their production with any form of irrigation (Table 1) which is an indication that the rain-fed farming is still the most dominant in the area. Access to credit is low in the area, only about 19% of the respondents reported having access to credit. Even those who had access to credit could only obtain an average of about hundred and twenty Ghana cedis (GHS 120) which is too small to support the production of the farmers. The average exchange rate at the time of data collection was 1 USD to GHS 3.82. Many financial institutions in the area demand collateral guarantee before advancing credit. The lack of collateral for accessing credit can affect the choice of farming practices. More than half (61%) of the respondents had access to extension services and this could be a source of knowledge and new methods of farming for their production. About 35% of the households belonged to farmer groups. Also, about 33% of households derived income from off-farm employment. On the average the total livestock owned by respondents in the study area is 4 which indicates that a farmer in the research area have at least a total of 4 livestock which could be a source of food, and income to cover some household expenses.

### *Farmer adaption to the various Conservation Agricultural (CA) practices in northern Ghana*

Figure 2 presents the results of the various conservation agricultural practices and the proportion of households that engaged in them. The results showed, that majority of the households in northern Ghana practices Contour ploughing or pit planting (65.9%), followed by crop rotation (65.3%).

**Table 1:** Definition of variables, measurements and summary statistics

| Variable | Measurement | Mean | Standard Deviation |
|---|---|---|---|
| Dependent Variable | | | |
| Soil Health | Dummy(1 if soil is resistant to erosion, otherwise 0) | 0.42 | 0.28 |
| Independent variables | | | |
| *Household-Specific Factors* | | | |
| Age of household head | Years | 47.69 | 14.56 |
| Sex of household head | Dummy(1 if male, otherwise 0) | 0.841 | 0.365 |
| Marital status of HH | Dummy(1 if married, otherwise 0) | 0.946 | 0.225 |
| *Socioeconomic Factors* | | | |
| Primary occupation of HH | Dummy(1 if agric., otherwise 0) | 0.99 | 0.096 |
| Farm size | Acres | 3.917 | 4.037 |
| Surface Irrigation | Dummy(1 if yes , otherwise 0) | 0.06 | 0.055 |
| *Ground Irrigation* | Dummy(1 if yes , otherwise 0) | 0.07 | 0.141 |
| *Institutional Factors* | | | |
| Credit Access | Dummy(1 if yes , otherwise 0) | 0.189 | 0.285 |
| Credit value | Amount in GH₵ | 120.33 | 166.41 |
| Extension Service | Dummy(1 if yes , otherwise 0) | 0.608 | 0.488 |
| Farmer groups | Dummy(1 if yes , otherwise 0) | 0.352 | 0.477 |
| Off-farm Income | Dummy(1 if yes , otherwise 0) | 0.333 | 0.471 |
| Total livestock | Count(Number of livestock) | 3.710 | 2.391 |

Agroforestry was the least practiced conservation agricultural technology in the study area. About 15% of households engaged in agroforestry while 19.6% engaged in fallowing. **Nkegbe and Shankar (2014)** found that adoption of agroforestry practices in northern Ghana was about 15.1%. This suggest, that agroforestry is not a pronounced CA practice in the area.

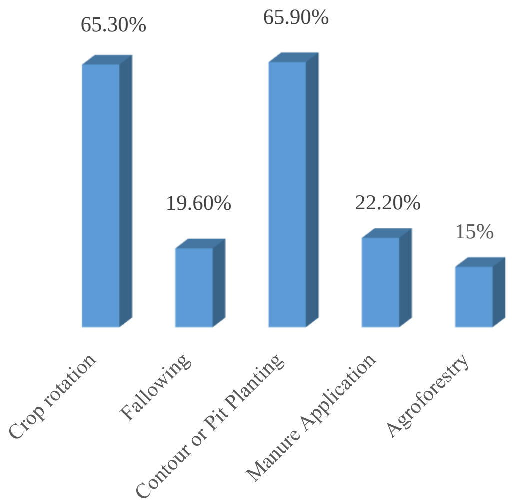


**Figure 2:** Farmer Adaption to the Various CA practices in northern Ghana

***Determinants of Conservation Agricultural Practices in northern Ghana***

Empirical estimates from the multivariate probit model showed, that the sex of the household head significantly influenced crop rotation and contour ploughing or pit planting. The marital status of the household head was also found to be significant for crop rotation and manure application, while household head's primary occupation significantly influenced manure application (Table 2 shows details of the determinants of CA practices).

The age of a household head negatively influenced fallowing and positively influenced contour ploughing or pit planting. This implies that older farmers are less likely to participate in fallowing but are more likely to participate in contour or pit planting. In order to preserve water throughout a production season, an experienced farmer more likely participates in contour ploughing or pit planting for water sustainability for his crops. The present results confirm that of **Chiputwa *et al.* (2010),** who identified that the age of the farmer positively affects the use of contour farming. It however, contradicts the findings of **Ngwira *et al.* (2014); Mlenga (2015),** that the age of the farmers does not influence the adoption decision of conservative agricultural practices.

The sex of the household head positively influenced both crop rotation and contour plouging or pit planting. The results showed, that male headed households are more likely to practice crop rotation and contour ploughing or pit planting as compared to their female counterparts. Because these conservation practices require more physical strength and the farmer needs to be very strong or should have more money to hire labour, the female household heads are at a disadvantage. Female farmers in the area are naturally less energy and tend to have less access to financial resources and farm lands. In a previous study, **Chiputwa *et al.* (2010)** also found out, that male farmers were more likely to adopt and increase the use of contour ridges compared to their female counterparts. However, **Ngwira *et al.* (2014)** also found out, that gender has no influence on conservative agricultural practices.

**Table 2**: Determinants of Conservation Agricultural Practices in northern Ghana

| Variable | Coefficient (Std Error) | | | | |
|---|---|---|---|---|---|
| | Crop Rotation | Fallowing | Contour Ploughing or Pit Planting | Manure Application | Agro-forestry |
| Household-Specific | | | | | |
| Age | 0.004 (0.003) | -0.007 (0.003)** | 0.005 (0.003)* | 0.004 (0.003) | 0.004 (0.003) |
| Sex | 0.344 (0.104)*** | 0.174 (0.123) | 0.191 (0.103)* | -0.061 (0.114) | 0.009 (0.123) |
| Marital Status of HH | 0.449 (0.167)** | -0.213 (0.185) | 0.222 (0.166) | -0.302 (0.180)* | -0.165 (0.196) |
| Socioeconomic Factors | | | | | |
| Primary Occupation of HH | 0.128 (0.380) | -0.242 (0.400) | -0.059 (0.378) | -0.783 (0.390)** | -0.145 (0.431) |
| Farm Size | 0.045 (0.011)*** | 0.059 (0.010)** | 0.007 (0.010) | -0.074 (0.015)*** | 0.007 (0.011) |
| Surface Irrigation | 0.316 (0.284) | -0.124 (0.338) | 0.894 (0.351)** | -0.148 (0.283) | -0.600 (0.384) |
| Groundwater Irrigation | 5.050 (177.4) | 0.094 (0.652) | 4.908 (165.5) | -0.148 (0.283) | -4.337 (173.2) |
| Institutional Factors | | | | | |
| Credit Access | 0.112 (0.153) | 0.175 (0.172) | -0.022 (0.141) | -0.003 (0.171) | -0.088 (0.163) |
| Credit Value | -0.001 (0.001) | -0.001 (0.001) | -0.001 (0.001) | -0.001 (0.001) | 0.000 (0.000) |
| Extension Service | 0.009 (0.079) | 0.077 (0.087) | -0.208 (0.078)** | 0.094 (0.089) | -0.196 (0.092)** |
| Farmer Group | 0.432 (0.084)*** | -0.235 (0.093)** | 0.312 (0.082)*** | 0.100 (0.089) | 0.270 (0.094)** |
| Off-farm Income | 0.193 (0.080)** | 0.098 (0.087) | 0.237 (0.079)** | 0.201 (0.086)** | 0.024 (0.092) |
| Total Livestock | -0.018 (0.027) | -0.024 (0.031) | 0.026 (0.027) | 0.276 (0.030)*** | 0.078 (0.031)** |
| Constant | 0.974(0.422)** | -0.429(0.454) | -0.291(0.421) | -0.480(0.441) | -1.167(0.487) |

Note: ***, ** and * represent 1%, 5% and 10% significance level respectively

Marital status of household head positively influenced crop rotation but negatively influenced manure application. The positive effect of marital status on crop rotation was expected and suggest, that household heads that are married are more likely to practice crop rotation. This is because household heads who are married are likely to have advantage of family labour who could help when the household participates in crop rotation. The negative influence of marital status on manure application was not expected. However, it could imply that married households shift to inorganic fertilizer application other than manure. **Ali *et al.*** (2018) found marital status to have a positive significant influence on their adoption of inorganic fertilizers. and less likely to participate in manure application. Moreover, if married households do not keep animals and/or cannot afford manure, it may also result in their less probability of manure application.

Farm size was found to positively influence crop rotation and fallowing but with a negative influence on manure application. This implies, that households with larger farm sizes are more likely to practice crop rotation and fallowing but less likely to practice manure application. Such results indicate that farmers with access to more farmland can afford fallowing portions of their land. A previous study by **Ngwira *et al.* (2014)** also found that total land size cultivated positively influenced conservative agriculture. However, **Chippewa *et al.* (2010)** found, that total arable area did not influence any of the conservative agricultural practices.

The results also show that surface irrigation positively influenced contour ploughing or pit planting. This implies, that households that participated in surface irrigation for production are more likely to also participate in contour ploughing or pit planting suggesting that most of the surface irrigation farmers employ this CA practice to conserve the moisture content.

Surprisingly, the results show that access to extension services delivery negatively affects some CA practices such as contour Ploughing or pit planting and agroforestry. This result could be attributed to the reintroduction of fertilizer subsidies by the government of Ghana since 2008 till date which have influenced the direction of trainings by agricultural extension agents (**Ragasa and Chapoto, 2017**). It is evident in the current efforts by the government of Ghana through its flagship planting for food and jobs programme which is seeking to boost production with subsidised chemical fertilizers could mean that farmers that have access to extension services are also more likely to have access to the subsidised fertilizers. As a result, they may not see the immediate need to engage in the labour demanding CA practices.

Membership of farmer group positively affects the CA practices of crop rotation and agroforestry but negatively affects fallowing. This implies, that household heads that belong to farmer groups are more likely to engage in crop rotation and agroforestry but less likely to engage in fallowing of their farmland. Farmer groups could provide the financial and labour support during cultivation and tree planting but may have less land available to permit fallow periods since about 50% of Ghanaian smallholder farmers own less than 3ha **(Ngwira *et al.*, 2014)** also found out, that membership of farmer group positively influenced conservation agricultural practices.

Households that receive off-farm income are more likely to engage in crop rotation, contour ploughing or pit planting and manure application (Table 2). Such results could mean that the extra income earned off- farm makes it possible for such household to support their farming activities with these conservation agricultural practices since they require some level of capital to establish. **Chiputwa *et al.* (2010)** found out, that disposable income positively influenced contour ridging.

Livestock ownership was found to have a positive influence on manure application and agroforestry. This was expected since many households in the area are known to make use of animal droppings as manure on their farms. Such households will have access to large amount of animal droppings which will serve as manure for their farms and will also serve as a motivation to grow trees on the farm to provide shade and serve as resting places for the livestock. **Chiputwa *et al.* (2010)** also identified, that the number of cattle had positively influenced zero-tillage**.** **Ngwira *et al.*, (2014)** found out that tropical livestock unit index had no influence on conservative agriculture. But **Zulu-Mbata *et al.* (2016**) identified tropical livestock units to negatively affect households that participated in their full conservation agricultural practices (minimum tillage, crop rotation and residue retention).

*Relationship between the various Conservation Agricultural Practices*

The multivariate probit results (Table 3), show that the various combinations of the conservation agricultural practices are mostly complementary when applied on various farms. **Chiputwa *et al.* (2010)** reported complementarities among zero-tillage, contour ridging and crop rotation emphasizing that most conservative agricultural practices are practiced together.

*Effect of conservation agricultural practices on soil health in northern Ghana*

The effect of the various CA practices in northern Ghana is presented in Table 4. The results showed a positive effect of four CA practices on soil health namely; crop rotation, fallowing, contour ploughing or pit planting and manure application. Agroforestry was not significantly associated with soil health.

The positive effect of crop rotation on soil health is in synch with **Wang *et al.* (2020)** who found a positive potential for diversified crop rotations to influence soil health indicators in China. **Kugbe and Zakaria (2015)** also reported that CA practices such as crop rotation positively influenced soil conditions in northern Ghana. This was expected because, different crops will utilize different nutrients in the soil and so nutrients are not over mined. Also, the integration of legumes in the crop rotation system helps to improve the fertility of the soil as well as microbial activity. Hence, crop rotation is expected to improve the structure of the soil thereby decreasing its probability of being eroded either by rain or wind. Also, fallowing was also expected to have a positive effect on soil health.

**Table 3**: Relationship between the Conservative Agricultural Practices

| CAPS | Coefficient (Std Errors) |
|---|---|
| Crop Rotation & Fallowing | 0.262 (0.048)*** |
| Crop Rotation & Contour Pit Ploughing | 0.335 (0.041)*** |
| Crop Rotation & Manure Application | 0.016 (0.051) |
| Crop Rotation & Agroforestry | 0.227 (0.052)*** |
| Fallowing & Contour or Pit Planting | 0.121 (0.048)** |
| Fallowing & Manure Application | 0.114 (0.054)** |
| Fallowing & agroforestry | 0.181 (0.055)*** |
| Contour or Pit Planting & Manure Application | 0.115 (0.050)** |
| Contour Pit Planting & Agroforestry | 0.050 (0.054) |
| Manure Application & Agroforestry | 0.058 (0.057) |

Note: ***, ** and * represent 1%, 5% and 10% significance level respectively

**Table 4**: IPWRA estimates of the effect of the various CA practices on soil health

| Outcome Variable | TE | Crop rotation | Fallowing | Contour Ploughing or Pit Planting | Manure Application | Agroforestry |
|---|---|---|---|---|---|---|
| | ATT | 0.02(0.023)*** | 0.053(0.031)* | 0.166(0.022)*** | 0.173(0.031)*** | -0.027(0.031) |
| Soil Health | POM | 0.161(0.017)*** | 0.220(0.012)*** | 0.121(0.015)*** | 0.191(0.012)*** | 0.234(0.012) |

Note: ***, ** and * represents 1% 5% and 10% significance level respectively

This is because, soils left on fallow improves on its vegetation cover since shrubs and all forms of grasses will grow on such uncultivated land. **Jalota *et al.* (2017)** also indicated that fallowing helps to protect the soil against soil erosion through improvement in the vegetation cover.

Contour ploughing or pit planting which showed the highest percentage of adaption by households in northern Ghana showed a positive effect on soil health. This is often done along contours to intercept run-offs thereby minimizing the incidence of soil erosion and hence the positive effect as revealed in the study. Finally, manure application also had a positive effect on soil health. Manure application improves the structure of the soil making it less susceptible to soil erosion. Agroforestry which was found to be the least practice CA was found not to be significant in influencing soil health.

## CONCLUSION AND RECOMMENDATION

The purpose of the study was to investigate the determinants of Conservation Agricultural (CA) practices in northern Ghana as well as the effect of these practices on soil health. The results showed that different household-specific factors (Age, sex and marital status of household head), socioeconomic (the primary occupation of household head, farm size and surface irrigation), and institutional factors (Extension services, farmer groups, off-farm income and total livestock reared by the household) influence farmers' decision to engage in various CA practices. Crop rotation and fallowing were significant and positively correlated with all CA practices. Contour ploughing or pit planting was not significantly correlated with agroforestry and manure application. The effect of crop rotation, fallowing, contour ploughing or pit planting and manure application were found to have had a positive effect on soil health through improved resilience to soil erosion. It is recommended, that conservation agricultural practices should be encouraged as part of the soil improvement strategies to help Ghanaian farmers to produce sustainably. Also, the current government flagship planting for food and jobs programme should include conservation agricultural practices as a priority module so that farmers could increase their productivity without compromising the quality of the soil.

Due to limitation of the data, the study used resilience to soil erosion as a proxy for soil health which captures only the physical dimension. We therefore suggest, that future research expand the scope to include other components of a healthy soil.

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# DETERMINANTS OF TECHNICAL EFFICIENCY OF SMALL-HOLDERS YAM FARMERS IN NIGERIA

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## ABSTRACT

**Research background:** Yam is rated as a principal tuber crop in the Nigeria economy, contributing to more than 200 dietary calories per capita daily in West Africa. It's also an important source of income generation and trade. However, increase in yam production over the years is attributed more to the large area planted than to increase in farm level productivity.
**Purpose of the article:** This study aimed at estimating the determinants of technical efficiency and inefficiency levels in small-holder yam farms in Nigeria. The research specifically determined farm level technical efficiency and estimated farmers' socioeconomic variables that contributed to inefficiency level in yam production in Nigeria.
**Methods:** Cross sectional data was collected from 80 yam farmers, randomly selected from the study area. Descriptive statistics (frequency, mean and percentage) and Cobb Douglas stochastic frontier production function model were the analytical tools used.
**Findings & value added:** Results indicated that the farmers were fairly educated and mainly males (75%) with a mean age of 36 years. Farmers level of education and their age showed negative influence on technical efficiency, while household size and farming experience showed positive influence on technical efficiency. MLE estimates indicated that coefficients of farm size and yam seedlings were significant at 5% while fertilizer and labour were not significant. Mean efficiency of yam farmers was 94.6%, indicating an allowance of 5.4% for improvement. The finding suggests that there is need to support yam farmers in the use of modern techniques in yam production, which would encourage older and educated farmers to remain in farming. High incidence of pest and diseases and high cost of farm labour were among other major challenges faced by the farmers. It is recommended that programmes that would help improve farmers' access to input supplies at subsided rate should be put in place to enhance farm productivity.

**Key words:** determinants; technical efficiency; small-holders; yam farmers
**JEL:** C01; C21; D22; D24

## INTRODUCTION

Yams (*Dioscorea* spp) are annual or perennial tuber-bearing and climbing plants with over 600 species, out of which six are economically important in terms of food and medicine (International Institute for Tropical Agriculture **IITA, 2007).** It belongs to the genus *"Dioscorea"* and family *"Dioscoreaceae"*, a tropical crop with many species, which originated from South East Asia and was brought into West Africa in the 16th century. It is one of the principal tuber crops in the Nigeria economy, in terms of land under cultivation and in the volume and value of production (**Bamire and Amujoyegbe, 2005**). Yam is rated as an important tuber because it contains a higher percentage of protein and vitamin C. Yam contributes more than 200 dietary calories per capita daily for more than 150 million people in West Africa and also an important source of income generation and trade (**Babaleye, 2005; Reuben and Barau, 2012**). It also has an important social status in gatherings and religious functions, which is assessed by the size of yam holdings one possesses. Yam is a preferred food and a food security crop in some sub-Saharan African countries (**IITA, 2008)**. The nutritional composition of yam includes 70% water, 25% carbohydrate, 1% sugar and 3-4% protein (**Onwueme, 2008).** Yam also plays vital roles in traditional culture, rituals and religion; as well as local commerce of African people (**Izekor and Olumese, 2010)**. Yam tubers may be eaten with sauce direct after roasting, boiling or frying in oil. The tubers may also be pounded into a thick paste after boiling and is eaten with soup. It may be processed into flour or cooked into pottage with added protein sauce and oils.

In Nigeria, yam production increased from 45,409.800 tons in 2016 to 46,912.650 tons in 2017 at end of the year with an average of 30,343.870 tons between 1995 and 2017. The highest production was 46,912.650 tons in 2017 and lowest was 22,522.500 tons in 2001

(**National Bureau of Statistics, 2017**). Nevertheless, yam production in Nigeria has doubled more over the past 10 years, from 22.5 million tons in 2001 to 46.9 million tons in 2011 (**NBS, 2012**). The increase in output is attributed more to the large area planted to yam than to increased productivity (**Zaknayiba and Tanko, 2013**).

The study of efficiency in agriculture is based on certain economic theories which describe various ways production resources could be used to achieve maximum output level; one of which is technical efficiency, an engineering concept for measuring the performance of the system given the available resources. Technical efficiency is associated with behavioural objectives of maximization of output (**Battese and Coelli, 1995**). However, production cannot be carried out in isolation since a farm is considered as an economic unit with scarce resources. According to **Ahmed *et al.* (2016)**, a producer is only efficient if he/she achieves objectives of production and inefficient if he/she fails to achieved its firms' objectives. Technical efficiency deals with efficiency in relation to factor-product transformation. For a farm to be called technically efficient, it has to produce at the production frontier level. However, this is not always the case due to random factors such as bad weather, animal destruction and or farm specific factors, contributing to producing below the expected output frontier (**Battese and Coelli, 1995**). They further argued that technical efficiency goes beyond evaluation based on average production to the one that is based on best performance among a given category. It is related to productivity where inputs are transformed into outputs.

Over the years, the farm hectare of yam production has been increasing with corresponding increases in the usage of inputs. Unfortunately, the increase in output seems not to have been commensurable with those in input usage (**Reuben and Barau, 2012**). However, the Nigerian Government made concerted efforts to encourage larger investment in the agricultural sector, including product such as yam for export. In 1998, the Nigerian Government initiated an Export Promotion Incentive Scheme. Under this scheme, some staple foods including yam were delisted from the export prohibition list. In 2001, the Nigerian Government initiated the Root and Tuber Expansion Program (RTEP) to improve farmers' productivity and profits from root and tuber crops. In 2003, an export subsidy of 10% on agricultural commodities was introduced and remained in place till date (**Akande and Ogundele, 2009**). Despite the government initiatives, **Oladeebo and Okanlawon (2010)** noted that the absolute level of yam production has remained static over a decade. This static trend may not be unconnected with production resources which are not being efficiently utilized. It is absolutely important to assess the level of technical efficiency among small holder farmers because of their contribution to the food security in Nigeria. It is on this note, the study was undertaken to determine technical efficiency of yam production in Ado Ekiti Local Government Area (L.G.A.), Ekiti State, Nigeria. Specifically, socio economic characteristics of yam farmers in the study area were identified and described; technical efficiency and inefficiency of yam farmers in Ado Ekiti L.G.A., Ekiti State were determined and major constraints in yam production were also identified.

## DATA AND METHODS

### *Area of Study*

The study was carried out in Ado Ekiti Local Government Area of Ekiti State Nigeria. Ado Local Government Area is a Local Government Area (LGA) which is among the 16 LGA's in Ekiti State. The population of the LGA according to **National Population Commission (2006)** was 313, 690 persons with projected figure of 427,700 people in 2016. The land area is 293 km² with a population density of 1,460/km². The LGA is located in Ekiti State which is located between Latitude 7° 37" and $15^0$ 99" and Longitude 5° 13" $17^0$ 04" E. The State is bounded on the south and on the East by Ondo State, on the west by Osun State and on the northern side by Kwara and Kogi State. The climate of the state is tropical with two distinct seasons, the rainy season which last from April to October and dry season from November to March. The vegetation of Ekiti state is guinea savannah including all forms of fauna and flora with an annual rainfall of 1,400mm. The main occupations of the people are farming and trading. The major agricultural crops cultivated include yam, cassava, maize, cocoyam, tomato among others.

This study adopted stochastic frontier production function approach used by different scholars who carried out similar studies in the past. Among others **Mango *et al.*, (2015)** adopted stochastic frontier model with linearized Cobb Douglas production function and determined technical efficiency in smallholder maize production in Zimbabwe. They found that maize output positively responded to increase in inorganic fertilisers, seed quantity, human labour and cultivated area. **Azumah., Donkoh and Awuni, (2019)** applied stochastic frontier analysis (SFA) in correcting bias in sample selection in a study in Northen Ghana, which determined technical efficiency (TE) and technology gap using cross-sectional data. The study showed that corrected sample selection TE estimates were marginally higher. However, it was reported that in the absence of appropriate correcting tools, inefficiency was overestimated while the gap in performance between irrigation farmers and their rain-fed counterparts was underestimated**. Edeh and Awoke (2009)** also employed a Cobb-Douglas stochastic frontier production function in the measure of technical efficiency level in improved cassava production. The study indicated that fertilizer application and tractor significantly increased cassava output at 5% level. **Muhammad-Lawal, Omotesho and Falola (2009)** used stochastic frontier model in the analysis of the technical efficiency of the Youth-in-Agriculture Programme in Ondo State, Nigeria which found that efficiency differentials exist among the youths in the programme. Furthermore, **Onyenweaku, Igwe and Mbanasor (2005)** applied stochastic frontier production function model in the study of technical efficiency of yam production in Nasarawa State, Nigeria. Based on the evidence of applications of the model in several related studies in the past, stochastic frontier production function model is viewed as the most appropriate model in the study of technical efficiency of farms in Nigeria.

***Sampling Technique***

A two- stage random sampling technique was adopted in the selection of the respondents for the study. In the first stage, purposive sampling technique was employed in the selection of4 villages out of the 12 villages in the Local Government Area. The four villages, namely, Erinfun, Emirin, Igirigiri, and Ilokun, were selected due to high concentration of yam farmers in the area. The second stage was the random selection of twenty (20) respondents from each of the selected villages giving, 80 respondents as the sample size.

***Method of Data Collection***

Data used for this study was essentially from primary data source which includes, the use of questionnaire showing various enquiries that was gotten from the yam farmers and from secondary data source which includes data already published in books and journals. The major instrument that was used in collecting the primary data was a well-structured questionnaire, which was administered to yam farmers through personal interviews, personal observations, and farm records.

*Method of Data Analysis:* Descriptive statistic such as mean, frequency distribution and percentage was used to analyse the socioeconomic features of the respondents; Stochastic frontier 4.1 version model developed by **Battese and Coelli (1995)** was used to analyse the technical efficiency and inefficiency of farmers while a 4-point Likert Scale Ranking was used to rank and identify constraints which hindered the efficiency of yam production according to their order of importance.

***Model Specification***

The stochastic frontier model adopts the Cobb-Douglas model estimate (double log). This has both efficiency parameters and inefficiency parameters. The technical efficiency model is explicitly specified as Eq. 1.

$$ln\,Y = \beta_0 + \beta_1\,ln\,X_1 + \beta_2 lnX_2 + \beta_3 lnX_3 + \beta_4 lnX_4 + (v_i - u_i) \quad (1)$$

Where:
$Y$ Farm output in kg of the i-th farm;
$\beta_0$ Constant;
$\beta_1 - \beta_4$ Coefficients;
$X_1 - X_4$ Estimated efficiency parameters;
$X_1$ Land area cultivated;
$X_2$ Labour in man-days;
$X_3$ Quantity of seedlings used in kg;
$X_4$ Quantity of fertilizer used in kg;
$v_i - \upsilon_i$ Composite error terms;
$v_i - \upsilon_i$ are assumed to be independently and identically distributed;
$v_i$ is a random error, which is associated with random factors not under the control of the farmers;
$\upsilon_i$ is a non-negative random variable, associated with technical inefficiency in production.

Technical inefficiency model is expressed as Eq. 2.

$$U_i = \delta_0 + \delta_1 Z_1 + \delta_2 Z_2 + \delta_3 Z_3 + \delta_4 Z_4 \quad (2)$$

Where:
$U_i$ Technical inefficiency;

$\delta_1$ Age of the farmers (years);
$\delta_2$ Household size in persons;
$\delta_3$ Level of education in number of years spent schooling;
$\delta_4$ Farming experience in years spent farming.

The four point Likert Scale Ranking includes:
4 Strongly agree
3 Agree
2 Disagree
1 Strongly disagree

## RESULTS AND DISCUSSION

The results in Table 1 show the socioeconomic characteristics of yam farmers. It was observed that majority of the farmers (48.8%) were between the age range of 31- 40 years and 75% of them were males. This clearly shows that yam farmers in the study area were in their productive age. The active age would likely mean that the farmers possessed physical strength which is required in doing farm operations. This result disagrees with the findings of **Ajibefun and Abdulkadiri (1999); Ekunwe *et al*. (2008)**, which reported that older farmers are dominating in farm activities in Delta and Kogi States Nigeria.

The data further showed that majority 76.3% of the respondents were married. This may have enabled them to own reasonable family size which is a major source of farm labour supply in developing countries. This result supports the finding of **Oluwatusin (2011)**, which reported that household size of farm families was 7 persons on average in Osun State, Nigeria. It was also noted that about 61.3% of the respondents had an average farming experience of 11 years. This clearly shows that yam farmers in the area were relatively experienced in farm business. The result on educational level shows that 21.3% and 40% of them had primary and secondary school education respectively. This is an indication that the farmers in the study area were fairly educated and literate. This characteristic may have enabled them made production management decisions that enhanced yam productivity in the area. However, this is contrary to the report of **Okoruwa, Ogundele and Oyewusi (2006)** on efficiency of rice farmers in North Central Nigeria which reported earlier that 75% of the farmers had primary education. The data observed that majority 55% of the farmers practiced mixed cropping while the remaining 45% practiced sole cropping. The result further showed that most of the respondents (65%) acquired farm land through family inheritance and purchase while 35% of them acquired land through rent payment. It was also indicated that 52.5% of the farmers had farm land sizes that was less than one hectare with a mean of farm size of 0.84 hectares. This corroborates with the findings of **Ndubueze-Ogaraku and Ogbonna (2016)** which, observed that the largest farm size of rice farmers in Abia State was within the range 0.1-0.9 hectares.

**Table 1**: Socioeconomic characteristics of the respondents

| Variables | Frequency | Percent |
|---|---|---|
| Age in years | | |
| Below 20 | 25 | 2.5 |
| 21-30 | 9 | 11.3 |
| 31-40 | 39 | 48.8 |
| 41-50 | 23 | 28.8 |
| 51 and above | 7 | 8.8 |
| Mean age | 36 | |
| Sex | | |
| Male | 60 | 75 |
| Female | 20 | 25 |
| Marital status | | |
| Single | 7 | 8.8 |
| Married | 61 | 76.3 |
| Separated | 5 | 6.3 |
| Widowed | 7 | 8.8 |
| Household size in persons | | |
| 1 -5 | 64 | 80 |
| 6-10 | 15 | 18.8 |
| 11 -15 | 1 | 1.2 |
| Mean household size in persons | 5 | |
| Farm experience in years | | |
| <10 | 49 | 61.3 |
| 11 -20 | 22 | 27.5 |
| 21 -30 | 6 | 7.5 |
| 31 – 40 | 3 | 3.8 |
| Mean farm experience in years | 11 | |
| Education | | |
| Formal education | 27 | 33.8 |
| Primary education | 17 | 21.3 |
| Secondary education | 32 | 40 |
| Tertiary education | 4 | 5.0 |
| Mean number of years spent schooling | 6 | |
| Cropping pattern | | |
| Sole cropping | 36 | 45 |
| Mixed cropping | 44 | 55 |
| Land ownership | | |
| Owned farm land | 52 | 65 |
| Rented | 28 | 35 |
| Farm size in hectares | | |
| < 1 | 45 | 47.5 |
| >1 | 35 | 52.5 |
| Mean farm size in hectares | 0.84 | |
| Total | 80 | 100 |

Source: Field data, 2019

***Technical Efficiency of the Yam Farmers***

Table 2 presents the maximum likelihood estimate of the technical efficiency and inefficiency of the sampled yam producers in the study area. The gamma $\gamma$ value which is associated with the variance of technical inefficiency effects in the stochastic frontier was estimated 0.99 and significant at 1%. This suggests that systematic influences that are unexplained by the production function were the dominant sources of random errors. In other words, it means that 99% of the total variability of farm output was due to differences in technical efficiencies.

From the results, it is observed that all the explanatory variables except yam seedlings and fertilizer had the expected positive sign. This suggests that greater output of yam will be obtained by increasing quantities of these variables *ceteris paribus*. The estimated coefficient of land resource was positive and statistically significant at 1% level. This supports **Umoh (2006**) finding on resource use efficiency study in urban farming. The significance of the variable could be attributed to its importance in crop production in the sense that its shortage would not only have negative influence on production but would also exhibit indirect negative effect on output by reducing the marginal productivity of other resources used in yam production. The farm recorded Return to Scale (RTS) of 0.80. This signifies existence of decreasing returns to the factors of production used by the farmers. This also implies that yam farmers were at Stage II region of production. Increasing the resource use would result in increase in yield *ceteris paribus*.

Yam seedling variable showed negative sign and was significant at 1% level. Implication of the negative sign means increase in the use of yam seedling for planting would result in low yield. This could likely be true because increasing plant population without the use of the requisite inputs like fertilizer, pesticides and adequate labour for weed control would result to poor yield instead of increase in the output. However, the result contradicts the finding of **Orewa and Izekor (2012),** which observed that the coefficients of farm size, yam seedlings, fertilizer and labour were positive and statistically significant. This suggested that more output of yam would be obtained from the use of additional quantities of these variables, *ceteris paribus*.

***Determinants of technical inefficiency***

The inefficiency variables were specified as those relating to farmers' socio-economic characteristics. Inefficiency result is interpreted differently. This is because a positive sign of an estimated parameter implies that the associated variable would exert a negative influence on technical efficiency and a negative sign indicates the variable would show positive influence on the technical efficiency. The variable, household size was negative but was significant at 5% level. The negative sign of the household coefficient implied that as the number of adult persons in a household increases, technical inefficiency would decrease, thereby increasing technical efficiency. This is so because members of same household will be diligent in carrying out farm activities since, they all share from the benefit of farming in terms of food consumption needs and income generation. This is in agreement with the hypothesized expected sign and supported the report of **Itam *et.al.* (2015**), which showed positive sign depicting that an increase in family size of cassava farmers in Cross Rivers State increased the average farm technical efficiency level in Nigeria. However, the finding is contrary to the report **of Besseah, and Sangho, K (2014)**, which showed that household size showed a significantly negative impact on technical efficiency, which explained that technical efficiency of cocoa farms in Ghana reduced with increase in family size. A possible explanation is that, more adult persons in a household implied that more farm hands would be available in carrying out farming activities, thus making the production process more efficient.

**Table 2:** Maximum likelihood estimates of technical efficiency and inefficiency

| Efficiency Variables | Parameter | Coefficient | Standard error | t-value |
|---|---|---|---|---|
| Constant | $\beta_0$ | 6.124 | 0.426 | 14.376*** |
| Farm size | $\beta_1$ | 1.431 | 0.143 | 10.022*** |
| Labour in man-days | $\beta_2$ | 0.036 | 0.042 | 0.874 |
| Yam seedling (kg) | $\beta_3$ | -0.553 | 0.164 | -3.373*** |
| Fertilizer (kg) | $\beta_4$ | -0.123 | 0.097 | -1.263 |
| Inefficiency variables | | | | |
| Constant | $\delta_0$ | 3.140 | 1.328 | -2.365** |
| Age | $\delta_1$ | 0.049 | 0.022 | 2.186** |
| Household size | $\delta_2$ | -0.113 | 0.052 | -2.191** |
| Educational level | $\delta_3$ | .038 | 00.016 | 2.424** |
| Farming experience | $\delta_4$ | -0.002 | 0.022 | -0.108 |
| Diagnostic statistics | | | | |
| Sigma-squared | $\sigma^2$ | 0.010 | 0.027 | 3.502*** |
| Gamma | Γ | 0.910 | 0.003 | 356.37*** |
| RTS (Return to Scale) | | 0.80 | | |
| Log likelihood function | | 126.954 | | |
| LR test of the one-sided error | | 125.406 | | |

Note: ***significant at 1%, **significant at 5%, *significant at 10%
Source: Field data, 2019.

The coefficient of educational level was positive and statistically significant at 5% level. The positive sign implies that if an individual acquires more educational training, it would likely result to paying less attention to farm businesses. This could mainly due to the fact that acquiring higher educational status could increase an individual's opportunity of getting better alternative means of livelihood that will generate more and steady income for the household. Paying less attention to farm business would result in making wrong production management decisions which would increase technical inefficiency thereby decreasing the technical efficiency. The result is in contrast with the findings of **Houngue and Nonvide (2020); Orewa and Izekor (2012)** who observed that farmers level of education was negative and significantly related to technical inefficiency, which implied that farmers with more years of education were more technically efficient in farm production.

The result also indicated that the age coefficient was positive and statistically significant at 5% level. This implies that as farmers increase in age, they would likely become less efficient in the management of the farm business. This is likely true because when farmers begin to age, they find it difficult to carry out strenuous farm tasks since farm operations require physical strength. This agrees with the finding of **Dessie *et al.* (2020),** which showed that age of producers, was statistically significant and positively influenced technical inefficiency of black cumin production in farming in northwest Ethiopia at 5% of level of significance. However**, Houngue and Nonvide (2020)** observed that the variable age had a negative and significant coefficient on technical efficiency of farms in Benin. This according to the report implied that the younger producers allocate their resources more efficiently than the older ones. However, the coefficient of farming experience was not statistically significant; this is not difference from the findings of **Hussain *et al.* (2012),** who found that years of farming experience did not show any significant influence on technical inefficiency.

**Table 3:** Frequency distribution of technical efficiency of yam farmers in the study area

| Efficiency Range | Frequency | Percent |
|---|---|---|
| 41- 60 | 2 | 2.5 |
| 61 -80 | 1 | 1.25 |
| 81- 100 | 77 | 96.25 |
| Mean | 94.6 | |
| Total | 80 | 100 |

Source: Field data, 2019

From the result in Table 3, it could be deduced that yam farmers were efficient in the use of inputs. An average farmer recorded technical efficiency of 94.6% which showed that they needed to increase resource us by about 5.4% to achieve the best possible frontier output of 100%. The result suggests that farmers could increase farm yield if they make intensive use of land, labour, seed yam and fertilizer inputs. This disagree with **Hussain *et al.* (2012)** which found that a mean technical efficiency of the sampled farmers was 47.1 percent in Punjab, Pakistan, implying that on an average 52.9 percent of their technical potentials in wheat production are not being realized. The result disagrees with the findings of **Ojo *et al.* (2009)** and **Shehu *et al.* (2010)** which observed an efficiency gaps in the yam farms in Nigeria. Also on average, it is observed that 96.25% of the respondents operated in the efficiency range of 81-100 percent. This could be attributed to large family size available to perform farm operations timely. The study further showed that 3.75% of respondents achieved technical efficiency range of 81-100 percent. This could be attributed to inadequate sensitization of farmers in the study area on the need to adopt new technology that would improve their farm outputs.

***Constraints***

Result in Table 4 showed that pest and diseases infestation was a militating factor to yam production. This could be due to poor access to farm inputs like pesticides and herbicides as indicated by the farmers.

**Table 4**: Constraints faced by the yam farmers in the study area

| Perceived constraints | SA | A | D | SD | Mean score | Remarks |
|---|---|---|---|---|---|---|
| High occurrence of pests and diseases | 50 (62.5) | 25 (31.25) | 5 (6.25) | - | 3.575 | Serious problem |
| Difficulty of access to improved variety | 45 (56.25) | 25 (31.25) | 10 (12.5) | - | 3.485 | Serious problem |
| High cost of planting materials and farming equipment | 40 (50) | 30 (37.5) | 10 (12.5) | - | 3.375 | Serious problem |
| High cost of farm labour | 38 (47.5) | 22 (27.5) | 20 (25) | - | 3.225 | Serious problem |
| High cost of land for yam production | 20 (25) | 16 (20) | 14 (17.5) | 30 (37.5) | 2.325 | Not serious problem |
| Shortage of farm labour | 25 (31.25) | 15 (18.75) | 18 (22.5) | 22 (27.5) | 2.537 | Serious problem |
| Inadequate capital for yam production | 15 (18.75) | 15 (18.75) | 15 (18.75) | 25 (31.25) | 2.125 | Not serious problem |
| Difficulty of access to yam market | 20 (25) | 10 (12.5) | 40 (50) | 10 (12.5) | 2.500 | Serious problem |

Source: Field Data, 2019
Note: ≥ 2.5 = serious problem, ≤ 2.5 = not serious problem.

It was also observed that difficulty in accessing improved yam variety was also a serious problem. This was mainly due to inadequate means of transportation or high cost of transportation. The result supports the finding of **Ayanwuyi., Akinboye and Oyetoro (2011),** which identified low soil fertility, lack of improved yam varieties, inadequate information on improved yam production practices, disease and pest attacks, high cost of higher labour among others as militating factors against yam production. In a similar study **Ndubueze-Ogaraku and Ogbonna (2016)** observed that 90.3% of farmers experienced insufficient fund, lack of credit facilities from the banks, pest and diseases among others were limiting factors to farming. Inadequate availability of capital required for the production of yam was not seen as a serious problem. However, shortage of farm labour required in carrying out farm operations is listed as a serious problem; this scenario is no doubt contributing to the scarcity of farm labour in the area. Labour scarcity in most rural communities is worsened by a new trend generating additional income, where a lot of young people are engaged in off farm jobs like okada riders (motor cycle transportation business) and mini car town shuttles.

## CONCLUSIONS AND RECOMMENDATIONS

The study estimated the determinants of technical efficiency and inefficiency levels among small-holders' yam farms in Nigeria. The study concludes that male farmers dominated in yam production business in the study area. Mean technical efficiency of farmers was 94.6%. The variable farm size increased technical efficiency level while yam seedlings significantly reduced technical efficiency. Age variable showed negative effects on technical efficiency while number of persons per household increased technical efficiency level. High occurrence of pests and diseases, high cost of farm inputs (planting materials and farming equipment), high cost and shortage of farm labour among others, were major challenges faced by farmers while high cost of land for yam production and inadequate capital for yam production were the minor challenges. Government should review and strengthen its policy on the provision of incentives such as access to affordable inputs, including loan, subsidies and grants. Finally, more awareness should be created to encourage young people to participate in farm business, especially yam production, since older farmers are becoming less efficient in the management of their farms. Inadequate funds and insecurity challenges in Nigeria limited the study locations to Ekiti State, Nigeria. Further research should be expanded to cover all agricultural zones in Nigeria, this would help identify regions where yam farmers are farm technical efficiency level in different regions and identify factors that would improve resource use efficiency in among yam producers.

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# CONSEQUENCES OF COVID-19 ON DIGITAL ECONOMY IN THE HORN OF AFRICA

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## ABSTRACT

**Research background:** The Horn of Africa is arguably the most vulnerable region for many shocks. Currently, the coronavirus disease-2019 (COVID-19) is spreading fast in the region. The number of new cases and the mortality of this pandemic have increased dramatically. As lockdown and movement restrictions are the major strategies suggested to minimize the spread of the virus, the impacts of the COVID-19 pandemic are not only limited to public health but also have a major impact on the economic aspects.
**Purpose of the article:** This review paper aims to synthesize the consequences of COVID-19 on the digital economy in the Horn of Africa. We review and recommend adopting the digital economy could be the remedy to go through COVID-19 safely as the world sees digital companies boom during the pandemic.
**Methods:** To achieve our purpose, we applied qualitative analysis and synthesis as a method, and recently published papers in the area (most suitable to our aim) are included as data sources.
**Findings & Value added:** The Horn region is already feeling the economic impact of the virus and we discussed it in terms of monetary, fiscal, current account balance, and unemployment expected impacts. However, this pandemic is not just about adverse impacts; it is also about unanticipated business opportunities. In this perspective, the decline of the international oil price during this pandemic can be seen as a blessing in disguise since countries in the region are net importers of crude oil. Moreover, Ethiopia's coffee export has increased rapidly at a level of record sales of about 665 million dollars from July 2019 to April 2020 (10 months' export). The lion's share of this upsurge has been achieved because of the rise in the coffee consumption from homes of the country's Arabic coffee importers, such as Germany, the U.S, and Saudi Arabia due to the lockdown measures. The paper also covers the prospects of the virus by pinpointing various booming companies that are digital-based businesses. Therefore, we urge the Horn of African countries to internalize these opportunities by swiftly investing in the telecom sector to shift to the online way of doing business.

**Keywords:** COVID-19; economic impact; digital economy; Horn of Africa
**JEL:** F40; F62; I18

## INTRODUCTION

Since the dawn of human civilization, our world has gone through myriad forms of unprecedented calamities; from deadly pandemics to devastating wars. Currently, the coronavirus pandemic is threatening the world in all aspects including economic turmoil. The world economy is being tremendously hit by the prevalence of the disease especially after the lockdown measures taken by respective governments **(Sumner *et al.*, 2020)**. Unemployment has skyrocketed, growth rates have plummeted, and hunger is looming in poor countries **(Loayza and Pennings, 2020).** As estimated by the United Nations Economic Commission for Africa **(Payne, 2020)**, for instance, the continent will observe at least a 1.4 percentage point Gross Domestic Product (GDP) decline equivalent to $29bn even though a GDP forecast is dubious when the virus trajectory is unknowable **(Carlsson-Szlezak *et al*., 2020)**.

The scale of the problem could be significant especially in Sub-Saharan African countries which would also be exacerbated by the already existing poor conditions. Most people are used to live on a daily basis particularly in urban areas of these countries with no savings. This subsistence way of living could trigger imminent hunger and food insecurity. For example, the **Food Security Information Network (FSIN) (2020)** has forecasted that hunger would be imminent at biblical proportions in the Horn of Africa which is thought to be a reasonable prediction.

Since COVID-19 was first reported in the Horn of Africa in March 2020, the virus has caused more than 170 deaths with over 9910 cases in the region as of June 12, 2020. The number of new confirmed cases is relatively low compared to other regions in Africa, but recent figures continue to increase daily. For instance, on May 22, 2020, 223 new cases and 10 deaths were recorded in Djibouti. In Ethiopia, a record of 245 new cases documented on June 12, 2020 **(Worldometer, 2020)**. Governments in the region moved swiftly to take measures to control the spread of the disease, including the closure of international borders and schools, movement restrictions, curfews, and lockdowns. Gathering for social or religious reasons have also been restricted. Restrictions on transport services continue on the number of passengers allowed per vehicle. Even if the number of confirmed cases and deaths associated with COVID-19 is low, its impacts will be multiple, one of which will be heightened economic impact. Therefore, it is vital to examine the economic impact of COVID-19 for future suggestions. Thus this synthesis paper aims to analyse and summarize the adverse economic impacts of the pandemic and digital business opportunities to be exploited in the region. To achieve the objectives of this review article, we applied qualitative methods and included the most recent peer-reviewed articles as data sources.

## LITERATURE REVIEW

The Horn of Africa is located in the easternmost point of the African continent (Figure 1) and for this article, it is defined as the region that is home to the countries of Djibouti, Eritrea, Ethiopia, and Somalia, whose cultures have been linked throughout their long history. The region covers approximately 2 million km2 and is inhabited by roughly 115 million people (Ethiopia: 96.6 million, Somalia: 15.4 million, Eritrea: 6.4 million, and Djibouti: 0.81 million). Currently, Horn of Africa countries are in a fragile state in terms of economy, security, and political transformation or have been severely weakened by internal war and government failures. Prolonged armed conflict, drought, and insecurity are very common. They possess neither the capacity to contain the COVID-19 pandemic nor to mitigate the resulting unemployment, poverty, and hunger. Currently, one-third of the population of Somalia depends on food aid and around 3.6 million have been displaced due to war or drought. Another challenge in the region is the high population density in the urban areas for instance in Ethiopia and a large number of day-labourers in the informal sector with no savings and poor healthcare services, are particularly at risk from COVID-19.


**Figure 1:** Location of Horn of Africa

### *The Economy of Horn of Africa*

The Horn of Africa is one of the poorest regions, in terms of economic measurements, in the world with a total GDP of about 107.42 billion dollars of which Ethiopia takes the lion's share with 91.17 billion dollars (about 85% of total nominal GDP of the Horn) even though Djibouti tops the group by per capita income parameter with about 2,936 US dollars **(WB, 2019)**. Member countries' economy is mainly made up of agriculture and related livelihoods such as livestock export with an average GDP growth rate of 7.7% for the last decade **(United Nations, 2019).** While agriculture's share in GDP has fallen recently, the service sector is taking the larger share of the GDP which indicates some sign of the structural transformation of the region's economy that is especially evident in Ethiopia.

Djibouti's economy, from the supply side, mainly depends on trade with Ethiopia, which accounts for 80% of Djibouti's port activities **(African Development Bank - ADB, 2020)**. The two countries are highly connected by using the same seaport since Ethiopia is a landlocked country. From a demand point of view, Djibouti's economy is driven by public investment in rail and port infrastructure which also targets to easing business with Ethiopia.

Mining and agriculture remained the dominant contributors to real GDP growth on the supply side of the Eritrean economy. On the demand side, government investment in infrastructure-notably in energy, roads, and irrigation-underpins growth **(ADB, 2020)**.

On the supply side, service, agriculture, and industry are the three major sectors contributing 39.6%, 33.3%, and 27.1% to the national income of Ethiopia, respectively **(National Bank of Ethiopia - NBE, 2019).** The industry was driven by construction, notably for industrial parks and infrastructure investments. Structural transformation is underway but needs to accelerate. While agriculture's share in GDP has fallen, the sector still employs more than 70% of Ethiopia's workforce, and manufacturing accounts for less than 10% of GDP **(ADB, 2020)**. On the demand side, private consumption and domestic investment were the primary growth drivers in 2019.

Remittances, livestock exports, and retail imports account for the bulk of economic activity in Somalia. Livestock is estimated to contribute over 40% of GDP and over 50% of export earnings. The economy grew by an estimated 2.9% in 2019, up from 2.8% in 2018 **(Boote, Byrne and Babay, 2020)**. The rebound is mainly due to recovery in agriculture and strong consumer demand. Inflation peaked at 5.1% in 2018 and declined to an estimated 4.4% in 2019 as food prices adjusted downward **(ADB, 2020)**. According to this source, the government budget remained in balance, given the restrictions on new public borrowing under staff monitored programs (SMPs) since 2016 and the need to keep inflation under control.

### *Digital Economy and its development in the Horn of Africa*

Various scholars tried to define what does it mean by the 'digital economy' (e.g. **Barefoot *et al.*, 2018; Carlsson, 2004; Gumah and Jamaluddin, 2006)** since the digital economy was first coined in the mid-'90s. However, there is no a generally accepted definition in the literature since any previous definition gets older soon in this dynamic new economy. In this regard, we endorsed the definition by **Knickrehm *et al.* (2016)** which encompasses many parts of digitization. According to these authors, the digital economy is: “the share of total economic output derived from a number of broad “digital” inputs. These digital inputs include digital skills, digital equipment (hardware, software, and communications equipment), and the intermediate digital goods and services used in production. Such broad measures reflect the foundations of the digital economy”.

According to **Bukht and Heeks (2018),** the digital economy makes up around 5% of global GDP and 3% of global employment. The digital economy is growing fast, especially in developing countries as the rate of growth estimated to be 15-25% per year albeit the global North has had the lion’s share of this economy to date.

The Horn of Africa is one of the least connected regions in the world and digital economy is in its infant stage in the region **(Gagliardone and Stremlau, 2011)**. However, recently, the region is quickly investing in the Internet sector to transform the economy to digitization. It has fewer legacy challenges to deal with and is therefore adopting digitized solutions faster out of necessity and the current moment also offers a leapfrogging opportunity **(AU, 2015)**. The number of mobile and internet users is increasing fast in this region which paves the way to digital transformation. All member states are striving to develop an internet connection and other infrastructures needed to vitalize the digital economy. For example, the government of Ethiopia and Alibaba Group sign agreements to establish eWTP Ethiopia Hub in November 2019. The country aims to build a dynamic and growing digital economy that contributes significantly to overall economic growth.

## COVID-19 AND ECONOMIC ACTIVITIES IN THE HORN OF AFRICA

The number of new cases and mortality of COVID-19 have significantly increased in the Horn of Africa. The virus seems to be transmitted from person to person mainly via small respiratory droplets through sneezing, coughing, or when people interact with each other **(CDC, 2020)**. Thus, lockdowns and movement restrictions are the major strategies used in the Horn of Africa for fighting the pandemic **(Weber, 2020).** This approach aims to reverse epidemic growth, reducing case numbers to low levels by social distancing the entire population, closing schools and universities, and halting all non-essential economic activities **(CDC, 2020)**. However, Pandemic-related lockdowns and spatial distancing are impacting economic sustainability and well-being **(Amewu *et al.*, 2020)**. Moreover, the economies of the region rely heavily on primary commodity exports including coffee, livestock, and livestock produce and vegetables, for which market value is collapsing due to measures taken to fight the disease and lack of frequent interactions for income-generating activities.

In writing this paper, we used a qualitative systematic review, which can be described as a method of comparing and synthesizing findings from qualitative studies. That is, a strict systematic review process is used to collect articles, and then a qualitative approach is used to assess them. We also used the inclusion and exclusion criteria of articles. Only peer-reviewed articles collected from Google Scholar, based on our keywords, are selected.

## ECONOMIC IMPACT OF COVID-19 IN THE HORN OF AFRICA

The economic impact of COVID-19 in the Horn of Africa region is multifaceted with monetary impacts, fiscal impacts, unemployment, and adverse impacts on the aviation sector which in turn puts pressure on the current account balance. Such crises may lead the region to political unrest. However, there are also some unanticipated opportunities that governments of this region should respond quickly. This part, therefore, aims to summarize the adverse economic impacts of the pandemic and to review the unanticipated business opportunities which may offset some of the losses.

COVID-19 is most definitely spreading economic suffering globally and the virus may be as infectious economically as it is medically **(Baldwin and Mauro, 2020)**. According to **Rodela *et al.* (2020)**, the economic implications related to COVID-19 in developing countries include a high health-related cost, high out-of-pocket expenses, the added burden of non-communicable diseases, missed economic opportunities, and socioeconomic consequences like unemployment and poverty.

The situation is worse in the Horn of Africa because of a desert locust invasion and other pressing problems such as climate change and migration **(United *et al.*, 2020)**. The region may struggle a lot in combating the two current human and crop infections, the coronavirus, and the locust invasion respectively. According to **Weber (2020)**, lockdowns and border closures will mean that economies that are already weak will face more overwhelming challenges and will slip into recession.

About half of gross national product (GNP) is generated in cities of the Horn despite a large portion of the population employs in agriculture **(Weber, 2020)**, which indicates how the urban economy could be impacted due to the lockdown. The service sector has been one of the urban key sectors contributing to the fast economic growth during the last few decades in the Horn region. This sector, for instance, contributes about 40% of Ethiopian GDP. Ironically, the same sector has been arguably the most stricken by the coronavirus pandemic. For example, hotels and restaurants are being closed, flights are being cancelled, and tourism is being halted which in turn forced firms to dismiss most of their employees.

Regional trade in goods, although small, has also been restricted by the COVID-19 measures. When Somalia closed its border, trade in the common stimulant Khat (*Catha edulis*) collapsed, and Ethiopian cultivators were left without any income. Moreover, producers of this commercial crop in eastern Ethiopia used to daily export to Djibouti have been impacted significantly. As stated earlier, the pandemic affects the economy through four impact mechanisms: monetary, fiscal, current account balance, and unemployment impacts **(United *et al.*, 2020)**.

*Monetary impacts***:** sufficient food availability, production, and supply have been disrupted because of the lockdown, stay-home, and social distancing measures; the coronavirus pandemic could lead to demand-pull inflation and volatility of the exchange rate because of less export. This scenario will have led to rising food costs and tremendously affect lower-income families and senior citizens **(McKibbin and Fernando, 2020)**. Since the above measures are more or less being taken in all the four Horn of Africa countries (Djibouti, Eritrea, Ethiopia, and Somalia), the monetary impact will also be more or less the same.

*Fiscal impacts:* the economic downturn is expected to reduce the GDP which will, in turn, reduce government revenue through less tax. Somalia could be the most impacted country from the Horn region that its authorities are forecasting a contraction of 35–45% of GDP **(Babay *et al*., 2020)**. It is also estimated that COVID-19 will shave 2.9 percentage points off this fiscal year's economic growth in Ethiopia **(UN ECA, 2020)**. This could also translate into potential reductions in external assistance as donor countries are also affected, which means fewer funds for child-focused social sectors and less space to increase public spending both for the longer term and for current spending in response to the COVID-19 emergency.

*Pressure on the current account balance:* the aviation sector is one of the most affected and African giants like Ethiopian Airlines lost $550 million because of international flight restrictions due to the COVID-19 pandemic. Adverse impact on the aviation sector will mean less foreign exchange earnings required for much-needed imports, plus hits on remittances, and the tourism sector will also affect foreign exchange earnings. This will hinder the ability to service debt payments. Increase the level of debt today implies a mortgaging of the future. Borrowing today often implies taking from today´s children and adolescents who will have to repay the debts tomorrow.

*Unemployment and poverty:* It is estimated that employment in the African continent will plummet to 48 percent due to the reduction in production of which the Horn region may owe a larger share **(AU, 2020)**. Any restriction related to the COVID-19 pandemic in the Horn limit the ability to work on daily bases and earn a living, particularly for daily labourers and informal workers who are mainly women and account for about 89% of all employment in the Horn of Africa, will put a strain on families. The precarious character of those work, as evidenced by the absence of a formal contract, means that their sources of livelihood may be impacted significantly by the COVID-19 pandemic due to lockdown and movement restriction which in turn lead to an unprecedented amount of people into poverty trap **(Lone and Ahmad, 2020).**

The COVID-19 pandemic is not just about the adverse effect on the economy; it is also about unanticipated opportunities. In this perspective, the decline of the international oil price during this pandemic can be seen as a blessing in disguise since countries in the region are net importers of crude oil. Moreover, Ethiopia's coffee export has increased dramatically at a level of record sales of about 665 million dollars from July 2019 to April 2020 (10 months' export) based on the public media outlet. This rise has been achieved because of the upsurge in the consumption of coffee drinks from the homes of Ethiopia's Arabic coffee importers such as Germany, the U.S, and Saudi Arabia due to the lockdown measures.

## CONCLUSIONS AND RECOMMENDATIONS

Digital technologies have become a critical enabler of connectivity facilitating the continuity of our regular lives and connecting people more than ever before during the global pandemic. More people have turned to their computers and smartphones as a lifeline and tools to substitute their in-person activities online as cities and countries have been asking the population to stay at home **(ITU, 2020)**.

The global crisis is hurting business but not all companies are losing out (**Baldwin and Mauro, 2020)**. There are some modern sectors immune from the pandemic so that people in the Horn of Africa should take advantage of them. According to various sources, virtual businesses are not just resilient to the lockdown because of the pandemic but they are also booming sectors **(**e.g. **Buheji and Ahmed, 2020; Ranasinghe *et al*., 2020; Surico and Galeotti, 2020)**. For instance, video conferencing companies like Zoom, online shopping companies like Amazon, online fitness classes, home delivery restaurants, TV shows, and movies, and YouTubers are on the top of the list including other businesses with forward and backward linkages to the mentioned companies.

Unfortunately, these types of businesses are not common in the Horn region due to the limitation of ICT infrastructure. However, if different countries in the region commit themselves to exploit this opportunity, they should increase investment in the telecom sector to expand more prudent internet connection. Moreover, governments of these countries encouraged to free regulations related to the hindrance of private sector participation in the industry. In this regard, Ethiopia is epitomized by having a single state-driven telecommunication firm that monopolizes all telecom related services in the country so that quality service provision is one of the lowest in the region. Consequently, Prime Minister Abiy Ahmed's regime is in the process to give a license for two private telecom firms to ameliorate service delivery by the industry.

History suggests that the global economy after a major crisis like COVID-19 will likely be different in several significant ways **(Carlsson-Szlezak *et al*., 2020)**. The authors explicitly name these ways as a microeconomic legacy, macroeconomic legacy, and political legacy. By explaining the microeconomic legacy, they epitomize the adoption of new technologies and crisis-driven business models such as the adoption of online shopping among Chinese consumers which in turn enhanced the rise of Alibaba after the SARS outbreak of 2003.

Likewise, the Harvard Business School experts expect some change of business practice after the COVID-19 pandemic **(Gerdeman, 2020)**. Business, as usual, may not be the way forward as of post-COVID-19. This is one of the visible opportunities that the Horn region should exploit. Since most of the population is youth in the region, the learning curve would be steeper if considerable effort will be exerted in ICT training and education.

The training will help the youth in how to do business online by using the internet which will be the new way of doing business during and after this pandemic which otherwise has been considered as a luxury. Accordingly, some skills are especially required for foreseeing prospects after the virus. Automated jobs will be in demand as companies are predicted to change business practices from the traditional office setup to remote working. Therefore, coding, digital marketing, closing a deal via phone, copywriting, and project management are some of the skills forecasted to be essential.

COVID-19 is affecting the world economy indiscriminately. However, economies of precarious states like the Horn African countries are being impacted more severely because they possess neither the capacity to contain the pandemic nor to mitigate the resulting unemployment, poverty, and hunger. Unless integrated solutions would be taken to reduce the impact, many vulnerable people will slip into poverty and starve to death. The existing poor macroeconomic situations would also worse. The budget deficit that would have been traditionally serviced from external sources including foreign aid may not be possible because of the virus's universal adverse impacts.

On top of the adverse economic impacts, there are also unanticipated business opportunities. The fall in the price of oil could have positive effects, for example by lowering fuel prices in the Horn region. Demand for some export commodities like Ethiopian Arabic coffee has increased dramatically because of coffee consumption surge from the import side. Moreover, there are also digital-based booming companies during the pandemic which should quickly be adopted in the Horn of Africa. Therefore, we recommend policymakers to adopt the online way of doing business by reinforcing investment in the telecom sector to swiftly shift to the digital economy.

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# FACTORS LIMITING QUALITY ASSURANCE PROGRAM IMPLEMENTATION IN FOOD MANUFACTURING COMPANIES IN SHANGHAI, CHINA

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## ABSTRACT

**Research background:** The motive behind intentional non-microbiological contamination or adulteration of foods is to limit costs, enhance competitiveness, and increase profits. Profits motivate entrepreneurs and costs caused by operating a quality assurance program that is not offset by revenue increases are resisted.
**Purpose of the article:** To understand the constraints preventing companies from having quality assurance programs, this study examines differences in importance of various constraints in three food industry sub-sectors in Shanghai, China.
**Methods:** The study applies the own survey data because there is a lack of readily available data on the selected topic. A total of 199 food company representatives completed a questionnaire during a workshop on food regulations between September and December, 2016. Descriptive statistics and the heteroskedasticity corrected regression technique are applied to identify statistically significant factors.
**Findings & Value added:** Results show that perishable food sub-sector companies more often agreed that constraints were important in limiting quality assurance programs as compared to the non-perishable food sub-sector. A company anticipating a decrease in revenues in the three years following the survey (2017-2019), employing seasonal workers, and represented by a middle level manager was more likely to view constraints as barriers. Although Shanghai is a large commercially area, the study does not include companies from other provinces recognizing that some regional specificity may matter in implementing quality assurance program. The identified factors suggest the role for government agencies in facilitating such implementation by offsetting selected costs associated with the process of adopting a quality assurance program, while the society at large learns about factors motivating or hampering the implementation of quality assurance programs by food manufacturing companies. This study fills the void in the literature and provides insights about the constraints faced a company generating knowledge for regional and national regulators useful in choosing subsectors and specific aspects facilitating food quality program implementation.

**Key words:** food safety; perishable food sector; non-perishable food sector; external constraint; internal constraint
**JEL Code:** Q13; Q17; Q19

## INTRODUCTION

Food safety issues have plagued the Chinese food industry, causing outbreaks of foodborne diseases affecting domestic and foreign consumers (**Zhang *et al.*, 2015**). Foodborne illness in China can result from multiple causes. Although **Zhang *et al.* (2015)** suggest food microbial contamination is a problem in China, despite under reporting of the incidents (**Xue and Zhang, 2013**), of particular importance is adulteration of food by adding chemicals (**Xiu and Klein, 2010**), using additives not intended for use in specific foods (for example, **Fairchild *et al.*, 2003**), allowing heavy metal contamination (**Sun *et al.*, 2011; Liu *et al.*, 2012; Wang *et al.*, 2019**), overuse of allowable substances (**Xinhuanet, 2011**), or avoiding certain steps in processing. Such contamination may result in chronic foodborne illnesses that develop over a relatively long period in contrast to common microbiological contamination that leads to acute symptoms relatively fast (**Xue and Zhang, 2013; Li *et al.*, 2019**). The motive behind intentional non-microbiological contamination or adulteration of foods is to limit costs, enhance competitiveness, and increase profits. Profits motivate entrepreneurs and costs caused by operating a quality assurance program that is not offset by revenue increases are resisted. Industry self-policing is an effective and inexpensive way of assuring the implementation of an agreed upon standard (**Fairchild *et al.*, 2003**), but in China the food manufacturing industry consists mostly of small and medium enterprises (**Jin *et al.*, 2016**), creating a polarized structure. This structure slows the emergence of informal institutions that are behind the culture of food safety in developed countries (**Liu *et al.*, 2012**).

In response to repeated food safety incidents, Chinese government regulators reacted by introducing more stringent and unified rules (**Yan, 2010; Yang *et al.*, 2019**).

Although the threat of retribution can possibly reduce food fraud such as adding harmful ingredients (e.g., melamine in dairy products (**Pei *et al.*, 2011; Wu *et* al. 2018; Yang *et al.*, 2020**)), they may not encourage implementation of sustained and documented efforts by companies to assure quality of their products. The short-term focus on maintaining economic viability overshadows the benefits of quality assurance as a source of sustained commercial pay-off in the long run.

Recognizing that the commitment of managers is essential for successful quality assurance program implementation in food manufacturing companies, this paper examines opinions concerning constraints preventing companies from having quality assurance programs. Although long-term economic viability can be substantially enhanced by such programs, managers may resist adding costs without clear market signals that such efforts will pay off. The current study uses data collected from food manufacturers located in Shanghai, China, the third largest city in the world (**United Nations, 2015**). Constraints considered in this study were identified during meetings with company managers and reflect a business rather than consumer or regulator view. The applied survey instrument probed not only for opinions about constraints to the implementation of a quality assurance program, but company and respondent characteristics in search of links that could provide insight to eliminate potential adoption barriers.

Chinese regulators recognize that typical companies are small and their managerial and other resources are limited. Overcoming the reluctance of companies with limited resources may require government assistance to offset some of the costs of implementing a quality assurance program, such as employee training or the cost of designing the program. Widespread public health benefits resulting from reduced risk of acute and chronic foodborne illnesses justify the use of public funds. Agencies entrusted with food safety regulation enforcement can streamline their efforts by learning the constraint s at the firm level. It is expected that having such programs in food manufacturing companies strengthens the competitive position of firms in domestic and international markets, and prevents food safety incidents.

The geographic scope of the survey is limited to Shanghai, a city that has been experiencing population and income growth. The city's population increased from about 14 million residents in 2000 to 25 million in 2017 and is expected to double to 50 million residents by 2050 (**World Population Review, 2017**). Shanghai households have the highest consumer expenditure in China, equivalent to $16,605 in 2013, more than three times higher than expenditures in the poorest region of the country. Additionally, the forecasted annual growth in basic food consumption is expected to increase 7.2% through 2020, while discretionary spending is expected to grow 10.2% annually (**Atsmon and Magni, 2012**). The Shanghai area contains highly concentrated purchasing power represented by relatively young, well-educated, and increasingly sophisticated consumers (**Hodgson, 2014**). Urban residents' food expenditures accounted for 35.8% of income in China in 2006 (**FAO, 2017**), and 28% in 2010, and are expected to decline to 20% in 2020 (**Statista, 2017**). Education, income, and lifestyles of Shanghai residents, like Chinese consumers in general, influence consumption patterns and shape preferences for a variety of foods, quality, and safety (**Atsmon and Magni, 2012; Kuo, 2017**).

## LITERATURE REVIEW

Earlier studies attempted to position food quality assurance in the context of the Corporate Social Responsibility (CSR) concept (**Zhang *et al.*, 2015**) or by discerning consumer trust of managerial or inspection service expertise (**Kim, 2012; Han *et al*., 2020**). The proposed approaches assume that company management will either apply the CSR concept or respond to consumer and establish a process to accommodate expectations of quality assurance. Food companies may employ well-educated quality managers, but they lack the authority and resources available to top management. The common approach to quality assurance is end-of-the-line verification rather than the sustained effort to monitor quality and safety at each processing stage characteristic of the global shift in supplier responsibility for food safety (**Trienekens and Zuurbier, 2008**). The CSR approach presupposes that a company manager displays actions consistent with the concept in the area of risk management, or that consumers base their trust regarding quality assurance in expertise of managers (**Kim, 2012**). Either approach is ambiguous with regard to the entrepreneur's profit motive (**Guo *et al*., 2019**) and the need to control costs in the price-competitive marketplace.

A company's attitude toward the issue of quality assurance seems to contrast with reported efforts of quality monitoring and control by the government to enhance the national food safety control system (**Ni and Zeng, 2009; Jia and Jukes, 2013; Han *et al.*, 2020**). Whether change in the institutional environment induces change in company behaviour is arguable. Enforcement of existing regulations may be patchy for a number of reasons. Efforts have focused on regulating processors of aquatic products, meat and meat products, fruits, vegetables, juices, and frozen products containing any of these ingredients destined for export markets (**Jin *et al*., 2016**) or on Western consumer perceptions (**Lee and Boccalatte, 2019)**, but the majority of firms supply exclusively domestic customers. Therefore, identifying internal constraints to implementing a quality assurance system as seen from the perspective of managers is a step in eliminating the hurdles. The hurdles could be economic, technical (e.g., require purchase of equipment), or reflect personal attitudes.

A number of studies have investigated Chinese consumer preferences for quality and safety of food (**Cheng *et al*., 2014; Zheng and Rastegari Henneberry, 2009**). Because of the vastness of China and its huge population (**Holtkamp *et al.*, 2014**), most studies focused on urban consumers. Empirical results identified and often quantified the influence of specific factors influencing food preferences, willingness to pay, and purchase decisions. For example, imported pork can effectively compete with domestic pork supplies by adding a food safety claim (**Ortega *et al.*, 2017**). Factors reflect socio-demographic, income and location characteristics. Constructs capturing opinions and cultural beliefs that are difficult to measure have been often applied to broaden insights into consumer attitudes and the process of making consumption choices. For example, consumers trust improved safety if the food was produced under government supervision (**Wu *et al.*, 2016; Yang *et al.*, 2019**), although self-imposed quality assurance programs could provide a competitive advantage by differentiating the product in a marketplace. Implementation of a quality assurance program offers opportunity to overcome information asymmetry between food companies and customers, otherwise leaving the latter dependent on government inspection services.

## DATA AND METHODS

Studies of company behaviour with regard to the implementation of quality assurance programs are less frequent than studies of consumer quality preferences. The paucity of data exists because systematic data collection is lacking, while efforts to collect data through a single survey are costly. Not only is it difficult to identify companies, but it seems that face-to-face interviews are more acceptable than mail or telephone questionnaires for conducting surveys in China (**Zhang *et al.*, 2015**). Business surveys require company cooperation, and allocation of time away from managing the firm. Additionally, companies may be asked to share information that in their view compromises their competitive advantage. The attitudes and behaviours of food manufacturing companies may vary across regions (**Hodgson, 2014; Holtkamp *et al.*, 2014**). Under such circumstances, the response rate from businesses in research surveys is frequently poor. Examples of company survey efforts include using students as trained enumerators to visit food processors (**Han *et al.*, 2009; Zhang *et al.*, 2015**), but even then the total number of responses may be only 10% (**Han *et al.*, 2009**). Surveys of businesses notoriously result in low response rates because they absorb manager time and probe for potentially sensitive information, and lack immediate benefits to the company.

### *Survey preparation and implementation*

The economic size and commercial and social importance of Shanghai justified its selection for the implementation of a survey probing for constraints in establishing a company-wide quality assurance program. Preparation and design of the survey consisted of several stages. The process was initiated by meeting with a small group of company managers to identify issues related to quality assurance and motives for adopting quality assurance procedures. Insights gained from these discussions were used to prepare specific questions contained in the drafted questionnaire. A draft survey instrument was used in a pilot study to detect potential errors or difficulties in answering questions. Managers in two companies were involved in the pilot study by self-administering the questionnaire to simulate the planned method of implementation. The pilot test did not lead to any changes in the survey instrument. To facilitate response and increase accuracy, a five-point Likert scale allowed choosing an option from “strongly disagree” (1) to “strongly agree” (5), where the middle value (3) captured the neutral stand, i.e., “neither agree nor disagree”. Use of the scale to indicate an opinion about an individual constraint enabled the respondent to have a choice and provided flexibility in later estimations in the empirical model.

Company participation in the survey was assured by distributing the questionnaires during a workshop devoted to regulatory issues in the food manufacturing industry. The questionnaire was distributed with the help of the Shanghai Minhang Quality Supervision Bureau and the Shanghai Fengxian Quality Supervision Bureau. Earlier studies reported selecting companies with which a particular institution of higher learning had established relationships as a result of unrelated projects (for example**, Zhang *et al*., 2015**). Approaching participants in food safety workshops was very cost effective and generated a high return rate. The survey was conducted between early September and early December 2016. From a total of 244 distributed questionnaires, 199 were completed and returned, yielding an 81.6% rate of return.

Specific questions pertaining to perceived constraints of implementing a quality assurance program were constructs reflecting different time horizons, issues internal to a company such as organizational aspects of operating a program, management resources, or already having an adequate quality assurance program, and issues accounting for external aspects regarding quality assurance programs. The constraints were grouped into external factors, internal factors, and changes in procedures (Table 1). Although constraints were identified in direct discussions with food company managers, several limitations have been widely recognized in earlier studies. For example, **Trienekens and Zuurbier (2008)** indicated that a company may reduce quality assurance costs by economies of scale. Size of the company reflects possible economies of scale and large companies are more likely to see benefits of quality assurance programs, but the vast majority of Chinese food companies are classified as small or medium (**Jin *et al.*, 2016**). The suggested benefits of building a reputation or brand based on a quality assurance system sound rational (**Semos and Kontogeorgos, 2007; Trienekens and Zuurbier, 2008**), but a company has to invest upfront into the system and cannot prevent competitors from adopting a similar program. Despite studies indicating that many consumers would pay for quality certification and safety assurance, the consensus is that market benefits from having a quality assurance program were not clear. Having a quality assurance program simultaneously imposes record keeping requirements and permanent monitoring (**Wang *et al.*, 2009**). Training of staff incurs costs and without training and re-training, implementation of a specific quality assurance program may be unsuccessful (**Maldonado *et al.*, 2005**). Employee retention in a vibrant economy like Shanghai’s may pose a challenge and increase training costs, especially if a company employs seasonal workers due to the nature of food product or harvest pattern.

### Estimation approach

The responses about the constraints in implementing the quality assurance program allowed to create an index as the sum of the selected responses. The specification allowed for the use of the OLS regression, but as a precaution against the possibility of heteroscedasticity, the applied methods was the heteroscedasticity-corrected OLS (**Gujarati, 2003**). The method generally generates the same size of the coefficients, but the adjusted standard errors affect the statistical significance. Consequently, the estimation results are more accurate than without the correction.

## RESULTS AND DISCUSSION

### Firm characteristics

The reported range of revenue was substantial but average revenues suggest that the majority of firms were small or medium in size. Respondents provided figures for revenues for 2015, the calendar year proceeding the year of the survey. The average revenues were nearly 87 million yuan-renimbi (or about $12.528 million at the exchange rate of $1=6.9447 yuan-renimbi recorded on January 1, 2017; (**XE Currency Converter, 2017**)).

An average firm employed about 141 individuals. Similar to results regarding total 2015 revenues, some firms appear to be quite small, while the largest firm reported nearly 4800 workers, causing the average number of employees to be high. Besides full-time employees, firms may hire part-time workers as determined by the needs of handling, processing, and shipping operations. Part-time employment may also help control costs. Among various forms of employment, 53 firms indicated having part-time year-round employees. An average firm had a total of about 17 year-round part-time employees with the largest number of this type of job being 261 persons. The need for part-time workers varies widely across companies. Food manufacturing is affected by seasonality of available raw material for processing and some plants may adjust their employment according to the season. An average firm (of 60 firms reporting seasonal workers) employed about 63 persons on a full-time basis as seasonal workers. Another 21 firms stated they employed part-time workers on a seasonal basis, with the average firm employing about 21 workers. Part-time seasonal employees present a challenge because their training demands company resources, but trained workers may not return to the company next season. In a fast-growing metropolitan area like Shanghai, finding another job is easy, thus requiring a company to spend resources on training new seasonal hires every year, thereby adding costs.

For 62% of firms, sales in the regional Shanghai market accounted for more than one half of total sales. Only 26% of firms reported sales in excess of 51% to other regional markets, while export market sales are of marginal importance despite Shanghai being a center of international commerce. Clearly, the food manufacturing firms surveyed in the area are oriented toward the domestic market, coinciding with observed figures regarding the number of employed workers. Domestic orientation stresses the importance of domestic and regional consumer preferences but with increasing consumer interest in food safety, having a quality assurance program seems highly desirable.

An important factor that potentially motivates adoption of improvements is expectations with regard to company performance in the near future. Companies were asked about forecast revenues for the three years following the survey. The majority of food manufacturing companies, 69%, expect their revenues to increase in the three years following the survey, i.e., 2017-2019. Only 8% of firms expected their revenues to decline. The very optimistic expectations correspond to the forecasted growth of discretionary income and rising expenditures on food among Shanghai residents. Whether the anticipated positive developments encourage the adoption of a quality assurance program by a company to secure continued growth and improved competitiveness remains to be seen.

### Respondent characteristics

In the current survey, 45% of respondents were males and nearly 37 years old on average (Table 2). The average education score is 2.45, suggesting that the education level fell somewhere between junior college and a college undergraduate degree. The most common position occupied was classified as “middle management” (Table 2). Although the period of working for the company ranged from less than a year to 35 years (Table 2), the average respondent had been with a given company only about 6.5 years. The length of employment with the company corresponds to the average age of a respondent, suggesting that many respondents were at the beginning of their professional careers. Not surprisingly, the age and education level of respondents corresponds well to the dominant group of consumers in Shanghai, who are generally not older than 35 years and college-educated.

### Quality assurance constraints

The set of 12 constraints was grouped into external factors, internal factors, and change in procedures. The questions probing for opinions about specific constraints allowed respondents to choose from among five options: from 1=strongly disagree to 5=strongly agree. The uneven scale included the middle option reflecting a neutral opinion regarding the issue (Table 1).

Respondent s of each external constraint show large differences across three food subsectors. The largest percentage of respondents agreed that external factors constraining implementation of quality assurance programs were most evident in the perishable food subsector. In particular, short-term implementation costs were viewed as a constraint. In contrast, 46% and 50% of non-perishable food manufacturing firms disagreed that the short- and long-term costs constrained the implementation of quality assurance programs. Among other food manufacturing companies, a large proportion lacked an opinion about the long-term costs as limiting quality assurance program adoption. An important issue is that while the market rewards companies having quality assurance programs, results show that a relatively large percentage of firms in the perishable food subsector and other food subsectors feel that such rewards are unclear. This directly contradicts studies reporting that consumers show preference for food safety and quality, and implies that although consumers may express such preferences, their purchase choices have not been clearly communicated to food processors. Under such circumstances, companies may feel the regulatory pressure to assure quality, but are not able to use quality assurance programs to enhance their reputation and compete in the marketplace. If loss of reputation is unlikely, company interest in implementing a quality assurance program is weak (**Liu *et al.*, 2012**).

Six constraints were classified as internal factors potentially limiting the implementation of quality assurance programs. Company size was viewed as a constraint by 40% of other food manufacturers and 48% of perishable food processors. Interestingly, the smallest percentage of respondents agreed that lack of time on the part of management was a constraint (Table 1). If managers are not limited in their time, other constraints are relatively more important and should be targeted to encourage quality assurance program adoption. Moreover, a relatively small share of perishable food manufacturers agrees (26%) that they lack knowledge of alternative quality assurance systems. The corresponding share of respondents from non-perishable food companies and other food manufacturers is also relatively small, 31% and 30%, respectively. The lack of competent consultants capable of advising on quality assurance program implementation is noted by 52% by respondents from the perishable food subsector, about twice as many as from the other two subsectors (Table 1). This clearly reveals the type of company that may require outside help in learning where to find the expertise needed to implement a quality assurance program, likely because handling perishable foods poses specific challenges compared to non-perishable foods. The lack of competent consultants as a constraint in perishable food companies is supported by the very low percentage (19%) of companies agreeing that their current food safety control system is sufficient. Indeed, respondents representing the other two subsectors also seldom agree that their current food safety control is adequate (Table 1). Responses to the statement that benefits of a quality assurance system are unclear are consistent with the observed response pattern observed for the two previously discussed constraints. Namely, only 19% of respondents from the perishable food subsector agree that benefits from having a quality assurance program are unclear, while the corresponding shares of respondents in the non-perishable food and other food subsectors are 24% and 30%, respectively. Overall, it appears that the responding companies recognize the benefits, but tend to lack knowledge about available alternative quality assurance systems and where to find reliable advisors to implement a program.

Among constraints classified as "changes in procedures," a relatively large share of respondents from each subsector category disagree that the requirement for additional record keeping is a constraint. However, the cost of permanently managing a quality assurance program is viewed as constraining by 38% of respondents from the other food manufacturing subsector, 41% of respondents from non-perishable food subsector, and 48% of respondents from the perishable food subsector. The most important constraint among "changes in procedures" is the need for additional staff training associated with implementation of a quality assurance program. Nearly identical shares of respondents from other food manufacturing subsector and non-perishable food subsector, 44% and 43%, respectively, contrasts with 67% of respondents representing the perishable food companies that view the requirement of additional staff training as limiting.

Overall, the perishable food subsector views several of the constraints differently than did the other two food subsectors. Among the external factors, two economically important constraints (short- and long-term implementation costs) causes concern in the perishable food subsector, while among internal factors the lack of knowledgeable consultants is viewed as a significant limitation. Changes in procedures of particular concern to the perishable food industry are the cost of permanently managing the quality assurance system and staff training. Concerns about those two constraints are also shared by respondents from the non-perishable food subsector. The other food manufacturing subsector expressed the most concern about the need for additional staff training and two internal factors, i.e., unclear benefits of having a quality assurance system and size of the company, suggest possible resource constraints and an opportunity for assistance from regulators to adopt a suitable quality assurance program.

***Regression analysis***

Responses regarding the 12 constraints were summed, creating an index. The sum is between 12 and 60 as the five steps in the response scale measuring the degree of agreement with each listed constraint ranged from 1=strongly disagree to 5=strongly agree. The higher the sum, the more often a respondent representing the company agreed that a stated constraint hampered implementation of a quality assurance program. The sum was converted into an index ranging from 1 to 100, where a sum of 12 (respondent "strongly disagreed" that any statement constrained the implementation of a quality assurance program) was lower boundary of 1, and a sum of 60 meant a respondent "strongly agreed" that constraint mattered, was the maximum index value.

Estimation results of the heteroscedasticity-corrected OLS are shown in Table 3. The overall fit shows the partial explanatory power of the equation, reflecting the complexity of the issue at hand, including the heterogeneity of the food manufacturing industry. The goodness-of-fit measures are $F = 3.02$ at $p < 0.0015$ and the adjusted R square is 0.1010. The latter tends to be smaller in the case of cross-sectional data such as those used in the current study compared to time-series data. Four variables in addition to the constant are statistically significant and provide interesting insights into factors associated with the listed constraints as obstacles in implementing a quality assurance program.

It was hypothesized that the constraints may vary among food companies primarily as a result of the perishability of raw material. For example, a seafood processor faces different risks of product safety than a noodle manufacturer.

**Table 1**. Percent of surveyed companies from the perishable food subsection, non-perishable food subsections, and other food subsection and the degree of agreement with regard to 12 constraints preventing quality assurance program adoption.

| Constraint | Other food subsect | | | Non-perishable food subsect | | | Perishable food subsect | | |
|---|---|---|---|---|---|---|---|---|---|
| | Disagree | Neither agree nor disagree | Agree | Disagree | Neither agree nor disagree | Agree | Disagree | Neither agree nor disagree | Agree |
| *External factors* | | | | | | | | | |
| Cost of implementation in the short run | 33 | 34 | 33 | 46 | 34 | 20 | 11 | 37 | 52 |
| Cost of implementation in the long run | 36 | 42 | 22 | 50 | 27 | 23 | 26 | 26 | 48 |
| Lack of clear rewards in the market for having a quality assurance system | 37 | 23 | 40 | 38 | 33 | 29 | 33 | 30 | 37 |
| *Internal factors* | | | | | | | | | |
| Size of company | 27 | 33 | 40 | 46 | 21 | 33 | 26 | 26 | 48 |
| Lack of time on the part of management | 44 | 29 | 27 | 52 | 20 | 28 | 33 | 37 | 30 |
| Lack of knowledge about advantages and disadvantages of alternative quality assurance systems | 44 | 26 | 30 | 44 | 24 | 31 | 37 | 37 | 26 |
| Lack of competent consultants to advise about the implementation of a quality assurance program | 36 | 36 | 29 | 34 | 40 | 26 | 15 | 33 | 52 |
| Current food safety control system is sufficient | 38 | 40 | 22 | 41 | 31 | 28 | 33 | 48 | 19 |
| Unclear benefits of having a quality assurance system | 45 | 25 | 30 | 43 | 32 | 24 | 26 | 56 | 19 |
| *Change in procedures* | | | | | | | | | |
| Requirement of additional record keeping | 47 | 19 | 34 | 47 | 32 | 21 | 37 | 37 | 26 |
| Cost of managing the quality assurance system permanently | 29 | 33 | 38 | 33 | 26 | 41 | 19 | 33 | 48 |
| Additional training requirements for the staff | 30 | 26 | 44 | 28 | 29 | 43 | 19 | 15 | 67 |

Three subsectors of the food manufacturing industry (i.e., perishable food, non-perishable food, and "other" food subsectors) present differences associated with the type of raw material handled and different regulatory approaches to assuring safety perishable foods. Specifically, companies producing meat and meat products, dairy products, fresh fruits and vegetables, and seafood are required to comply with practices not imposed on non-perishable food companies. The test on differences among mean values of the indices for each of the subsectors, i.e., perishable, non-perishable, and other food companies, indicated a statistical difference (at $p <= 0.05$) between the perishable food sub-sector and the other two subsectors. Subsequent regression analysis includes a binary variable indicating only companies classified as handling perishable food to account for possible differences in constraints limiting the implementation of a quality assurance program. This binary variable is statistically significant (Table 3), suggesting that respondents from perishable food subsector companies perceived the constraints differently and, specifically, they were likely to agree more often with their effect than were those from companies in other subsectors.

Not surprisingly, companies that admitted they expected their revenues to decrease in the three years following the survey were more likely to have a high value of index. It is plausible that the anticipation of shrinking revenues was an overwhelming constraint preventing commitment of company resources to implement a quality assurance program. The survey did not probe for possible reasons behind such expectations, but it may be that such companies were already unable to effectively compete in the market place and likely to limit their presence.

Among company employment measures, the binary variable indicating the use of seasonal workers was associated with the high value of the index. Highly seasonal production may imply that a company operates only for a period of time each calendar year, and the pool of permanent employees was small. Hiring seasonal employees meant that each worker could be viewed as posing a relatively higher risk to food safety and had to be thoroughly trained or re-trained in procedures consistent with the implemented quality assurance program. Any such intense training absorbs company resources.

Respondent characteristics were also included in the specified relationship and served as the basis to create the following variables: length of time working at the business (a binary variable indicating a period of no more than 5 years), being a member of middle or upper management, and respondent's age. Interestingly, those in the position of middle management were more likely to perceive the presented constraints as limiting quality assurance program implementation than were employees in other positions. It is quite likely that middle level managers would be responsible for implementing and monitoring the program, maintaining records, and training staff. Being the closest to the actual production process, middle level managers visualized the extent of tasks involved not only during the implementation but also subsequent operation of a quality assurance program. Additionally, they would most likely be directly responsible for any failures compromising food safety.

**Table 2**. Descriptive statistics of companies and respondent characteristics in the survey of food manufacturing industries in Shanghai, China in 2016.

| Variable name | Mean | Std. dev. | Min | Max |
|---|---|---|---|---|
| Revenues in 2015 | 86487982.55 | 297322883 | 22.47 | 3000000000 |
| Total number of full-time employees | 142 | 430 | 4 | 4795 |
| Number of part time year-round employees | 17 | 39 | 1 | 261 |
| Number of full-time seasonal employees | 63 | 106 | 5 | 600 |
| Number of part-time seasonal employees | 21 | 47 | 1 | 222 |
| Age | 37 | 7 | 22 | 60 |
| Gender | 124 | 270 | 4 | 2678 |
| Education | 2 | 1 | 1 | 4 |
| Years with the company | 6 | 6 | 1 | 35 |

**Table 3.** Heteroscedasticity corrected OLS proportional regression results of the equation modelling measurement of constraints in quality assurance program implementation by food manufacturing companies in Shanghai, China.

| Variable name | Coefficient | Std. error | t-value | p-value |
|---|---|---|---|---|
| Intercept | 35.80191[a] | 7.1048 | 5.04 | <.0001 |
| Company size 1 | 3.24242 | 2.8280 | 1.15 | 0.2532 |
| Company size 2 | 4.02436 | 3.1332 | 1.28 | 0.2007 |
| Number of employees | -3.97921 | 3.0463 | -1.31 | 0.1932 |
| Employs seasonal workers | 4.56559[a] | 2.4094 | 1.89 | 0.0598 |
| Years respondent with the company | 4.50685 | 2.8331 | 1.59 | 0.1135 |
| Middle management | 5.57491[a] | 2.8565 | 1.95 | 0.0526 |
| Upper management | 4.69082 | 3.8006 | 1.23 | 0.2188 |
| Perishable food industry subsector | 8.63364[a] | 2.3279 | 3.71 | 0.0003 |
| Expect sales decrease in the next 3 years | 10.83076[a] | 2.6948 | 4.02 | <.0001 |
| Respondent's age | -0.20919 | 0.1630 | -1.28 | 0.2012 |

Note: [a] Significant at $\alpha = 0.10$.

## CONCLUSIONS AND IMPLICATIONS

Food safety incidents in China has led to regulatory changes and increased consumer awareness, yet the key to implementing quality assurance programs rests with company management. This study focused on issues surrounding food safety and quality risks, proposed solutions, benefits of comprehensive safety programs, and consumer preferences for safe food by investigating the constraints to quality assurance program implementation among food manufacturing companies in Shanghai. The lack of information about constraints and their importance required collecting of data through a survey of company representatives at workshops devoted to industry regulations. Improving the understanding of company perspectives regarding constraints is essential to design effective ways of adopting successful quality assurance programs.

In this study, we identified 12 constraints and classified them into three groups through a discussion with several food company managers. Furthermore, recognizing the diversity of processed foods, companies were categorized according to the type of food they processed, i.e., perishable food subsector, non-perishable food subsector, and other (unidentified) food sub-sector. Each subsector showed some differences in constraints, but statistical tests confirmed significant differences between the perishable food subsector and the other two subsectors. The former included companies processing meat, dairy, seafood, and fresh fruit and vegetable products. This result likely reflects s of food manufacturing companies across China and even other countries.

The measures of agreement regarding each constraint were summed for every respondent to create an index. Higher index values indicated stronger recognition of constraints as obstacles to implementing a quality assurance program. The index was regressed on company and respondent characteristics to identify possible factors associated with its high value. Statistically significant variables provide a reference to overcome s preventing implementation of quality assurance programs. Results confirmed a difference in s between the perishable food subsector and other food manufacturing companies. Clearly, perishable food processors face a complex set safety risks to their products stemming from the nature of raw materials and the required handling to protect quality as well as a very narrow marketing window. Given the heterogeneity of perishable foods, assisting this subsector in designing and implementing quality assurance programs, and the necessary staff training, poses a challenge. Such challenges have been overcome in other countries, but a specifically Chinese situation is the dominance of small and very small companies. The size of companies likely limits resources that can be used, suggesting a need for governmental assistance. Central and provincial governments may consider absorbing the costs of designing programs, given specific characteristics of raw and processed products, e.g., meats, seafood, fruits, or vegetables. The assistance may be provided free of charge or require repayment proportional to total annual revenues. Micro and small companies could then expect to benefit relatively more than large- scale firms.

Since assistance cannot reach all companies immediately, the order in which companies are assisted needs to be considered. Results of this study show that companies expecting declining revenues viewed constraints more seriously than those anticipating growth or no change in revenues. For example, choosing companies showing rapid growth in revenues may enhance their competitiveness and consumer preference for products. Nevertheless, in the case of some companies with declining revenues assistance may be helpful if these firms supply food products of special importance.

Another criterion for selecting companies for funding with developing quality assurance programs may be those employing seasonal workers. Regression results indicate that having seasonal workers increased the constraints as preventing quality assurance program implementation. Yet, seasonal food products are highly sought by consumers. Seasonal supplies of specific foods with their associated high demand are particularly vulnerable because any incident which results in demand contraction can mean a substantial loss of revenues, putting the economic existence of a company at risk. By absorbing all or some seasonal worker training costs, a government agency can provide effective help to a company. Such assistance can be provided for a defined period, for example three seasons, until the company implements the necessary procedures, but also to avoid criticism of favouring any particular subsector. It is possible that initial assistance may be administered by public health agencies motivated by the need to address a potentially large threat to consumers, evidenced by recent incidents of foodborne illness.

The study's limitation is its narrow geographical focus. However, organization of a survey with a larger regional or national scope would require substantial resources and preparation time. Moreover, constraints reflect those identified by a small number of managers and some important issues might have been omitted. A future study may revise the list of constraints and involve top managers of companies, who have the authority to make decisions about implementing quality assurance programs, or focus only on micro-companies to examine size-specific quality assurance issues and search for effective solutions.

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# EFFECT OF INTEGRATED PEST MANAGEMENT TECHNOLOGY ON THE LIVELIHOODS OF SMALL-SCALE MAIZE PRODUCERS

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## ABSTRACT

**Research background**: In Kenya, maize production has been severely constrained by parasitic pests and weeds such as *Striga*, stem borer, and fall armyworm. The government of Kenya and its partners have developed, disseminated, and promoted the continual uptake of integrated pest management technologies such as Push-Pull technology (PPT) as a way of addressing these constraints. Understanding the effect of these technologies on smallholder livelihoods is crucial, however, it is largely ignored in the literature.
**Purpose of the article:** This study evaluates the effect of continual uptake of PPT as an integrated pest management technology on livelihood outcomes of small-scale maize producers in Homa Bay County.
**Methods:** A multi-stage sampling procedure was used to select a sample of 240 respondents. Cross-sectional data were gathered through face-to-face interviews using a pretested semi-structured questionnaire, and analysed using descriptive statistics and propensity score matching models.
**Findings & Value added:** Findings were that age, education level, total land owned, perception on *Striga* weed, stem borer, and fall armyworm severity, and land tenure positively influenced continual uptake of PPT, whereas the distance to nearest administrative centre was negatively associated with it. Propensity score matching results revealed that continual uptake of PPT had a positive and significant effect on household consumption expenditure and household dietary diversity, with a negative impact on poverty. The study, therefore, recommended policies that will ensure efficiency, literacy development, extension training, and resource availability among PPT non-adopters and dis-adopters to the level of the PPT continuous users.

**Key words:** integrated pest management; push-pull technology; continual uptake; livelihood outcomes; propensity score matching
**JEL Code:** C01; C13; C31; Q12

## INTRODUCTION

Globally, agriculture plays a vital role in spurring economic growth, increasing income, enhancing food and nutritional security, as well as overcoming poverty **(Yeyo *et al.*, 2014)**. In much of sub-Saharan African (SSA) countries, the sector remains the main pathway for small-scale farmers contributing to increased income, poverty reduction, and food and nutrition security **(World Bank, 2008)**. In Kenya, agriculture accounts for about 65% of the total exports, contributes to about 30% of Gross Domestic Product (GDP), and provides employment opportunities to more than 80% of the population, therefore, remains a major source of livelihood for about 80% of the rural populace **(Kenya National Bureau of Statistics, KNBS, 2016; KNBS, 2017)**. Despite being the mainstay of the Kenyan economy, agriculture is constrained with many factors that limit the production levels as well as the quality of marketed products. These constraints include declining farm or agricultural productivity due to adverse effects of climate change, increased pest and weed infestation, adoption of outdated technology and inputs, as well as low and declining soil fertility **(Vanlauwe *et al.*, 2008; Midega *et al.*, 2016)**. The Government of Kenya (GoK) has been identifying and promoting the development, dissemination, and continual uptake of new and improved agricultural production technologies as a fundamental strategy for mitigating these challenges **(GoK, 2012)**.

In this regard, a number of new and improved agricultural technologies have been developed and effectively disseminated by the Government of Kenya and other Non-Governmental Organizations (NGOs) with the aim of increasing agricultural productivity to meet the demand of the growing population. This also helps in spurring economic growth, arresting environmental degradation, as well as improving the livelihoods of small-scale farmers **(Obare *et al.*, 2011; GoK, 2012)**. These new and improved agricultural technologies are largely promoted in Kenya to ensure the efficient production of major staples, cash, or food crops such as maize (*Zea mays* L.) and sorghum (*Sorghum bicolor* L. Moench) **(Romney**

***et al*., 2003)**. Among these new and improved technologies is an integrated pest and weed management technology known as Push-pull technology (PPT) developed by International Centre of Insect Physiology and Ecology (ICIPE), Kenya Agricultural and Livestock Research Organisation (KALRO) and Rothamsted Research in the United Kingdom **(Oswald, 2005)**. Push-pull technology as an integrated pest and weed management system was invented to address six major constraints affecting maize production in Kenya **(Murage *et al*., 2012; Murage *et al*., 2015)**. These maize production constraints are experienced by the majority of small-scale farmers in Kenya, especially in the western region, and they include infestation by lepidopteran stem borers (*Busseola fusca* or *Chilo partellus*), parasitic *Striga* weed (*Striga hermonthica*), fall armyworm, soil erosion, inadequate fodder, and declining soil fertility **(Vanlauwe *et al*., 2008; Cairns *et al*., 2013)**.

Stem borers, fall armyworm, and parasitic *Striga* weed often constrain cereal production in the southern part of the western region including Homa Bay County, resulting to up to 10-100% of total grain output loses depending on their biological and nocturnal characteristics, phonological stage at infestation, population density as well as conventional and cultural control practices in place **(Kfir *et al*., 2002; Khan *et al*., 2008a; Midega *et al*., 2016)**. According to **Midega *et al*. (2016)** stem borers, fall armyworm, and parasitic *Striga* weed competes for nutrient and moisture needs, thereby suppressing the growth of maize crops. This results in a severe reduction in the amount of maize output or even total crop damage in severe cases **(Khan *et al*., 2008b)**. Stem borers, fall armyworm, and parasitic *Striga* coupled with low and declining soil fertility, soil erosion and other adverse effects of climate change often make countless Kenyans go hungry **(Rodenburg *et al*., 2005)**. Moreover, controlling these pests and weeds have been a difficult activity for small-scale maize producer in this area largely because of their biological and nocturnal characteristics, availability of impractical and uneconomical recommended control strategies, as well as persistent use of conventional and cultural control practices which have overtime shown minimal and localized success **(Pickett *et al*., 2008; Midega *et al*., 2016)**.

International Centre of Insect Physiology and Ecology (**ICIPE, 2018**) has largely promoted PPT, as an integrated pest and weed management technology, with the aim of reducing maize and sorghum yield losses due to stem borers, fall armyworm, and parasitic *Striga* weed infestation. The technology also helps in minimizing agrochemical usage, improving soil fertility and moisture, increasing livestock feeds, as well as lowering the cost of production thereby improving livelihood outcomes of small-scale farmers both at the household and national level **(Kfir *et al*., 2002; Pickett *et al*., 2008; Khan *et al*., 2008a; Midega *et al*., 2016)**. PPT, therefore, involves intercropping maize with a stemborer moth repellent fodder legume known as desmodium (*Desmodium uncinatum*). Desmodium applies a stimuli-deterrent diversionary strategy to control cereal stem borers **(Cook, Khan, and Pickett, 2007)**. Again, brachiaria grass or napier grass (*Pennisetum purpureum)* is cropped around the farm as an attractant trap plant. The mechanism involves the *push* where desmodium repels stem borers and fall armyworms and suppresses *Striga* attack. The *pull* is where napier grass attracts and kills stem borers and fall armyworms **(Cook, Khan and Pickett, 2007)**. Desmodium being legume plant also helps in improving soil fertility and moisture through nitrogen fixation. Desmodium and napier grass also helps in providing fodder and income.

Many studies have been conducted to determine the effect of PPT adoption on household welfare **(Vanlauwe *et al*., 2008; Khan *et al*., 2008b; DeGroote *et al*., 2010; Martin, 2010; Murage *et al*., 2015; Chepchirchir *et al*., 2016; Ogot *et al*., 2017)**. However, the enormous PPT literature, which includes the determinants of PPT adoption decision, intensity, and its impacts on welfare, presents diverse results depending on the location of the study and welfare indicators. **Vanlauwe *et al.* (2008)** estimated the economic benefits of four related integrated pest management systems namely traditional maize-bean intercrop, crotalaria-maize rotation, push-pull intercrop, and soybean-maize rotation. They found that the PPT system significantly reduces stem borer damage and *Striga* emergence from the second season onwards, thereby resulting in higher yields, enhanced food security, and poverty alleviation compared to other systems. In a related study, **Khan *et al.* (2008b)** used cost-benefit ratio analysis to calculate gross margins and net present values (NPV) of land and labour of PPT against other cropping systems in western Kenya. They reported that maize yields and associated gross margins were significantly higher for PPT farming than other systems. Even though, the results indicated higher production costs and net return to land and labour in the PPT system during first cropping year, a reduction in cost was evidenced from year two of operations onwards in most plots of the studied districts **(Gwada, 2019)**. **DeGroote *et al.* (2010)** used marginal effect and discounted partial budget analysis to determine the economic performance of different integrated soil fertility and pest management options in maize production systems in Western Kenya. They added that PPT farming generated the highest income than other options, thereby making it appropriate technology for poverty reduction and food security.

In the light of the foregoing, **Martin (2010)** conducted a peer-review evaluation in 12 districts of eastern Uganda and western Kenya and found that PPT significantly reduced the smallholder farmers' vulnerability by promoting better and higher maize and sorghum grain yields, reduced soil erosion, increased soil fertility, improved livestock health as well as extra income from diversified sources such as the sale of desmodium and napier fodder. It was added that these benefits have greatly contributed to improved food security, increased well-being, and poverty reduction among those farmers **(Martin, 2010)**. **Khan *et al.* (2011)** further reiterated that PPT is an appropriate and effective integrated pest control system as it addresses important cereal production problems as well as increasing maize and sorghum yields from 0.1 to 3.5 tonnes per hectare. They highly recommended PPT for continued food security and poverty reduction among resource-poor farmers. Using the marginal rate of return methods, **Murage *et al. (*2015)** studied the potential ex-ante effect of climate-smart PPT in Tanzania, Kenya, and Ethiopia with a view to promoting wide-scale dissemination. The results indicated that the marginal rate of return for maize and sorghum were 143.4 % and 109.2 %, respectively with an expected improvement in food security and poverty alleviation status among smallholder farmer. A recent study by **Chepchirchir *et al*. (2016)** revealed that when the intensity of PPT uptake increases, on average, the probability of a farmer being poor reduces from 47% to 27% through improved crop output, farm incomes, and household per capita food consumption expenditure. **Ogot *et al.* (2017)** also reported that PPT technology positively impacted the nutritional outcomes of farmers' children. Most of these studies reviewed posited that PPT elevates production, boosts income, and food expenditure thus resulting in higher income, poverty reduction, and better food and nutritional status.

Importantly, it can be said that a lot of literature exists on PPT, however, very little has been documented on the impacts of continual uptake of PPT on livelihood outcomes such as per capita consumption expenditure, household dietary diversity, and poverty reduction especially in Homa Bay County, Kenya. In fact, the previous studies reviewed did not look at the impact of continual uptake of PPT in Homa Bay county. However, the literature reveals that most of the previous studies focused on PPT perception and adoption determinants without taking into consideration factors that greatly influence its continual uptake decision **(Gwada, 2019)**. Again, such studies did not consider the application of propensity score matching as one of the recommended models of eliminating selection bias and heterogeneity when analysing the impact of technology adoption on livelihood outcomes.

This study, therefore, deviates from previous studies and evaluates the effect of continual uptake of PPT as an integrated pest and weed management technology, on livelihood outcomes of small-scale maize producers in Homa Bay County, Kenya. Livelihood outcomes under study are per capita consumption expenditure, household dietary diversity (HDDs), and poverty reduction as these were not given much attention in the previous studies. This study contributes to the existing literature on the impact of agricultural technology adoption by presenting a micro perspective on the effect of continual uptake of PPT. Evaluating the effect of continual uptake of PPT helps in providing feedback to the researchers, as well as in setting priorities. It also guides governments, NGOs, policymakers, and those involved in the dissemination of integrated pest and weed management technologies to have a better glimpse of the way new technologies can be assimilated and disseminated among small-scale maize farmers for continual uptake. The study also provides evidence that maize farmers benefit from continual PPT uptake, thus improving the contribution of the agricultural sector to the country's economy to meet its broader development goals such as Sustainable Development Goals (Goal 1 of ensuring no poverty, goal 2 of ensuring zero hunger, goal 10 of ensuring reduced inequality, and goal 12 of ensuring responsible consumption and production) and the Big Four agenda (agenda 2 of ensuring 100% food security and nutritional commitment) **(Gwada, 2019)**.

## DATA AND METHODS

### *Study Area*

This study was conducted in Homa-Bay County. Homa Bay County is one of the counties in the western region of Kenya. The county has eight sub-counties namely Ndhiwa, Suba North, Kasipul, Homa Bay Town, Karachuonyo, Suba South, Kabondo-Kasipul, and Rangwe. The choice of Homa-Bay county was motivated by the fact that it has the majority of the farmers practicing maize production as part of their livelihood (**GoK, 2018**). Again, it is one of the counties along the shore of Lake Victoria where stem borer, fall armyworm, *Striga* weed, climate change, and low and declining soil fertility are major problems to sustainable maize production. Lastly, it is where PPT has been widely promoted or disseminated by ICIPE and government of Kenya for the effective control of *Striga* weed, fall armyworm, stem borers, and declining soil fertility **(Gwada, 2019)**. Homa Bay county covers approximately 3183.3 square kilometres with a population of 963,794 people, and a population density of 117 persons per square kilometre **(KNBS, 2009)**. The altitude of the county ranges from 1134 to 1230 meters above the sea level and located between latitude 0˚ 40' 60.00" North and a longitude of 34˚ 27' 0.00" East. Homa Bay county experiences a bimodal rainfall pattern; where the long rains occur between March and July and short rains occurring between August and October. Annual rainfall in the study area ranges from 250 to 1200mm per year while the temperature ranges from 26 to 34 degrees Celsius. Agriculture is the main economic activity in the area. The county is characterized by well-drained, rich, and fertile soils that support the production of major crops like maize, sorghum, beans, and millet.

### *Sampling and Data Collection*

Since the population was known, the study sample size of 240 respondents was determined using proportionate to the number of households sampling methodology as propounded by **Kothari (2004)**. Based on quantitative research design, a sample of 240 respondents was randomly selected from a population of small-scale maize producers in Homa Bay County using a multistage sampling technique. Primary data were collected through face to face interviews, using a pretested semi-structured questionnaire administered by a group of trained enumerators. This was divided equally between PPT adopters (dis-adopters included), and non-adopters in the county to achieve perfect compliance **Kothari (2004)**. However, 2 observations were excluded from the analysis because they were regarded as outliers.

### *Econometric Model Specification*

Impact evaluation can be done for both experimental (randomized) and non-experimental programs. For experimental studies, impact evaluation for technology uptake can be done by simply comparing individual welfare outcomes of adopters, dis-adopters, and non-adopters to compute the Average Treatment Effect (ATT) **(Becker and Ichino, 2002)**. However, many integrated pest and weed management technologies such as PPT are not randomly assigned, in that farmers' decision to adopt or not and to dis-adopt or not depend on the amount of information they have **(Dehejia and Wahba, 2002)**. This brings the problem of a counterfactual outcome where it is difficult to determine the welfare outcomes of farmers who adopted the technology had they not adopted that technology **(Dehejia and Wahba, 2002)**. Previous studies have refuted the use of ordinal least squares (OLS) model in impact evaluations since it generates biased estimates by its assumption that adoption or dis-adoption of agricultural technology is determined exogenously, and yet it is potentially endogenous, voluntary and depends on individual self-selection and expected benefits which systematically differs across individuals **(Heckman *et al*., 1998; Wooldridge, 2005)**.

This results in the problem of self-selection that makes it difficult to directly compare the welfare outcomes of adopters, dis-adopters, and non-adopter. Again, there are some unobserved individual, farm, and institutional characteristics that may affect adoption and dis-adoption as well as the welfare variable, thus resulting in inconsistent estimates, due to endogeneity problem **(Smith and Todd, 2005)**. It is, therefore, important to apply an econometric model that eliminates both endogeneity and selection bias while evaluating the impact of technology adoption on welfare outcomes such as per capita consumption expenditure **(Heckman *et al*., 1998)**. This motivated the use of propensity score matching (PSM) model to control for both endogeneity and sample selection bias between PPT continued uptake decision and other explanatory variables. This is known as confoundedness assumption. PSM is based on the expected utility theory which states that a rational decision maker will only choose a decision with the highest expected utility. Again, PSM is recommended because it does not depend on distributional assumptions and functional form, makes it easier to compare the observed outcomes of continual PPT adopters with those of counterfactual non-adopters, and finally works well with a single cross-sectional dataset like the case of the proposed study **(Heckman *et al*., 1998)**.

PSM method helps in matching the observations of PPT continued users and non-adopters, based on predicted propensity score or probability of adopting PPT continuously. This is done by creating the conditions of a randomized experiment for evaluating the causal effect just like in a controlled experiment situation **(Dehejia and Wahba, 2002)**. This ensured that all observational characteristics are controlled thereby making the continual PPT adoption or dis-adoption a random assignment and uncorrelated with the outcome variables which in this case are per capita consumption expenditure, household dietary diversity score, and poverty indices **(Smith and Todd, 2005)**. To arrive at robust results, chances of systematic difference between the outcomes of PPT continued users and non-adopters that are caused by the selection of unmeasured characteristics were eliminated when conditioning as shown below **(Smith and Todd, 2005)**.

Let $A$ denotes a dummy variable for PPT continual uptake status where $A_i = 1$ is if $i^{th}$ individual adopted PPT continuously, and $A_i = 0$ is otherwise or non-adoption. In addition, let $Y_{1i}$ and $Y_{2i}$ denote expected observed livelihood outcomes for continual PPT adopters and non-adopter, respectively. Then treatment effect, $TE$ is expressed by Eq. (1).

$$TE = Y_{1i} - Y_{2i} \quad (1)$$

Eq. 1 gives the impact or treatment effect of PPT continued uptake on the $i^{th}$ individual. Since we only observe Eq. (2).

$$Y_i = A_i Y_{1i} + (1 - A_i) Y_{2i} \quad (2)$$

Rather than $Y_{1i}$ and $Y_{2i}$ for the same farmer, we find it difficult to arrive at the treatment effect for every farmer. Therefore, we can only calculate the average effect of treatment on the treated, $ATT$ as shown in Eq. (3) **(Becker and Ichino, 2002)**.

$$ATT = E(Y_{1i} - Y_{2i} \,|A_i = 1) \quad (3)$$

According to **Rosenbaum and Rubin (1983)** the propensity scores for continued uptake are estimated as shown in Eq. (4).

$$Prob(X) = Prob(A_i = 1|X) \quad (4)$$

Depending on the conditional independence assumptions (Eq. 5),

$$Y_{1i}, Y_{2i} \perp \mathrm{A}|X \quad (5)$$

the potential livelihood outcomes are independent of technology continued uptake given $X$ which represented vector of the independent variable, which implies Eq. 6-7.

$$E(Y_{2i}|A = 1, Prob(X)) = E(Y_{2i}|A = 0, Prob(X)) \quad (6)$$

and

$$0 < Prob\ (X) > 1 \quad (7)$$

For all $X$, there is a positive likelihood of either continuously adopting PPT ($A = 1$) or not adopting ($A = 0$) as this guarantees every PPT continued user a counterpart in the non-adopter population. Therefore, resulting $ATT$ can be estimated as Eq. 8-10.

$$ATT = E(Y_{1i} - Y_{2i}|A = 1) \quad (8)$$

$$ATT = E[E(Y_{1i} - Y_{2i}|A_i = 1, Prob(X))] \quad (9)$$

$$ATT = E[E(Y_{1i}|A_i = 1, Prob(X)) - E[Y_{2i}|A_i = 0, Prob(X))] \quad (10)$$

Since propensity scores or probabilities are continuous variables, there is no way of getting PPT continued user with the same score to be used as counterfactual, as this renders Eq. 9 insufficient in computing average treatment effect **(Smith and Todd, 2005)**. Therefore, it is important to apply more than two matching methods to help in checking the robustness of result estimates. This study, therefore, applied 3:1 nearest neighbour matching (NNM) and kernel matching (KE) techniques to ascertain the consistency and robustness of impact estimates. Therefore, using a STATA software, a propensity score matching method was used to assess and compare the impact or Average Treatment Effect of PPT continued uptake on smallholder per capita consumption expenditure, household dietary diversity score (HDDs), and poverty status. Poverty was measured by the poverty gap index and poverty severity index. Household dietary diversity score was used to measure dietary diversity as nutritional outcomes based on the number of food groups households consumed. It accurately reflects the diversity of macro and micronutrient intake **(Kennedy *et al.*, 2011)**. HDDs, therefore, had 0-12 scores for 12 food groups consumed by households based on 24hr-recall. These include cereals, fish and seafood, root and tubers, pulses, legumes or nuts, vegetables, milk and milk products, fruits, oil or fats, meat, poultry, or offal, sugar or honey, eggs, and miscellaneous. These food groups were added to give HDDs for each household.

To evaluate poverty levels among the households, this study adopted the Foster, Greer, and Thorbecke (FGT) poverty index **(Foster, Greer and Thorbecke, 1984)**. FGT poverty index uses the poverty line as the threshold level of wellbeing that distinguishes poor individuals from non-poor individuals, to compute some aggregate poverty measures. This study adopted the mean consumption expenditure of Kenyan Shillings (KES). 154.28 as the poverty line. Foster, Greer, and Thorbecke's poverty index is measured as shown in Eq. (11).

$$P_j = \frac{1}{N}\sum_{i=1}^{Q}\left(\frac{Z-Y_i}{Z}\right)^{a} \tag{11}$$

Where: $P_j$ represents Foster, Greer, and Thorbecke poverty indices ranging between 0 and 1. $N$ is the total number of farmers in the study, $q$ is the number of farmers leaving below the poverty line, $Z$ is the national poverty line or mean consumption expenditure, and $Y_i$ is household per capita expenditure on food and non-food items of the $i^{th}$ individual. Therefore, the poverty status of the respondents was divided into three indicators as follows. When $a = 0$, $P_0$ gives the headcount index measuring the incidence of poverty. When $a = 1$, $P_1$ gives the poverty gap index measuring the depth of poverty, and finally when $a = 2$, $P_2$ gives the poverty squared poverty gap index measuring the severity of poverty among the household. Description of dependent and independent variables and their expected signs are provided in Table 1.

## RESULTS AND DISCUSSION

### *Descriptive Statistics of the dependent and independent variables*

Descriptive statistics of continuous and categorical variables used in the analysis are presented in Tables 2 and 3, respectively. Maize producers were classified into three groups namely; PPT continuous users (n = 74), dis-adopters (n = 49), and non-adopters (n = 115). To test for significant differences among variables across the PPT farmer categories, ANOVA/F-test and a Chi-square test were used for continuous and categorical variables, respectively. In terms of age of the household head, PPT continuous users were significantly older (about 55 years) with more years of education (11) compared to PPT dis-adopters and non-adopters who had a mean age of 51 and 50 years with approximately 10 and 7 years of schooling, respectively. Significantly, PPT continuous users had a higher mean household size of about 8 members with approximately 2.97 acres of land compared to PPT dis-adopters and dis-adopters who had roughly 6 and 5 family members with 1.52 and 1.82 acres of land, respectively **(Gwada, 2019)**. The results revealed that there was a statistically significant difference in the mean walking distance to the nearest administrative center across the groups. On average, PPT continuous users had to travel approximately 37.32 minutes to the nearest administration center compared to 56.22 minutes travelled by the PPT dis-adopters and 69.29 minutes travelled by non- adopters. This implies that PPT continuous users were taking significantly lesser minutes to reach the nearest administrative center compared to PPT dis-adopters and non-adopters. By implication, as the distance to the most adjacent administrative center decreases, there is the possibility of reduced transaction costs associated with ease of accessing extension information and credit markets, thus increasing the likelihood of adoption and continued use of new technologies by a household **(Awotide, Karimov and Diagne, 2016)**. Again, PPT continuous users had a significantly higher number of group memberships (4 groups) compared to non-adopters (2 groups) and dis-adopters (2 groups). On average, PPT continuous users had significantly higher tropical livestock units (7.42) compared to non-adopters (3.86) and dis-adopters (4.34). Tropical livestock unit (TLU) was measured using **FAO (2015)** guidelines. Similarly, PPT continuous users were earning significantly higher annual off-farm income of KES. 245,869.95 (2458.69USD) compared to non-adopters and dis-adopters earning KES. 130,782.51 (1307.82 USD) and KES. 106,519.37 (1065.19 USD) per annum, respectively.

The results in Table 3 indicated that the majority (71.43%) in the whole sample were married households **(Gwada, 2019)**. Similarly, the proportions of married families for PPT continuous users, dis-adopters, and non-adopters were 75.68%, 71.43%, and 68.70%, respectively. The sampled households composed of both female and male heads of households. Overall, the majority (64.71%) were male-headed households while 35.29% were headed by females. The male-headed household's proportion for PPT continuous users, dis-adopters and non-adopters were 82.43%, 63.27%, and 53.91%, while female-headed household's proportion for the PPT continuous user, dis-adopters and non-adopters were 17.57%, 36.73%, and 46.09%, respectively. This shows that female-headed households were significantly fewer than male-headed households for each PPT uptake category **(Gwada, 2019)**. Results significantly revealed that PPT continuous users recorded the highest percentage (86.49%) of those farmers owning land with title deeds compared to dis-adopters (46.94%) and non-adopters (29.57%).

Descriptive statistics revealed that the majority of PPT continuer users (89.19%) significantly perceive stem borer and armyworm as a major problem compared to PPT dis-adopter (77.55%) and non-adopters (45.22). Similarly, the majority of PPT continuous users (89.19%) significantly perceive stem *Striga* weed as a major problem compared to dis-adopter (77.55%) and non-adopters (40.87%). Since PPT is designed to effectively control *Striga* weed, stem borers, and fall armyworms, farmers' experience on these constraints especially in the last cropping seasons could influence its continual uptake.

***Econometric estimation of the effect of continued uptake of push-pull technology on the livelihood outcomes***
***Selection of Livelihood Outcome Variables***

Table 4 shows one-way ANOVA and Chi-Square results for selected livelihood outcomes. Results revealed a statistically significant difference in household per capita consumption expenditure per day across the PPT uptake categories. The average household per capita consumption expenditure per day for the entire sample was KES. 154.28/1.54 USD. Continuous users of PPT recorded a statistically significantly higher average household per capita consumption expenditure per day of KES. 196.16/1.96 USD followed by non-adopters (KES. 141.57/1.42 USD), and lastly dis-adopters (KES. 119.88/ 1.20 USD) **(Gwada, 2019)**. This is attributed to more income from PPT production used in purchasing various goods. These results are consistent with those from a study by **Chepchirchir *et al.* (2016)** on the impact of intensity of PPT uptake on household welfare. They found a higher per capita consumption expenditure among PPT adopters than non-adopters in eastern Uganda.

Overall, the majority (62.18%) in the entire sample were living below the poverty line with only 37.82% of the households living above the poverty line as shown in Table 4. The proportions of households living above the poverty line for PPT continuous users, dis-adopters, and non-adopters were 60.81%, 14.29%, and 33.04%, respectively. Again, the proportions of households living below the poverty line for PPT continuous users, dis-adopters, and non-adopters were 39.19%, 85.71%, and 66.96, respectively. This implies that the majority of the continuous users were significantly living above poverty live compared to other PPT adoption categories. In terms of the poverty gap, there was a statistically significant difference across PPT adoption categories **(Gwada, 2019)**.

The poverty gap for the entire sample was 0.22, with a lower depth of poverty among PPT continuous users (0.09), followed by non-adopters (0.27) and lastly dis-adopters (0.30). In other words, the depth of poverty was statistically significantly lower among PPT continuous users compared to non-adopters. Lower depth of poverty witnessed among PPT continuous users compared to dis-adopter or non-adopters could be linked to the perceived benefits of PPT in terms of improved production or income received from its diversified outcomes. The severity of poverty for the entire sample was 0.09, with significantly lower severity among PPT continuous users (0.03), followed by non-adopters (0.12) and dis-adopters (0.12) **(Gwada, 2019)**.

One-way ANOVA results revealed that there was a statistically significant difference in Household Dietary Diversity Score across the farmer groups. On average, PPT continuous users recorded significantly a higher Household Dietary Diversity Score of 10.38, followed by dis-adopters (6.67) and lastly non-adopters (6.39). This implies that on average PPT continuous users have higher access to quality food diet compared to non-adopters and dis-adopters. This is attributed to more income from PPT production that can be used in purchasing various food groups. In a related study, **Ogot *et al.* (2017)** opined that PPT as an agricultural intervention has improved the nutritional status of farmers' children in western Kenya.

***Selection of Variables and Determination of Propensity Scores***

In order to measure the causal effect of PPT continued uptake on selected livelihood outcomes, PPT dis-adopters were excluded, and another a probit model adopted to estimate the probability of continued PPT uptake. Based on the conditional independence assumption, only regressors that are significant determinants of livelihood outcomes, as well as PPT continued uptake, were selected. First, the variance inflation factor (VIF) was performed to examine the presence of multicollinearity among independent variables, and results are presented in Table 5. Result revealed that VIF values of individual variables range from 1.22 to 2.03 with mean VIF of 1.61. This presents that no collinearity existed between these independent variables since all VIF values were below the recommended value of 10 **(Greene, 2000).** The results of the Breusch-Pagan test for heteroscedasticity ($X^2$=1.92, $p$=0.1658) showed that the model was free from heteroscedasticity problems, as the null hypothesis for homoscedasticity (constant variance) was not rejected.

Table 6 presents the associated estimates of the probit model. Table 6 shows a log-likelihood ratio of -47.35 indicating how the model quickly converges. The likelihood ratio chi-square statistic (LR $chi^2(13)$ = 158.34, $p$ = 0.000) and Pseudo $R^2$ of 0.626 show that the model wholly and significantly fits the data well, and in that the decision to continuously uptake PPT were attributed to the explanatory variables considered in the probit model. This also shows that the combination of explanatory variables meets the balance requirement. Table 6 also presents information about some of the factors influencing farmers' decisions to continuously uptake PPT where the explained variable takes the value of one (1) if the farmer adopted and still practicing PPT, and zero (0) if the farmer completely never adopter. The results of the probit model showed that age of the household head, education level of household head, total farm size owned, type of land ownership, perception on *Striga* weed severity, perception on stem borer/fall armyworm severity, and distance to the nearest administrative center has a statistically significant influence on continued uptake of PPT as shown in Table 6.

The age of the household head was found to be a positive and significant determinant of continued uptake of PPT at a 10% level. An increase in the age of the household head raises the probability of adopting PPT continuously.

**Table 1:** Description of dependent and independent variables and their expected signs

| Variables | Description | Variable Type | Measurement | Expected Sign |
|---|---|---|---|---|
| *Dependent Variables* | | | | |
| PPT adoption | If the farmer adopted PPT or not | Dummy | 1= Yes, 0= No | None |
| PPT continual adoption | If the farmer continues with PPT adoption or dis-adopted | Dummy | 1= Yes, 0 = No | None |
| Per capita consumption expenditure | Annual household expenditure on food and non-food items | Continuous | Kenyan Shillings (KES)/ USD | None |
| Poverty gap index | A measure representing poverty intensity of a household | Continuous | Number | None |
| Squared Poverty gap index | A measure of severity of household poverty | Continuous | Number | None |
| HDDs | Household dietary diversity score | Continuous | Number | None |
| *Independent Variables* | | | | |
| Age | Age of the household head in years | Continuous | Years | ± |
| Gender | Gender of the household head | Binary | 1=Male, 0= Female | ± |
| Marital status | Marital Status of the household head | Binary | 1= Married, 0 = No spouse | ± |
| Education level | Years of schooling of the household head | Continuous | Number | ± |
| Log off-farm income | Natural logarithm of total income from off-farm sources | Continuous | Number | ± |
| Household size | Number of the person within a household | Continuous | Number | ± |
| Perception of *Striga* weed severity | Perception of *Striga* severity | Categorical | 1= Major problem, 0 = not a problem | ± |
| Perception of stem borer/ armyworm severity | Perception of stem borer/ armyworm severity | Categorical | 1= Major problem, 0 = not a problem | ± |
| Group membership | Number of farmer groups | Continuous | Number | ± |
| Distance to the nearest administrative center | Distance to the nearest administration center | Continuous | Walking minutes | ± |
| Land ownership | Type of land ownership | Binary | 1=Owned with title, 0= No title | ± |
| Total farm size owned | Total land size owned | Continuous | Acres | ± |
| Tropical livestock unit | Total Livestock Unit | Continuous | Units | ± |

**Table 1**: Descriptive statistics for continuous variables

| | Push-Pull Technology Uptake Status | | | | | |
|---|---|---|---|---|---|---|
| | Overall sample n=238 | All Adopters n=123 | Continuous Users n=74 | Dis-adopters n=49 | Non- adopters n=115 | Statistics |
| Variables | Mean/std. dev. | Mean/std. dev. | Mean/std. dev. | Mean/std. dev. | Mean/std. dev. | F-test |
| Age of household head (Years) | 51.79 | 53.52 | 54.86 | 51.48 | 49.93 | 5.83*** |
| | (9.92) | (10.33) | (10.44) | (9.91) | (9.14) | |
| Education level (Years) | 8.73 | 10.43 | 10.82 | 9.84 | 6.91 | 31.61*** |
| | (3.90) | (3.19) | (3.02) | (3.37) | (3.78) | |
| Household size (number) | 7.03 | 7.63 | 7.84 | 6.33 | 5.38 | 4.59** |
| | (3.56) | (3.47) | (3.45) | (3.51) | (3.13) | |
| Total farm size owned (Minutes) | 2.12 | 2.39 | 2.97 | 1.52 | 1.82 | 27.31*** |
| | (1.35) | (1.37) | (1.34) | (0.89) | (1.26) | |
| Distance to the nearest administrative center (walking minutes) | 56.66 | 44.85 | 37.32 | 56.22 | 69.29 | 11.23*** |
| | (47.17) | (43.16) | (33.39) | (53.10) | (48.17) | |
| Group membership (number of groups) | 2.89 | 3.48 | 3.92 | 2.82 | 2.25 | 10.86*** |
| | (2.50) | (2.51) | (2.49) | (2.42) | (2.34) | |
| Tropical livestock units [a] | 5.06 | 6.19 | 7.42 | 4.34 | 3.86 | 12.76*** |
| | (5.10) | (5.87) | (6.07) | (5.06) | (3.80) | |
| Off-farm income (USD) | 1615.70 | 1903.56. | 2458.69 | 1065.19 | 1307.82 | 17.29*** |
| | (1605.27) | (1882.33) | (2219.81) | (564.80) | (1174.88) | |

Note: Mean variables shown with standard deviations in parenthesis; *** and ** denote significance at 1% and 5% levels, respectively. [a] According to FAO (2015), TLU for Africa South of Sahara is typically taken to be equivalent to: Cattle=0.50, sheep=0.10, Goat=0.10, Pigs=0.25, Asses=0.50, Horses=0.50, Mules=0.60, Camels= 0.70, or Chicken = 0. 01.

**Table 3:** Descriptive statistics for categorical variables

| Variables | Push-Pull Technology Uptake Status<br>Overall Sample n=238 Freq | Percent | All Adopters n=123 Freq | Percent | Continuous Users n=74 Freq | Percent | Dis-adopters n=49 Freq | Percent | Non- adopters n=115 Freq | Percent | Statistics Chi$^2$-test |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Gender of household head (%) | | | | | | | | | | | |
| Female | 84 | 35.29 | 31 | 25.20 | 13 | 17.57 | 18 | 36.73 | 53 | 46.09 | 16.09*** |
| Male | 154 | 64.71 | 92 | 74.80 | 62 | 82.43 | 31 | 63.27 | 62 | 53.91 | |
| Household head marital status (%) | | | | | | | | | | | |
| Married | 170 | 71.43 | 91 | 78.98 | 56 | 75.68 | 35 | 71.43 | 79 | 68.70 | 6.41 |
| No spouse | 68 | 28.57 | 32 | 21.02 | 18 | 24.32 | 14 | 28.17 | 36 | 31.30 | |
| Perception of *Striga* weed severity (%) | | | | | | | | | | | |
| Not a problem | 87 | 36.55 | 19 | 15.45 | 8 | 10.81 | 11 | 22.45 | 68 | 59.13 | 68.22*** |
| Major problem | 151 | 63.45 | 104 | 84.55 | 66 | 89.19 | 38 | 77.55 | 47 | 40.87 | |
| Perception of stem borer/armyworm severity (%) | | | | | | | | | | | |
| Not a problem | 82 | 34.45 | 19 | 15.45 | 8 | 10.81 | 11 | 22.45 | 63 | 54.78 | 68.22*** |
| Major problem | 156 | 65.55 | 104 | 84.55 | 66 | 89.19 | 38 | 77.55 | 52 | 45.22 | |
| Land tenure (%) | | | | | | | | | | | |
| No title | 117 | 49.16 | 36 | 29.27 | 10 | 13.51 | 26 | 53.06 | 81 | 70.43 | 58.75*** |
| Owned with title | 121 | 50.84 | 87 | 70.73 | 84 | 86.49 | 23 | 46.94 | 34 | 29.57 | |

Note: *** denote significance at 1% levels.

**Table 4:** Descriptive statistics on selected livelihood outcomes

| Variables | Push-pull Technology Uptake Status<br>Overall sample *n*=238 Mean/std. dev. | All Adopters *n*=123 Mean/std. dev. | Continuous Users *n*=74 Mean/std. dev. | Dis-adopters *n*=49 Mean/std. dev. | Non- adopters *n*=115 Mean/std. dev. | Statistics F-test/ Chi$^2$-test |
|---|---|---|---|---|---|---|
| Per Capita Consumption Expenditure per Day (USD) | 1.54 (0.91) | 1.66(0.91) | 1.96 (0.91) | 1.20 (0.71) | 1.42 (0.90) | 13.96*** |
| Headcount Ratio (%) | | | | | | |
| Above the poverty line | 37.82 | 42.28 | 60.81 | 14.29 | 33.04 | 29.29*** |
| Below Poverty Line | 62.18 | 57.72 | 39.19 | 85.71 | 66.96 | |
| Poverty gap (Depth of Poverty) | 0.22 (0.20) | 0.17 (0.10) | 0.09 (0.15) | 0.30 (0.19) | .27 (0.23) | 22.68*** |
| Squared Poverty Gap (Severity of poverty) | 0.09 (0.12) | 0.07 (0.10) | 0.03 (0.08) | 0.12 (0.11) | 0.12 (0.13) | 16.20*** |
| Household Dietary Diversity Score | 7.69 (2.53) | 8.90 (2.36) | 10.38 (1.24) | 6.67 (1.84) | 6.39 (2.02) | 122.83*** |

Note: *** denote significance at 1% level.; Standard deviations in parenthesis.

**Table 5:** Multicollinearity diagnosis results of variance inflation factor (VIF)

| Variable | VIF |
|---|---|
| Age of household head | 1.46 |
| Gender | 1.50 |
| Marital status | 1.27 |
| Education level | 1.76 |
| Household size | 1.58 |
| Natural logarithm of off-farm income | 1.59 |
| Total farm size owned | 2.03 |
| Tropical livestock unit | 2.03 |
| Land ownership | 1.45 |
| Perception of *Striga* weed severity | 1.86 |
| Perception of stem borer/fall armyworm severity | 1.59 |
| Number of farmer groups | 1.54 |
| Distance to the nearest administrative center | 1.22 |
| Mean VIF | 1.61 |

**Table 6:** Results of probit estimation of propensity scores

| Variables | Coefficient | Standard Error | z-Value |
|---|---|---|---|
| Age of household head | 0.033 | 0.019 | 1.74* |
| Gender | 0.372 | 0.413 | 0.9 |
| Household head Marital status | -0.549 | 0.427 | -1.29 |
| Education level | 0.191 | 0.054 | 3.55*** |
| Natural logarithm of off-farm income | 0.0489 | 0.233 | 0.21 |
| Household size | -0.023 | 0.058 | -0.39 |
| Tropical livestock unit | 0.034 | 0.042 | 0.82 |
| Total farm size owned | 0.321 | 0.152 | 2.11** |
| Land ownership | 1.042 | 0.327 | 3.18*** |
| Perception of *Striga* weed severity | 0.298 | 0.194 | 1.53* |
| Perception of stem borer/fall armyworm severity | 0.64 | 0.197 | 3.24*** |
| Distance to the nearest administrative center | -0.013 | 0.004 | -3.29*** |
| Number of farmer groups | -0.08 | 0.075 | -1.06 |
| Constant | -5.687 | 2.788 | -2.04** |

Note: Number of observation = 189; Log-likelihood =-47.35; log-likelihood $\chi^2$ (13) = 158.34, Breusch-Pagan test for heteroscedasticity: $X^2$=1.92, $p$=0.1658. Prob > $\chi^2$ = 0.000; Pseudo $R^2$ = 0.626; ***, ** and * denote significant at 1%, 5% and 10% levels, respectively.

This is attributable to the fact that older farmers have high accumulated knowledge and farming experience obtained from years of experimentation thus able to continuously adopt a technology. Again, older household heads have larger household size, and higher capital accumulation to continuously adopt labour and capital intensive technology like PPT. **Onyenweaku *et al.* (2010)** also reported a similar positive relationship between farmers' age and continuous uptake of agricultural technologies. Continuous uptake of PPT was also positively and significantly influenced by the education level of the household head at a 1% level. A higher level of education increases the probability of adopting PPT continuously. Education helps farmers in making better decisions regarding continuously technology adoption. Educated farmers are well informed and are able to search, consolidate, and interpret agricultural knowledge as well as extension information related to agricultural technology adoption. These results are consistent with the findings by **Awotide *et al*. (2016)** and **Onyeneke, 2017).**

Continuous uptake of PPT was significantly and positively influenced by the total size of land owned by farmers at a 5% level. By implications, farmers who own a large tract of land are more likely to uptake PPT continuously. This is attributable to the fact that farmers who own a large tract of land have higher levels of land use diversification due to low conflicts and competition on possible uses of land, thus able to adopt a technology continuously. Land tenure had a positive and statistically significant influence on the continuous uptake of PPT at a 1% level. That is, farmers who own their land with title deeds are more likely to adopt PPT continuous than those owning land without titles. This is attributable to the fact that better land tenancy provides long-term security which raises the probability that farmers will adopt and continue using agricultural technologies, which require long-term investment to capture their returns such as PPT. **Kpadonou *et al.* (2017)** also reported similar results that higher levels of land ownership and user right security positively influence investments in long-term projects such as forest conservation projects.

The influence of perception on *Striga* weed and stem borer/fall armyworm severity on continued uptake of PPT was also found to be positive and significant at 10% and 1%, respectively. In other words, farmers who still perceive *Striga* weed, stem borers, and fall armyworm as major problems to maize production are more likely to uptake PPT continuously as opposed to those who perceived them as a non-problem. Since PPT is an integrated pest and weed technology designed to control *Striga* weed, fall armyworm, and stem borer, farmers' who still face these constraints on their farms are more likely to continuously use PPT. **Murage *et al*. (2015)** also found a similar result that farmers who perceived an agricultural problem as severe would be more willing to adopt any technology available to combat it, than those who perceived it as less severe. Finally, the distance from the farm to the administrative center negatively and significantly influenced PPT's continual uptake decision at a 1% level. This inverse relationship implies that, as the distance to the nearest administrative center decreases, there is possibility of reduced transaction costs associated with accessing extension information, input and output markets, as well as credit markets, thus increasing the likelihood of continual use of agricultural technologies like PPT (**Awotide *et al.*, 2016**).

***Balancing Test and Common Support Determination***

To determine the effect of continual PPT uptake, it is essential to consider the fact that PPT continuous users might also have realized a higher level of livelihood outcomes, even if they had not continuously practiced PPT. As a result, the study adopted propensity score matching techniques that account for all observable factors or characteristics to distinguish the intrinsic effect of PPT continued uptake on household livelihood outcomes. Therefore, the "balance test" was performed to balance the distribution of the relevant covariates between PPT continuous users and non-adopters, before and after matching. The common support condition or the overlap was checked using a line graph that presents the propensity score distribution (x-axis) between PPT continuous user (treated) and non-adopters (untreated). The region of common support ranged from 0 to 0.999 as presented in Figure 1. Common support condition helps in ensuring that all combination of observed household characteristics in the treatment and control group are matched. Looking at the propensity score distributions based on the common support region and the overlaps, it can be seen that most of the scores between the PPT continuous users' category and non-adopters' category were within the region of common support. This is also evidenced by more overlaps between the treated and untreated groups. As a consequence, only a few observations were rejected from the analysis; hence a good match was obtained.

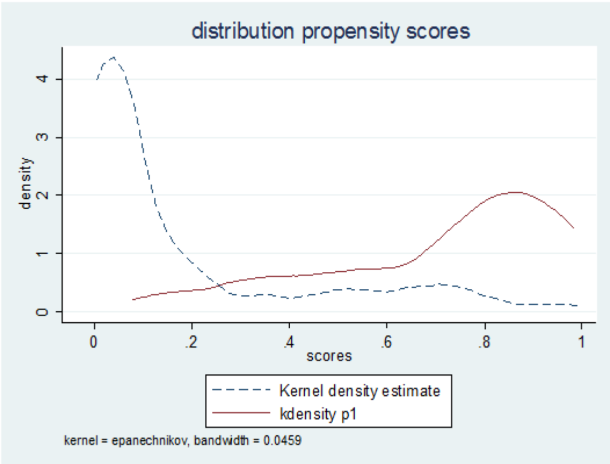


**Figure 1.** Common support graph
Source: Own computation based on PPT data (2019)

**Assessing the Matching Quality**

It is essential to note that two matching algorithms namely kernel matching (KM) and nearest neighbour matching (NNM 3:1), were used to examine the effects of PPT continued use on farmers' livelihood outcomes. However, these two different algorithms resulted in different quantitative findings, but with similar qualitative results. The matching algorithms resulted in a unique common support area and were based on somewhat different samples, thus resulting in the selection of various observations. Therefore, in assessing the matching quality, a balancing test was used to examine whether the differences in the explanatory variables or covariates in the matched sample category have been eliminated. Different propensity score quality indicators were used to check the quality of the matching process, before and after matching to determine the balance in the distribution of the covariates in all groups **(Gwada, 2019)**. Results in Table 7, therefore, presents the mean differences, percent reduction in bias after completion of the matching algorithm, and a percent bias of the matched and unmatched group based on the observed characteristics used in the probit model of PPT continued adoption decision. After controlling for bias, a better balance was achieved in the matched sample for all the covariates. According to **Rosenbaum and Rubin (1983)**, a percentage bias after matching of each covariate and the mean absolute bias should be less than 20% for validation of the balancing property. Overall, all variables satisfied this criterion after matching thus validated the balancing property. Therefore, PPT continuous users and non-adopters with similar observable characteristics were successfully matched. Therefore, 3:1 nearest neighbour and Kernel matching techniques were then considered as the best matching techniques for this study since they resulted in a significant reduction in bias after matching all the covariates.

Moreover, there were no significant differences in the mean distribution (p>*t*) in matched untreated and treated groups. Generally, there were insignificant p-values of the likelihood ratio test, greater reduction in total bias, and low pseudo $R^2$ after matching for all algorithms as shown in Table 8. This implies that the propensity specification was successful with respect to the balancing of covariates distribution between the treated and untreated groups. Specifically, the mean standardized biases for all variables observed were 83.6 before matching. However, after matching, mean standardized biases significantly reduced to 12.60 and 17.6 for 3:1 nearest neighbour and kernel matching, respectively. This implies that 3:1 nearest neighbour matching produced the best matching quality in terms of low mean standardized biases. The pseudo-$R^2$ value before matching was 0.626. By re-evaluating the scores based on matching the PPT continuous users' category and non-adopter category, and comparing the values of pseudo-$R^2$ before and after matching process, the finding revealed that the pseudo-$R^2$ values for the nearest neighbour matching (0.078) and the kernel matching (0.090) were significantly reduced to lower values after matching process. This implied that the matching process significantly reduced the selection bias thus the balancing property was satisfied. In other words, it implied that the regressors were randomly distributed in the treated group and untreated group. Further, p-values were all rejected after matching for all the matching algorithms implying that there was no difference in the distribution of the observed covariates between treated and control groups. The total percentage reduction bias for NNM and KM was 84.93% and 78.95%, respectively. However, this was above the recommended value of 20% suggested by **Rosenbaum and Rubin (1983),** thus indicating that the matching process significantly reduced the selection bias.

### *Hidden Bias and Sensitivity Analysis*

It is vital to note that propensity score matching is designed to only control for the selection bias in the observable variables. This calls for the need to test or check for the hidden bias. This is based on the Average Treatment Effect on the Treated (ATT) sensitivity to hidden bias resulting from unobservable variables especially after matching. According to **Rosenbaum and Rubin (1983)** an unobserved variable may simultaneously influence individual assignment into the treatment group as well as the welfare outcomes. This might result in hidden bias thus leading to inaccurate and non-robust matching estimators. To solve this issue, a bounding approach or sensitivity analysis is used to evaluate how strongly unobserved factors might affect the treatment selection process to alter the matching analysis implications **(Rosenbaum and Rubin, 1983)**.

This bounding approach involves the calculation of upper and lower bounds with a Wilcoxon sign-rank test to test the null hypothesis of no participation effect for different hypothesized values of unobserved selection bias **(Rosenbaum and Rubin, 1983)**. The absence of a hidden bias means that the selection process indeed ensured that two parties having the same observed covariates have the same chances of getting the treatment, resulting in the odds ratio of one. Under the absence of hidden bias assumption, *Q_mh+* for overestimation of the treatment effect and *Q_mh-* for underestimation of the treatment effect resulted in a similar result or rather an odd ratio of one, implying the unobserved selection bias or absence of hidden as shown in Table 9.

### *Effect of continual PPT uptake on Consumption Expenditure, Poverty Status, and Household Dietary Diversity*

After getting a common support condition and the best matching algorithms selected to match the different propensity scores of PPT continuous users (treated) to those of non-adopters, the average treatment effects on the treated (ATT) were estimated. The results of kernel matching (KM) and 3:1 nearest neighbour matching (NNM) showing the effect of PPT adoption and continued use on smallholder livelihood outcomes are presented in Table 10. The livelihood outcomes are measured by per capita household consumption expenditure per day, squared poverty gap, and household dietary diversity. Overall, using 50 times bootstrapping for testing of the statistical significance, the results of the two matching methods indicate that continual uptake of PPT had a positive significant effect on per capita household consumption expenditure per day and household dietary diversity score. For 3:1 nearest neighbour matching method, per capita household consumption expenditure per day and household dietary diversity scores were positively influenced by continual uptake of PPT and were both statistically significant at 1% level.

**Table 7:** Mean differences in covariates before and after matching

| Variable | Sample | Mean Sample Treated | Control | Bias Bias (%) | Reduction bias (%) | t-test t | p>t |
|---|---|---|---|---|---|---|---|
| Age of household head | Unmatched | 54.865 | 49.93 | 50.3 | | 3.42 | 0.001 |
| | Matched | 52.257 | 52.435 | -1.8 | 96.4 | -0.08 | 0.935 |
| Gender | Unmatched | 0.824 | 0.539 | 64 | | 4.17 | 0.000 |
| | Matched | 0.714 | 0.831 | -26.2 | 59 | -1.16 | 0.249 |
| Household head marital status | Unmatched | 0.757 | 0.687 | 15.5 | | 1.03 | 0.302 |
| | Matched | 0.686 | 0.803 | -26 | -67.3 | -1.11 | 0.269 |
| Education level of the household head | Unmatched | 10.824 | 6.913 | 114.3 | | 7.49 | 0.000 |
| | Matched | 9.714 | 11.498 | -52.1 | 54.4 | -2.07 | 0.142 |
| Natural logarithm of off-farm income | Unmatched | 12.077 | 11.502 | 72.3 | | 4.94 | 0.000 |
| | Matched | 11.856 | 11.915 | -7.5 | 89.7 | -0.34 | 0.736 |
| Household size | Unmatched | 7.838 | 6.383 | 44.2 | | 3 | 0.003 |
| | Matched | 6.771 | 6.589 | 5.5 | 87.5 | 0.27 | 0.790 |
| Tropical livestock unit | Unmatched | 7.423 | 3.858 | 70.4 | | 4.97 | 0.000 |
| | Matched | 5.528 | 5.686 | -3.1 | 95.6 | -0.15 | 0.881 |
| Total size of land owned | Unmatched | 2.969 | 1.819 | 88.6 | | 5.98 | 0.000 |
| | Matched | 2.501 | 2.441 | 4.6 | 94.9 | 0.21 | 0.833 |
| Land ownership | Unmatched | 0.865 | 0.296 | 140.4 | | 9.15 | 0.000 |
| | Matched | 0.714 | 0.739 | -6 | 95.7 | -0.23 | 0.821 |
| Perception of *Striga* weed severity | Unmatched | 1.595 | 0.574 | 141.3 | | 9.37 | 0.000 |
| | Matched | 1.314 | 1.156 | 22 | 84.5 | 0.78 | 0.437 |
| Perception of stem borer/ fall armyworm severity | Unmatched | 1.622 | 0.617 | 140 | | 9.28 | 0.000 |
| | Matched | 1.371 | 1.028 | 47.8 | 65.8 | 1.69 | 0.096 |
| Distance to the nearest administrative center | Unmatched | 37.324 | 69.287 | -77.1 | | -4.99 | 0.000 |
| | Matched | 50 | 58.169 | -19.7 | 74.4 | -0.87 | 0.385 |
| Number of farmer groups | Unmatched | 3.919 | 2.252 | 69 | | 4.66 | 0.000 |
| | Matched | 2.943 | 3.088 | -6 | 91.3 | -0.24 | 0.814 |

**Table 8:** Propensity score quality indicators

| Matching algorithms | Nearest neighbour Matching NNM (3:1) | Kernel matching (KM) |
|---|---|---|
| Before Matching | | |
| Pseudo $R^2$ before matching | 0.626 | 0.626 |
| LR $chi^2$ before matching | 158.34 | 158.34 |
| Mean standardized bias before matching | 83.6 | 83.6 |
| Prob > $chi^2$ | 0.000 | 0.000 |
| After matching | | |
| Pseudo $R^2$ after matching | 0.078 | 0.090 |
| LR $chi^2$ after matching | 7.61 | 8.70 |
| Mean standardized bias after matching | 12.6 | 17.6 |
| Prob > $chi^2$ | 0.868 | 0.795 |
| Total % bias reduction | 84.93 | 78.95 |

**Table 9:** Sensitivity analysis with Rosenbaum bounds

| Gamma | Q_mh+ | Q_mh- | p_mh+ | p_mh- |
|---|---|---|---|---|
| 1 | . | . | . | . |
| 1.05 | . | -0.169 | . | 0.567 |
| 1.1 | . | . | . | . |
| 1.15 | . | -0.1691 | . | 0.567 |
| 1.2 | -0.169 | . | 0.567 | . |
| 1.25 | . | -0.169 | . | 0.567 |
| 1.3 | -0.169 | -0.169 | 0.567 | 0.567 |
| 1.35 | . | -0.169 | . | 0.567 |
| 1.4 | -0.169 | -0.169 | 0.567 | 0.567 |
| 1.45 | -0.169 | . | 0.567 | . |
| 1.5 | -0.169 | -0.169 | 0.567 | 0.567 |
| 1.55 | . | -0.169 | . | 0.567 |
| 1.6 | -0.169 | -0.169 | 0.567 | 0.567 |
| 1.65 | -0.169 | . | 0.567 | . |
| 1.7 | -0.169 | -0.169 | 0.567 | 0.567 |
| 1.75 | -0.169 | -0.169 | 0.567 | 0.567 |
| 1.8 | -0.169 | . | 0.567 | . |
| 1.85 | -0.169 | -0.169 | 0.567 | 0.567 |
| 1.9 | -0.169 | -0.169 | 0.567 | 0.567 |
| 1.95 | -0.169 | . | 0.567 | . |
| 2 | -0.169 | -0.169 | 0.567 | 0.567 |

Note: Gamma: odds of differential assignment due to unobserved factors;
Q_mh+ : Mantel-Haenszel statistic (assumption: overestimation of treatment effect);
Q_mh- : Mantel-Haenszel statistic (assumption: underestimation of treatment effect);
p_mh+ : significance level (assumption: overestimation of treatment effect);
p_mh- : significance level (assumption: underestimation of treatment effect).

**Table 10** Effect of push-pull technology continued uptake on consumption expenditure, poverty status, and household dietary diversity

| Matching Algorithm | Livelihood Outcome | Sample size | | Mean outcome | | ATT | Standard error | t-Statistics |
|---|---|---|---|---|---|---|---|---|
| | | Treated | Control | Treated | Control | | | |
| Nearest neighbour matching (3:1) | Per capita consumption expenditure per day (USD) | 35 | 115 | 2.04 | 1.45 | 0.59 | 25.778 | 2.29*** |
| | Squared poverty gap | 35 | 115 | 0.028 | 0.097 | -0.069 | 0.037 | -1.89** |
| | Household dietary diversity | 35 | 115 | 10.114 | 7.352 | 2.762 | 0.672 | 4.11*** |
| Kernel Matching | Per capita consumption expenditure per day (USD) | 35 | 115 | 2.04 | 1.56 | 0.48 | 27.471 | 1.72** |
| | Squared poverty gap | 35 | 115 | 0.028 | 0.077 | -0.049 | 0.036 | -1.66* |
| | Household dietary diversity | 35 | 115 | 10.114 | 7.240 | 2.874 | 0.560 | 5.13*** |

**Note:** *, ** and *** denote significant at 10%, 5%, and 1% levels, respectively; *t*-values are calculated using bootstrap with 50 replications. ATT denotes the Average Treatment Effect on the Treated.

For the kernel matching method, per capita consumption expenditure per day and household dietary diversity score was positively influenced by continual uptake of PPT use and were statistically significant at 5% and 1% level, respectively as shown in Table 10. The average treatment on the treated (ATT) column shows the difference in these livelihood outcomes between the treated (PPT continuous users) and control (non-adopters) groups **(Gwada, 2019)**. On average, the treated group performed better than their counterparts as revealed by the positive difference. Overall, the results also indicated that the continual uptake of PPT has a significant negative effect on farmers' squared poverty gap. For 3:1 nearest neighbour matching method, the squared poverty gap was negatively influenced by continual uptake of PPT and was statistically significant at a 5% level. For the kernel matching method, the squared poverty gap was negatively influenced by the continual uptake of PPT and was statistically significant at the 10% level. The effect of continual uptake of PPT on household per capita consumption expenditure ranges from KES 47.81/0.48 USD to KES. 59.02/ 0.59 USD daily. This implies that on average PPT continuous users were spending more on food and non-food items more than non-adopter of PPT.

The results imply that PPT technology has a positive impact on household consumption expenditure as it leads to significant improvements in soil fertility thus increasing cereal yields, milk, and dairy production **(Gwada, 2019)**. More income raised from different enterprises under PPT is, therefore, used to purchase many food and non-food items. **Chepchirchir *et al*. (2016)** used the Tobit model and generalized propensity scores (GPS) to evaluate the effect of intensity of PPT uptake on household welfare in eastern Uganda and found that there exists a significant and positive impact of the intensity of PPT adoption on per capita consumption expenditure. **Kassie *et al.* (2014)** and **Lunduka *et al.* (2017)** also revealed robust, significant, and positive effects of agricultural-related technologies uptake on per capita household consumption expenditure. Based on the nearest neighbour and kernel matching methods used, the estimated effect of continued use PPT on farmers' squared poverty gap is estimated to range from -0.069 to -0.049. This implies that on average the severity of poverty among PPT continuous users is estimated to be 4.9% to 6.9% much lower than the corresponding value for PPT non-adopters **(Gwada, 2019)**. This means that PPT results in high productivity and more income that enable its adopter to spend above the poverty line thus reducing the depth of poverty. **Nabasirye *et al.* (2012)** also used the propensity score matching approach and found the same results where uptake of improved maize technology had a significant positive effect on productivity hence direct implications for the alleviation of poverty in Uganda. **Kassie *et al.* (2014)** also used general propensity score methodology and found that adoption and continued use of improved maize technology significantly declined the extent of poverty in rural Tanzania.

Finally, based on the nearest neighbour and kernel matching process used, the estimated effect of continual PPT uptake on farmers' household dietary diversity score ranges from 2.762 to 2.874. In other words, PPT continuous users had access to approximately 3 food groups more than non-adopters. This also implies that PPT continuous users had better food access and a more diversified and quality diet thus higher nutritional outcomes compared to their counterparts. **Ogot *et al.* (2017)** also reported that agricultural technologies positively impact maize productivity, income, and thus food expenditure resulting in a higher and better nutritional status. The direct effects of continual uptake of PPT on household dietary diversity score attributed to the productivity benefits PPT adopters enjoy over non-adopters, which usually come in the form of higher farm income leading to increases in consumption on various food items. The productivity changes result in improved livelihoods, thus resulting in better nutritional and economic well-being and poverty alleviation in many areas where it is being practiced.

## CONCLUSION

Understanding the effect of continual uptake of PPT on livelihood outcomes is crucial for formulating sustainable small-scale agricultural policies. This study aimed to evaluate the effect of PPT continual uptake on livelihood outcomes of smallholder farmers in Homa Bay County, Kenya. Maize producers were classified into three groups namely PPT continuous users, PPT dis-adopters, and PPT non-adopters. The study concludes that significant variations in the socio-economic, farm and institutional characteristics exist across these PPT uptake groups. Probit regression results established that continual uptake of PPT was significantly influenced by age of household head, education level, total farm size owned, perception on *Striga* weed severity, land ownership, and perception on stem borer/ fall armyworm severity, all which had a positive effect. However, distance to the nearest administrative center negatively and significantly affected the continual PPT uptake. The study concludes that higher levels of education, aging, perception on stem borer, fall armyworm, and *Striga* weed as a major problem, larger land size, possession of land titles, and closeness to the nearest administrative center were significant in explaining the continual uptake of PPT among the surveyed households. Further, the study revealed that continual uptake of PPT had a positive and significant effect on per capita household consumption expenditure per day and household dietary diversity scores. However, it had a negative and significant effect on the depth of poverty as well as the severity of poverty among small-scale households. The study, therefore, concludes that continued uptake of PPT as integrated pest and weed management technology significantly impacts the livelihood outcomes of small-scale maize producers in Homa Bay county. Conclusively, continual uptake of PPT significantly improves consumption expenditure and access to a more diversified and nutritional diet, however, it reduces poverty. Also, the counterfactual results showed that the poverty gap between PPT continuous user and non-adopters could be closed if non-adopters were enabled to continuously practice the technology.

The study, therefore, recommends policies that will ensure intensive literacy development and extension training among young and elderly farmers as a strategy for promoting continual uptake of integrated pest and weed management technologies like PPT. The study also recommends land reforms to ensure the distribution and redistribution of land securities. In addition, there is a need for an integrated PPT development system that involves the collaboration of all stakeholders in ensuring continual supply, affordability, and accessibility of PPT components or inputs. Concerned stakeholders such as ICIPE should also continue supporting maize farmers with PPT inputs, as well as extension advice. Finally, in order to close the expenditure gap, nutritional gap, or the poverty gap between PPT-adopter and non-adopters, policymakers should consider policies that will improve efficiency or resource returns, and the number of resources of the non-adopters to the level of the PPT continuous users.

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# QUALITY OF LIFE FOR OCCUPATIONAL RISKS OF COCOA FARM WORKERS IN NIGERIA

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## ABSTRACT

**Research background:** Cocoa remains the Nigeria's highest foreign exchange earner among all agricultural commodities, Contributed 12.5-14% of the national GDP. Currently, Nigeria is the fourth largest cocoa producing country in the world, produced approximately 328,652 tons annually. Occupational risk is a major factor reducing productivity of farm workers as it impairs physical capacity and increase vulnerability to ill health, diseases and injuries. Risk of agrochemical exposure has been attributed to work demand and unhealthy work environment.
**Purpose of the article:** This study aimed to estimate life quality for agrochemical exposure risks of cocoa farm workers in Ondo state Nigeria. The study specifically estimates the amount an individual willingness to pay by respondents for occupational risk reduction**.**
**Methods:** Multistage sampling technique that guaranteed cocoa farmers who could provide desired information on the basis of the objectives of the study was adopted for the study. Random selection of 180 cocoa farm workers from the study area. Descriptive statistics (frequency, mean and percentage) and Discrete Choice Experiment (DCE) approach that dovetailed into choice modelling and conditional logistic regression were the analytical tools used.
**Findings & Value added:** the result revealed that 74% of the cocoa farm workers are on active age and mainly male with the mean age of 46 years. Most of the workers are illiterate that cannot read instructions on the agrochemical container. Average workers are willing to pay 830 Nigerian naira for personal protective equipment, 92 Nigerian naira for 15% wage discount as financial benefit of workplace injuries and 1024 Nigerian naira for training of workers in pesticide usage. The study concluded that better health conditions and appropriate use of personal protective equipment minimize the occupational risk. It was therefore recommended that educational programmes that will enhance farmer's knowledge, skills and attitude to use safe methods (appropriate use of protective equipment) in pesticide usage should be adequately planned. Appropriate use of personal protective equipment to reduce exposure to agrochemicals and the risks involved in the misuse and abuse of agrochemicals should be adopted.

**Key words:** quality of life; cocoa farm workers; choice experiment approach
**JEL Codes:** R52; R58; H41

## INTRODUCTION

The importance of cocoa (Theobroma cacao) to Nigeria's economy cannot be overemphasized. Though Nigeria gets her foreign exchange earnings from crude petroleum, yet cocoa remains the Nigeria's highest foreign exchange earner among all agricultural commodities. However, the contribution of cocoa to Nigeria's total exports earnings during the last two decades has dropped considerably. **Nwachukwu *et al.* (2010)** identify low yields, inconsistent production patterns, disease incidence like Black pod; swallow shoot virus etc. pest attack like mirids and little agricultural mechanization as key factors leading to decreasing cocoa production in Nigeria.

In 2007 and 2008, agricultural produce contributed 41.9% and 37.8% to non-oil export out of which cocoa contributed 12.5% and 13.9% respectively (**CBN, 2011**). National Bureau of statistics **(NBS, 2019)** reported that Nigeria's cocoa commodity export was 18 billion Nigerian naira (NGN) (47.2 million USD) in the second quarter of 2019. This represents a 29.65% increase in the value of cocoa commodity exports year-on-year. Currently, Nigeria is the fourth largest cocoa producing country in the world, produced approximately 328,652 tons 2020 (**FAO, 2020).**

Additionally, the ageing of cocoa producing trees also plays a role in the decrease of productivity. Particularly, 60 percent of cocoa farms are over 40 years old, thus hampering productivity.

Quality of life is the marginal rate of substitution between income and mortality risk. Promptly, this measures the amount at which individuals are willing to trade money for reduced risk of death (**Viscusi and Aldy, 2003**).

In principle, this trade-off can be measured by observing individual character. The value of risk reductions is a major element of the benefits of environmental policies. They are two key pieces of information for the quality of life calculation. A quantifiable risk reduction magnitude and an individual's willingness to pay for a risk reduction of that magnitude.

The other method regularly used to estimate quality of life is stated preference studies, which are sometimes used because the value of the risk reduction in question is often difficult to assume from observed behaviour and market prices. Stated preference methods provide non-market valuation techniques that are designed to estimate how much people would be willing to pay for a good or service that is not actively traded in markets. By using surveys, researchers can quietly question individuals about how much they would be willing to pay for various types of risk reductions.

Occupational risk can be described as a condition surrounding a work environment that increases the probability of death, illness or disability to a worker while hazard is the intrinsic property of a substance or process that could cause injury or damage (**WHO, 1987**).

Farm can be source of life-threatening hazards (**International Labour Organization, 1994**), The most important indicator for safety and health is workload per worker both physical labour and decision- making or mental workload, farmers experienced many fatal injuries happen to them working with familiar equipment in familiar fields, while doing tasks that they have been performing for years and even decades. Risky agricultural materials such as pesticides, fertilizers, flammable liquids and other solvents are responsible for acute and chronic illness in farm workers and family members. Tractors and other mechanized equipment have permitted a dramatic increase in the land but mechanization has contributed to severe injuries in agriculture significantly to the health risks (**ILO, 1994**). In many countries, the use of agrochemical is highly regulated. Occupational risks are injuries that occur at the location of a person's employment which can include exposure to chemicals or other substances as well as accidents. Occupational accidents, work injury, work-related injury, work accidents, work-related accidents are other names for occupational injuries. The main cause of occupational injuries is the result from exposure to harmful agents usually toxins, gases, inhalants, etc. while working (**Andrina, 1998**).

Agriculture is one of the most hazardous sectors of activity, both in industrialized and developing countries. According to the International Labour Organization **(ILO, 2000),** estimated that 14% of all occupational injuries are due to exposure of pesticides and other agrochemical constituents, and 3.4% of agricultural workers are killed each year. About hundred (100) Millions of agricultural workers will be injured on the field with poisoned by pesticides and other agrochemicals by 2020. The World Health Organization (WHO) and the United Nations Environmental Programme (UNEFP) estimated that one to five million cases of pesticide poisoning occur among agricultural workers each year with about 20000 fatalities **(United Nation, 2002).**

**Vigneri (2007)** also reported that the major challenging of cocoa which was observed in the 2001 and 2003 season was initially the result of the cocoa mass spraying programme, combined with a dramatic rise in fertilizer use. The cocoa sector continues to face problems such as inadequate storage facilities, pest and diseases, child labour issues, and occupational risks.

This study was carried out to estimate life quality for agrochemical exposure risk. Specifically, the study would; Estimate the amount an individual willingness to pay by respondents for risk reduction.

## LITERATURE REVIEW

Quality of life estimation naturally acquires or apprehends how much people are willing to pay to minimize the risk of death. Because risks to life come from a plenitude of sources and individuals can undertake many different actions to reduce these risks, it follows that there are many ways to estimate the quality of life.

Methods to estimate the quality of life can be broadly group into stated preference and revealed preference approaches and to date most of the empirical studies eliciting individual willingness to pay (WTP) to reduce occupational risks have been based on either the hedonic regression method **(Rosen, 1974)** applied on compensating-wage-differentials **(Aldy and Viscusi, 2007),** or the contingent valuation (CV) method applied in a vast range of different settings **(Lindhjem *et al*., 2011).** The former is a revealed preference (RP) method in which actual decisions are used to derive monetary values. A discrete choice experiment (DCE) is a stated preference survey approach which allows the researcher to quantify the relative importance of factors that influence decision making. DCE provides information on the strength of preferences, trade-offs individuals are willing to make, and changes in the probability of choices if levels within factors are changed **(World Health Organization, 2012)**. The approach which combines random utility theory, consumer theory, experimental design theory, and econometric analysis assumes that individuals choose between options to achieve the highest utility or benefit **(De Bekker-Grob, Ryan, & Gerard, 2012; Cameron and DeShazo, 2013)**. There has been a steady increase in the use of stated preference (SP) methods to estimate willingness to pay (WTP) for non-market goods. **Andersson *et al*. (2014)** suggests that DCE is more common to value non-market goods than the CVM method.

In this study, DCE employed to elicit individual preferences to minimize occupational risks among cocoa farm workers. The reason for using Stated Preference method because of the combination of the public goods and the conditions of the special market, which means that we prefer a controlled hypothetical market to actual market data by elicit preferences for several attributes. Nonmarket valuation techniques usually consider respondents' WTP for training for effective usage of agrochemical and personal protective equipment **(Johnston *et al*., 2017)**.

**Wenyu *et al*. (2018)** estimate farmer's willingness to pay for health risk reductions of pesticide use in china using contingent valuation approach and binary logit regression. The results showed the means willingness to pay (WTP) was 451.11CNY per household per year. It was reported that education or training programs should be launched for farmers to enhance their knowledge of pesticides and their risk perceptions. **Kamara *et al*. (2018)** investigate willingness to pay for health insurance among informal sector workers in Sierra Leone using Discrete Choice Experiment (DCE) approach and random effect logit regression model. The result revealed that workers are willing to pay about 10,180SLL/$1.38 for switching to a faith-based provider and 24712SLL/$124.86 to public provider for health insurance. It reveals that informal sector households are WTP more for a faith-based provider than a public provider for an improvement in coverage. It was concluded that policy maker that is in establishing a health insurance scheme should focus more on the faith based provider and the type of coverage.

**Fadiji *et al*. (2020)** determined compensating wages of agrochemical exposure risks of cocoa farm workers and the causes of agrochemical exposure risks in Ondo state using hedonic regression. The results show that 57.8% of the respondents violated the permissible residue prescription, 88.9% of respondent were unable to read instructions on the agrochemical containers and 65% of respondents were not aware of personal protective equipment and it was concluded that appropriate use of personal protective equipment minimizes agrochemical exposure risks.

## DATA AND METHODS

### *Sampling Procedure*

Multistage sampling technique that guaranteed cocoa farmers who could provide desired information on the basis of the objectives of the study was adopted in selecting respondents. The first stage was the purposive selection of Idanre Local Government Areas the Nigeria's leading cocoa producing area.

The second stage is the random selection of 12 communities/villages namely Oke-idanre, Baale-ojumu, Owomofewa, omilifon, Apomu, Ala-Elefosan, Owena, Atosin, Arapa, Obatedo, Apefon and Iramuje from the selected LGA. The last stage is the random selection of fifteen (15) cocoa labourers working with cocoa farmers from each village, making a total sample size of one hundred and eighty (180) respondents.

### *Source, Type and Method of Data Collection*

The use of primary data was employed for this study. Primary data was collected from cocoa farm workers through the use of structured interview schedule or guide, data collected was on socioeconomic characteristics such as age, sex, marital status, level of education, Farming experience, etc. question on occupational risk reductions based on the choice experiment method such as training of workers on effective use of pesticides, wage discount as the financial benefit of the workplace injury and illness and provision of personal protective equipment for farm workers, was also collected.; Choices made by each individual, together with the values of each attribute in each choice.

The questionnaire was developed by using the results from pilot study (pre-test). The purpose of the pre-test is to ensure the clarity of the questions in the questionnaire and to check the appropriateness of the chosen attributes as well as their levels. The results from the pre-test survey were used to adjust the price and to refine the draft questionnaire.

Choice sets were designed by orthogonal design, to ensure that all levels of the attributes are considered equally.

Table 1 shows the attribute and level used for the estimation of willingness to pay for risk reductions. Attributes selected for the study were based on the questionnaire.

Respondents were provided with seven (7) choice sets. Each choice set contains two or more alternatives with common attributes but different levels. Respondents were asked to choose the most preferred option from each choice set. Table 2 show the choice sets used for the estimation of willingness to pay for risk reductions.

In the face to face interview the respondents were asked to choose the most preferred option from each choice set and clarification were provided where necessary.

Data for this study was analysed with both descriptive and econometrics techniques. The descriptive techniques employed include; frequency counts, percentages, means and standard deviation, the econometric techniques employed was regression analysis and conditional logistic regression analysis.

### *Discrete Choice Experiment*

For analytical purposes, the Discrete Choice Experiment (DCE) approach was used to estimate willingness to pay for risk reduction. The method is firmly established in Lancaster's theory of consumer choice (**Lancaster, 1966**) which postulates that consumption decisions are determined by the utility that is derived from the attributes of a good, rather than from the good itself. The econometric basis of the Choice Experiment depends on the behavioural framework of random utility theory, which describes discrete choices in a utility-maximizing framework **(McFadden, 1974; Ben-Akiva *et al.*, 1985)**. Thus, it can be assumed that farm workers, asked to look for reduction of occupational risks, make their choices on the basis of the specific features for risk reduction. The utility obtained from a certain risk reduction feature is then the sum of the utilities obtained from each choice in the attributes defined in the Choice experiment design.

Questionnaire data were analysed using a random utility theory, which was chosen because we modelled choices on reduction of occupational risks.

The random utility model is represented by Eq. 1.

$$U_{in} = V_{in} + \varepsilon_{in} \qquad (1)$$

Where:

$U_{in}$ is the utility derived by worker i when choosing reduction of risk n;

$V_{in}$ is the deterministic component of the utility, typically assumed to be certain;

$\varepsilon_{in}$ is the error component that captures the factors unobservable influences on choice.

The risk reductions are uncertain because it depends on stochastic variables such as Training, premium discount and personal protective equipment among others. According to **Lusk and Norwood (2005)**, claimed that the probability of an attribute to occur could be included as another attribute of choice, this is in accordant with random utility theory. The regular and orderly part of the utility is then given by Eq. 2.

$$V_{in} = \alpha_n + \beta_1(Ptraining)_{in} + \beta_2(Pnone\ training)_{in}\ \beta_3(Pwage\ discount(none))_{in} + \beta_4(Pwage\ discount(10\%))_{in} + \beta_5(Pwage\ discount(15\%))_{in} + \beta_6(Ppersonal\ protective\ equipment)_{in} + \beta_7(PnonePPE)_{in} + \beta_8(Pprice)_{in} \quad (2)$$

Where:

$\alpha_n$ alternatives specific constant that represents the utility of choosing the status quo risk reduction (n=option C);

*Ptraining* probability of training of workers in pesticides usage (workers to undergo training on how to use the pesticide);

*Pnone training* no training of workers on pesticide application;

*Pwage discount (none)* is the probability that cocoa farm workers are not willing to pay for financial compensation for workplace injuries and illness;

*Pwage discount (10%)* probability that cocoa farm workers are willing to pay 10% discount of daily wage as the financial compensation for workplace injuries and illness;

*Pwage discount (15%)* probability that cocoa farm workers are willing to pay 15% discount of daily wage as the financial compensation for workplace injuries and illness;

*Ppersonal protective equipment* probability of given protective gadget;

*Pnone personal protective equipment* probability of no protective gadget;

*PPrice* probability of the price attribute;

The probability that the respondent will make a particular choice is given by Eq. 3.

$$Prob\{V_{in} + \varepsilon_{in} \geq V_{jn} + \varepsilon_{jn} \text{ for all } j \in C_n\} \quad (3)$$

Where:

$C_n$ is the choice set for individual n. If $\varepsilon_{in}$ are independently and identically distributed across the n alternatives and N individuals with a type I extreme-value distribution, then the probability that the respondent will make a particular choice is estimated using the conditional logit (CL) model by Eq. 4.

$$prob(n \text{ is chosen}) = \frac{\exp^{V_{in}}}{\sum_{j \in C} \exp^{V_{jn}}} \quad (4)$$

The Conditional Logit approach is limited by the assumption of independence of irrelevant alternatives (IIA) and by model errors being independently and identically distributed across alternatives.

According to **(Speelman, 2013)**, estimate that farm worker willingness to pay for a change in attribute levels by taking the ratio between the coefficients of individual attributes and the price attribute as follows by Eq.5.

$$WTP_a = \frac{-\beta_a}{\beta_{price}} \quad (5)$$

Where:

$WTP_a$ is the willingness to pay for occupational risks reduction (i.e ratio of marginal utility and estimated parameter of price associated to the alternatives);

$\beta_a$ is the marginal utility of an attribute *a*;

$\beta_{price}$ is the estimated parameter of price associated to the alternatives.

**Table 1:** Attribute and level in discrete Choice

| Attributes | Level 1 | Level 2 | Level 3 |
|---|---|---|---|
| Training | Training | Training | None |
| Wage discount | None | 10% discount | 15% discount |
| Personal Protective equipment | PPE | PPE | None |

**Table 2:** Choice Sets

| Card ID | Runs | Training | Wage discount (%) | Personal Protective Equipment | Price (NGN) |
|---|---|---|---|---|---|
| 1 | 1 | Training | None | PPE | 100 |
| | 2 | Training | 15% | None | 150 |
| | 3 | None | 10% | PPE | 200 |
| 2 | 1 | Training | 10% | None | 150 |
| | 2 | Training | None | PPE | 200 |
| | 3 | Training | 15% | PPE | 200 |
| 3 | 1 | Training | None | None | 100 |
| | 2 | None | None | PPE | 150 |
| | 3 | Training | 15% | None | 100 |

## RESULTS AND DISCUSSION

### Socio-economic characteristics of the Respondents

The results in Table 3 show the socioeconomic characteristics of cocoa farm workers. The results of the age distribution of the cocoa farmers in the study area shows that cocoa farm workers fall within 36-60 years (74.44%), The mean age is 46 years. While youth comprised only 20.56%. This indicates that most of the farmers are in their active and productive age. It is expected that younger farmers will be more innovative to reduce occupational risks while older farmers may be poorer in terms of welfare ages.

The productive activities of males and females in agriculture are very important and must be taken into consideration. The result of the analysis shows that majority (88.33%) of the respondents are males while 11.67% are females, **Osewa *et al.* (2013)** revealed that women in the rural area in Nigeria are being naturally denied access to land for cultivation of cash crops. The result is in line with the findings of **Mabe *et al.* (2020)** that cocoa production is perceived not to be a suitable occupation for women.

The results show that 55.0% of the cocoa farm workers had first school leaving education. While only 13.39% had above 9 years of education. The modal years of schooling were primary school. The implicit meaning is that most workers are illiterate.

The marital status shows that the majority of the respondents (81.67%) are married, 4.44% are single while 4.44 % are divorced and 9.44% are widowed. The implicit meaning is that cocoa farmers depend on family labour as a direct source of labour therefore, the more the number of a family, the more the valid labour force and consequently, the more the productivity.

The results show that about 84.4 % of the farmers have above 20 years working experience. The mean cocoa farming experience of about 22 years in the study area suggest that cocoa farmers in the study area had considerable years of farming experience which could translate to increased productivities. This clearly portrayed that most respondent in the study area have adequate experience in cocoa production.

The Rate of payment shows that the majority of the respondents 95% are paid on daily basis, 3.33% are paid monthly while 0.56 % are paid hourly and sharecropping. Majority (70.56%) of the cocoa farm workers had not undergone pesticide training while 29.44% of the respondents had been trained on pesticide application by Non-governmental organizations (NGOs). This implies that cocoa farmers in the study areas were not knowledgeable in the arts of pesticide application.

Conditional logit models were estimated using the data obtained from the survey. This is a basic specification that provides the importance of the chosen attributes in explaining respondents' preferences for different options. Table 4 shows the utility that was determined by the attributes (Training, None, Wage discount 10% and 15%, PPE and price) and their levels in the choice sets. The value of probability of chi-square of 0.000 shows the overall significance of the model at 1% probability level ($p<0.01$), pseudo R-squared shows that 7.55% variations of risk reduction was jointly explained by the significant explanatory variables.

The coefficients for the training attribute are negative and significant ($p<0.01$), meaning that an increase in risk as a result of lack of training due to pesticide use as a likelihood decrease the utility of the respondents.

The negative sign of PPE ($p<0.01$) means that respondents would be willing to pay more for adequate care and save work environment. This implies that usage of private gadgets ensures safe work environment and so less wage compensation.

The negative sign of the coefficient for price ($p<0.05$) attribute means that an increase in cost as a likelihood decrease the utility of the respondents.

The negative sign of the coefficient of 15% wage discount ($p<0.01$) means that respondents would be willing to pay more for financial benefit of workplace injuries and illness.

The 10% wage discount is positive but not significant means that the variable associated with the 10% wage discount did not influence the respondent's choice, this implies that the 10% wage discount is not consideration important to the respondents.

### *Estimation of Willingness to Pay for Agrochemical Exposure Risks reduction*

Willingness to pay is the maximum amount that average cocoa farm workers willing to pay or trade-off for reduction of occupational risk (i.e ratio of marginal utility and estimated parameter of price associated to the alternatives). Table 5 shows that on average workers are willing to pay more for risk reduction, the negative coefficients shows that respondents are willing to pay for risks reduction. Upper and lower limit indicate the confidence limit s of the willingness to pay estimates.

Average cocoa farm workers are willing to pay about 1043 NGN per season for training on effective use of pesticides application, for the risk reduction that features in the attribute. This is in line with **Osawa *et al.* (2013)** findings that the cocoa farmers do not follow the recommendations of the instructions printed on pesticide bottles/containers.

Average workers are willing to pay 843 NGN for personal Protective equipment for risks reduction. The result is in accordance with **Devi *et al.* (2012)** that protective equipment minimizes the health risk and injuries associate with the job of the cocoa farm which emphasizes the necessity for ensuring the use of protective measures in farm fields against the risk exposed due to pesticide application.

Average cocoa farm workers were WTP about 92 NGN for 15 per cent daily wage discount as the financial compensation for workplace injuries and illness. Wage discount is a financial benefit that will stand as an income protection for the cocoa farm workers and give support to the farm workers through a period where they cannot work due to illness or injury.

**Table 3:** Socioeconomics characteristics of the Respondents

| Characteristics | Frequency | Percentage (%) |
|---|---|---|
| Age(Years) | | |
| ≤ 35 | 37 | 20.56 |
| 36 – 60 | 134 | 74.44 |
| Above 60 | 9 | 5.00 |
| Total | 180 | 100 |
| Mean | 46±9.6 | |
| Sex | | |
| Female | 21 | 11.67 |
| Male | 159 | 88.33 |
| Total | 180 | 100 |
| Educational background | | |
| ≤ 3 | 18 | 10.00 |
| 4-6 | 99 | 55.00 |
| 7-9 | 38 | 21.11 |
| Above 9 | 25 | 13.89 |
| Total | 180 | 100 |
| Mean | 6.56±2.5 | |
| Marital status | | |
| Single | 8 | 4.44 |
| Married | 147 | 81.67 |
| Widowed | 17 | 9.44 |
| Divorced | 8 | 4.44 |
| Total | 100 | 100 |
| Farming experience | | |
| ≤ 10 | 2 | 1.11 |
| 11 – 20 | 25 | 13.89 |
| Above 20 | 152 | 84.44 |
| Total | 180 | 100 |
| Mean | 22±11.2 | |
| Pattern of Payment | | |
| Hourly | 1 | 0.56 |
| Daily | 171 | 95.00 |
| Weekly | 1 | 0.56 |
| Sharecropping | 1 | 0.56 |
| Monthly | 6 | 3.33 |
| Total | 180 | 100 |
| Trained on Pesticide Application | | |
| Yes | 53 | 29.44 |
| No | 127 | 70.56 |

Source: Field Survey, 2019.

**Table 4:** Estimated coefficient of Conditional Logit models

| Variable | Coef. | Std. Err. | z-value | p>z |
|---|---|---|---|---|
| Price | -0.0010374** | 0.000487 | -2.13 | 0.036 |
| Training | -1.081836*** | 0.2206205 | -4.23 | 0.000 |
| None | 1.049257*** | 0.2477841 | 4.75 | 0.000 |
| Wage discount (10%) | 0.1574165 | 0.1310448 | 1.20 | 0.230 |
| Wage discount (15%) | -0.095109 | 0.1610257 | -0.59 | -0.555 |
| Wage discount (none) | 0.4591829*** | 0.1360101 | 3.38 | 0.001 |
| PPE | -0.8749302*** | 0.109102 | 8.02 | 0.000 |
| Log-likelihood | -1284.60 | | | |
| Prob > chi$^2$ | 0.000 | | | |

Note: ***, **, * Significant at 1%, 5% and 10% respectively
Source: Field Survey, 2019.

**Table 5:** Willingness to pay for Occupational Risk Reduction

| | Training | None training | 10% discount | None discount | 15% discount | PPE |
|---|---|---|---|---|---|---|
| WTP | -1042.79 | 1011.394 | 151.736 | 442.613 | -91.677 | -843.3582 |
| Lower limit | -3272.89 | -3132.947 | -184.195 | -499.581 | -507.066 | -1017.128 |
| Upper limit | 1187.295 | 1110.159 | 487.667 | 1384.807 | 323.712 | 2703.844 |

Source: Field Survey, 2019

## CONCLUSIONS AND RECOMMENDATIONS

Based on the findings, the study concluded that better health conditions and appropriate use of personal protective equipment minimize the occupational risk.

Low usage of Personal Protective Equipment also exposes farmers to the risk of being exposed to agrochemicals. These constitute some serious health risk as a consequence of the toxicity contents of some chemical compounds that these agrochemicals contain. This study find that the use of personal protective equipment minimizes the risk of health damage and less compensation for risk, which emphasizes the necessity for ensuring the use of protective equipment on the farm fields against the risk exposed due to agrochemical application.

Educational programmes that will enhance farmer's knowledge, skills and attitude to use safe methods (appropriate use of protective equipment) in agrochemical usage should be adequately planned. Appropriate use of personal protective equipment to reduce exposure to pesticides and the risks involved in the misuse and abuse of pesticides.

Moreover, the study shows that respondents are willing to pay on average, more for protective gadget, compensation insurance and training of workers on effective use of pesticides.

Lastly the result shows that a high preference for the training of cocoa farm workers for effective usage of pesticide, and are WTP on average, about 1043 NGN for the risk reduction that features in this attribute. This in line with the many studies which have shown that the farmers do not follow the recommendations on the instructions printed on pesticide bottles/containers.

The authors suggest that policy maker should provide insurance program like income protection policy for farm workers as financial benefit for farm workers on any illness or injury sustained on the farm field.

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# FACTORS DETERMINING THE TRUST OF VEGETABLE FARMERS FOR INTERMEDIARIES IN EASTERN ETHIOPIA

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## ABSTRACT

**Research background:** There is higher level of mistrust between vegetable farmers and intermediaries in vegetable market transaction in Eastern Ethiopia. This mistrust adversely affected farmers' livelihood which largely depended on the agriculture sector. Hence understanding factors that affect trust of farmers for intermediaries is essential.
**Purpose of the article:** The purpose of this study is to analyse the factors determining vegetable farmers trust for intermediaries using cross sectional data collected from vegetable farmers in Eastern Ethiopia.
**Methods:** Multistage sampling was used to select 385 households for the study. The collected data were analysed using partial least square path modelling procedure.
**Findings and value added:** The empirical results indicated that relational investment, collaborative communication, and flexibility positively influenced trust. Moreover, collaborative communication and flexibility also positively influenced relational satisfaction. However, relational investment negatively affected opportunism.
**Recommendation:** Intermediaries should use effective communication to improve farmers trust and relational satisfaction. They should also engage in relational investment by giving assistance and advice as this could contribute to enhancement of trust and reduction of opportunism. Intermediaries need to also attract farmers by offering satisfactory price and demonstrating flexibility where it is necessary.

**Key words:** determinants of trust; Eastern Ethiopia; farmer-intermediary relationships; vegetables
**JEL Codes:** D23; D43; D83; L13; Q12; Q13

## INTRODUCTION

Vegetable farmers in eastern Ethiopia use the marketing channel that involve brokers to market their produce (**Emana and Gebremedhin, 2007**). There are up to three brokers operating between the primary producer and the trader. The brokers are paid a known commission for every quintal of vegetables transacted. The seldom contact between farmers and traders enabled brokers to set the price and hide their margin. Moreover, the lack of norm and regulation that control the activity of brokers also negatively affected farmers. Farmers in this market rely on intermediaries and traders they trade with for market information. This dependency made farmers vulnerable to opportunistic tendencies of intermediaries.

The transaction between vegetable farmers and intermediaries involve distrust and disputation regarding price, standards and schedule of payment. Farmers also face contract breach in the form of late payment, partial payment and non-payment in trade transaction with intermediaries (**Jema, 2010**). Hence the consequences of facing contract breach is serious as the livelihood of farmers largely depend on it. The consequence of lack of trust also create a condition where every transaction is scrutinized and checked which lead to an increase in transaction cost (**Yeshitila *et al.*, 2020**). Effectiveness and efficiency which is important in supply chains is negatively affected. In addition, engaging in value adding activities with trading partners also become unthinkable and decision makers often spend their time analysing their trading partners' trustworthiness, reliability and credibility instead of concentrating on market transaction.

According to **Sako (1998),** trust is categorized as contractual, competence and goodwill trust. Contractual trust rest on the norm of keeping promise and honesty while competence trust is based on the expectation that the trading partner competently perform its role. The willingness of the trading partner to do more than expected is represented by goodwill trust. **Kumar *et al*. (1995)** defines trust to comprise the partner's honesty and benevolence. Hence, in this study, trust comprises the partner's attribute of honesty, promise keeping and benevolence (**Sako, 1998**; **Kumar *et al*., 1995**).

Different factors affect the trust between the farmers and their trading partners. Trust is positively influenced by pursuit of compatible goals, price satisfaction, relational satisfaction, specific investment, flexibility, collaborative relationship and good reputation between farmers and their trading partners (**Batt, 2003a; Gyau and Spiller, 2007; Masuku and Kirsten, 2010; Fischer *et al*., 2007;**

**Zinashbizu *et al*., 2020**). Some of the factors may result in the undermining of trust between trading partners. These factors include coercive behaviour, cultural dissimilarity, opportunism and lack of cooperation (**Masuku and Kirsten, 2010; Batt, 2003b; Gyau and Spiller, 2007**). However, there is mixed result regarding the effect of duration of exchange relationship on trust (**Masuku and Kirsten, 2010; Fritz and Fisher, 2007; Shulze and Spiller, 2006**).

Most of the aforementioned studies on trust were conducted among trading partners in developed countries. However, few studies examined the determinants of trust of the farmer for the intermediary in the developing country context. Hence, in this study we identify factors that influence the trust of the vegetable farmer for an intermediary in Eastern Ethiopia.

## TRUST: THEORETICAL REVIEW

Different definitions were given for trust construct. **Sako (1998)** recognizes three types of trust: contractual trust, competence trust, and goodwill trust. He argues that fulfilling a minimum set of obligations constitutes contractual trust, while honouring a broader set of obligations represent goodwill trust. Others contend trust comprises two essential elements; honesty and benevolence (**Geyskens and Steenkamp, 1995; Kumar *et al*., 1995**). **Anderson and Narus (1990)** define trust as the belief that business partners perform act that result in a positive outcome for the firm and not take unexpected actions that may result in negative outcomes.

Trust can be a significant part of social capital that contributes to economic development (**Fukuyama, 1995; North, 1990; Ostrom, 2000; Dasgupta, 2000**). Trust is related to institutions and affects the costs of transacting. If the confidence in an enforcement authority diminishes, trust in people will be less and agreements will not be established (**Dasgupta, 2000**). Trust by the buyer reduces the perception of risk and reduces transaction cost in an exchange relationship (**Ganesan, 1994; Doney and Cannon, 1997**).

In the relationship between the farmer and the intermediary, trust is expected to play a very important role in their transaction. Trust is expected to be influenced by opportunism, flexibility, price satisfaction, relational satisfaction, relational investment, power and communication relationship existing between the trading partners (**Batt, 2003a; Batt, 2003b; Gyau and Spiller, 2007; Pusputwati et al., 2013; Massuku and Kirsten, 2010; Fischer *et al*., 2007**).

## THE CONCEPTUAL FRAMEWORK OF THE STUDY

Figure 1 illustrates the conceptual framework of this study showing the determinants of trust of the vegetable farmer for the preferred intermediary. Relational investment is based on three items and comprise getting advice on demanded vegetable variety and help during harvest from the preferred intermediary (**Batt, 2003a**). Collaborative communication is based on three items and includes frequent exchange of information and sharing of complete, correct and frank information (**Boniface, 2011; Gyau and Spiller, 2007**). Flexibility is based on four items and is represented by making arrangements fit with the current scenario, adjusting the contract condition and solving problems (**Pusputwati et al., 2013**).

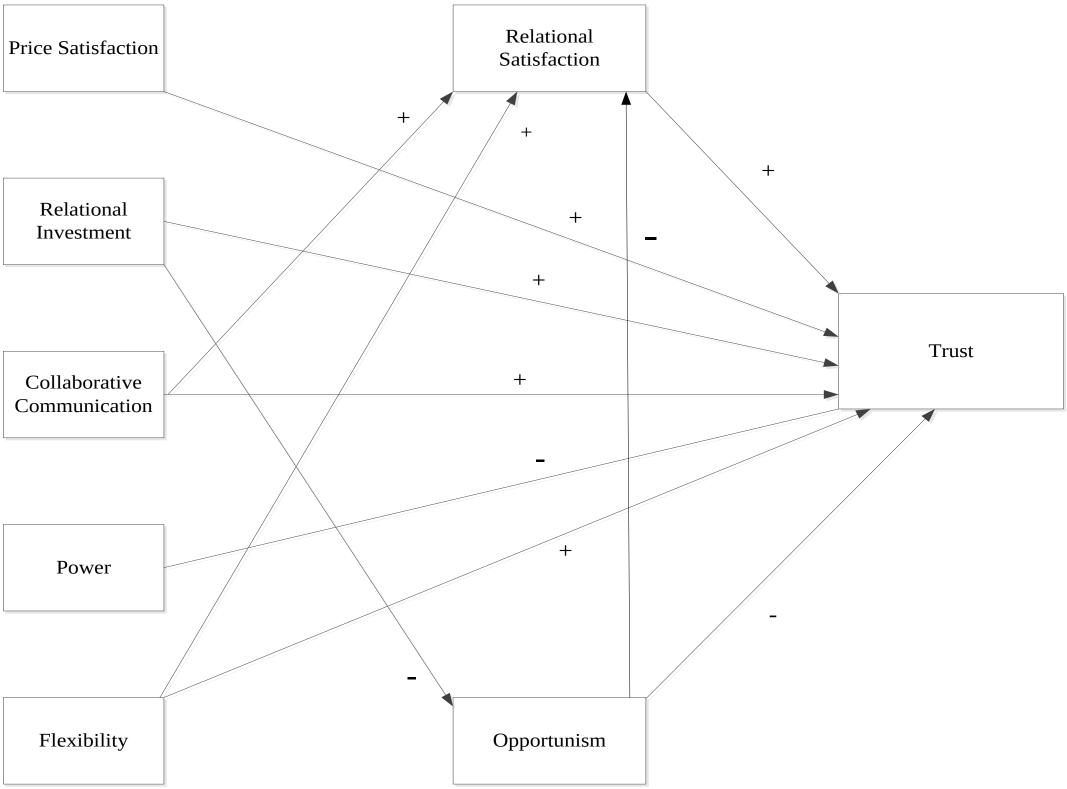


**Figure 1.** Conceptual framework of the study

**Table 1**: Construct items for the trust and trust determining dimension

| Blocks | Items | | Reference |
|---|---|---|---|
| Relational investment | X1 | My preferred market intermediary informs me of the vegetable market condition during wet and dry season | Batt (2003a) |
| | X2 | My preferred market intermediary helps me during harvest in produce collection without pay | Batt (2003a) |
| | X3 | My preferred market intermediary often advises me of potential market demand | Batt (2003a) |
| Collaborative Communication | X4 | My preferred market intermediary provide me with all the relevant market information | Anderson and Narus (1990) |
| | X5 | We share common information frequently with the preferred market intermediary | Gyau and Spiller (2007); Boniface (2011) |
| | X6 | Price changes are communicated to me in a timely manner | Leat *et al*., (2010) |
| | X7 | The price information provided by my preferred market intermediary is complete, correct and frank | Han et al. (1993) |
| Flexibility | X8 | My preferred market intermediary is flexible to make the arrangement fit with the current scenario | Pusputawati *et al*., (2013) |
| | X9 | My preferred market intermediary can adjust the contract condition to fit with my present requirement | Pusputawati *et al*., (2013) |
| | X10 | When I have marketing related problem, my preferred market intermediary will make sure the problem does not jeopardize our business relationship | Pusputawati *et al*., (2013) |
| | X11 | When I have problem with my preferred market intermediary, we meet and solve the problem together | Pusputawati *et al*., (2013) |
| Power | X12 | My preferred market intermediary has all the power in setting price below my expectation | Gyau and Spiller(2007); Boniface (2011) |
| | X13 | My preferred market intermediary controls all the information regarding our transaction (price and other market information) | Batt (2003a) |
| | X14 | My preferred market intermediary uses harsh language in transaction | Batt (2003b) |
| Price satisfaction | X15 | I agree with the vegetable produce price and the grading system | Boniface (2011) |
| | X16 | I get a reasonable price quality-ratio (i.e. the price obtained matches the value) | Gyau and Spiller (2007); Boniface (2011) |
| | X17 | The preferred market intermediary offer me fair and reasonable price for my produce | Boniface (2011) |
| | X18 | The price that my preferred intermediary offer me is higher than I expected | Gyau and Spiller (2007);Boniface (2011) |
| Opportunism | X19 | My preferred market intermediary does not often act opportunistically by increasing his margin | Batt (2003a) |
| | X20 | My preferred market intermediary is not honest with me | Batt (2003a) |
| | X21 | My preferred market intermediary does not offer me information which will benefit me | Williamson (1993) |

**Table 1** (continue): Construct items for the trust and trust determining dimension

| Blocks | Items | | Reference |
|---|---|---|---|
| Relational satisfaction | X22 | My preferred market intermediary often meets my expectations in offering better price | Parining (2009) |
| | X23 | I feel I am adequately rewarded by my preferred market intermediary in terms of price | Parining (2009) |
| | X24 | My preferred market intermediary is quick to handle complaints | Parining (2009) |
| | X25 | There is good cooperation between my preferred market intermediary and myself | Schulze and Spiller (2006) |
| Trust | X26 | I have confidence in my preferred market intermediary that he will make sure I am paid for the produce I had delivered | Batt (2003a);*Lu et al*. (2008) |
| | X27 | My preferred market intermediary always considers my best interests in terms of profit margin | Batt (2003a) |
| | X28 | My preferred market intermediary always keeps his promises | Batt (2003a) |
| | X29 | I believe in the information provided by my preferred market intermediary | Batt (2003a) |

Power is based on three items and is represented by exercising power, controlling information and employing harsh language (**Batt, 2003a; Gyau and Spiller, 2007**). Price satisfaction is based on four items and is represented by agreement on price and grading, obtaining reasonable price-quality ratio and obtaining price higher than expected (**Boniface, 2011; Gyau and Spiller, 2007**). Opportunism is based on three items and is represented by acting opportunistically, dishonesty and failing to disclose information (**Batt, 2003a; Williamson, 1993**). Relational satisfaction is based on four item and is represented by handling complaints, treating fairly, meeting expectation, reducing conflict and showing good cooperation (**Shulze and Spiller, 2006; Parining, 2009**). Trust is based on four item and is represented by considering the interest of others, keeping promise and providing reliable information (**Lu *et al*., 2008**). Table 1 reports list of items used for data collection purpose.

***The study hypothesis***

Hypothesis 1: Trust is influenced positively by the extent to which the farmers most preferred intermediary is willing to make relationship specific investment.

Committing resources to the relationship is essential if the preferred intermediary wishes to improve its relationship to achieve future benefits. It is contended that any resource devoted beyond the amount required to facilitate the current exchange is regarded as an investment (**Campbell and Wilson, 1996**). According to **Ganesan (1994)**, committing relationship specific investment indicates that the intermediary cares for the relationship, that the intermediary can be believed and that he can go as far as making more sacrifices. Hence, spending on relationship enhancing investment signals the trustworthiness of the intermediary.

Hypothesis 2. Trust is positively affected by engagement in collaborative communication with the vegetable farmer.

Communication is exchanging frequent, timely and meaningful information between transacting parties **(Khalid and Ali, 2017)**. Effective communication (including its two component of adequate communication frequency and high information quality) is essential to good business relationship (**Fischer *et al*., 2007**). Some believe that effective communication occurs when detailed and meaningful information is shared between trading parties (**Reynolds *et al*., 2009**). It is also proposed that timely communication help solve conflicts that arise and lead to the development of sustainable business relationships. Studies indicate that both trust and satisfaction are positively influenced by communication in various trading relationships (**Li *et al*., 2019**).

Hypothesis 3: The extent of flexibility of the preferred intermediary to address the concern of the farmer positively influence the trust of the farmer for the intermediary.

This involve going beyond the terms and conditions specified in the contractual agreements as circumstances require (**Heide and John, 1992**). The positive response to request for change by the trading partner to contractual agreements enhances the trust between the trading partners. So making the necessary changes to the contractual agreements after considering the ongoing situation help the trading partners to build confidence and resolve problems that may happen in the future. Hence should an unexpected situation occur in the future, the parties would easily design new deal that considers the existing circumstances.

Hypothesis 4: The use of power by the farmer's preferred intermediary will negatively influence trust.

Trading partner that wield significant power in both an absolute and relative sense could easily influence his/her trading partners (**Xhoxhi *et al*., 2019**). This could have positive or negative consequence depending on how power is utilized by the powerful partner. If power is utilized to promote collective goals, high level of goal compatibility will exist otherwise not (**Ganesan, 1994**).

Hypothesis 5: Price satisfaction has positive influence on the farmers trust for the preferred intermediary. This refers to the affective satisfaction enjoyed by the seller from price related factors. **Gyau and Spiller (2007)** indicated that price satisfaction enhanced the trade relationship between trading parties in the international fresh produce business. Therefore, to enhance trust and develop sustainable relationship, the offer of reasonable and fair price by buyers to sellers is highly recommended (**Susanty *et al*., 2017**).

Hypothesis 6: Trust will be negatively impacted if the farmer's preferred intermediary engagement in opportunistic behaviour.

Opportunism refers to calculated efforts to confuse, mislead, or disguise the trading partner by providing incomplete and distorted information (**Williamson, 1985**). The deliberate strategy of forbearance with a view of future trade benefit and a demonstration of non-reneging behaviour is essential to sustaining a trusting relationship (**Parkhe, 1993**). Trust may prove still a risky investment even after trading with a partner for a long time. This is because the trustee could exploit the trustor at any time since the trustor is vulnerable (**Lane, 2000**). Moreover, detecting the risk of opportunism is also difficult as it is difficult to predict. Trading partners are tempted to be opportunistic to maximize gains over others (**Gundlach *et al*., 1995**). However, this provokes retaliatory behaviour from the affected party instigating them to react with intensity (**Yen and Hung, 2017**). The deterioration of the trusting relationship leads to the severing and abandoning of the trade relationship.

Hypothesis 7: Relational satisfaction has positive influence on the trust of the farmer for the preferred intermediary.

Relational satisfaction is related with the trading partners' role with regard to solving problems, communication and negotiation (**Gyau and Spiller, 2007**). Moreover, it also concerns with fairness between the trading partners in trade relationship (**Dlamini-Mazibuko, 2019**). Moreover, relational satisfaction has an aspect of timeliness and punctuality. Hence relationships characterized by open communication, negotiation, equity and joint problem solving enhance the level of trust between partners.

Hypothesis 8: Relational investment by the intermediary negatively influence the perception of opportunism of the farmer towards the preferred intermediary.

If the intermediary wish to improve his/her relationship with the farmer, he will need to invest in various resources to strengthen the relationship (**Ford *et al*., 1996**). Relational investment is expenditure in any resource committed in excess of the amount required to execute the current exchange transaction (**Campbell and Wilson, 1996**). Committing such resources help to smooth the trade relationship and reduce perception of opportunism.

Hypothesis 9: The collaborative communication between the farmer and the preferred intermediary positively influence relational satisfaction.

Relational problems occur due to communication difficulties and communication is regarded as a glue that hold together the market supply channel (**Mohr and Nevin, 1990**). Collaborative communication may improve the exchange partners' business relationship and enhance trust building by solving relationship problems (**Glavee-Geo *et al*., 2020**). Thus it is hypothesized that collaborative communication has a positive influence on relational satisfaction of the vegetable farmer towards his preferred intermediary.

Hypothesis 10: The flexibility of the transaction arrangement contributes to an increase in relational satisfaction of the farmer.

Flexibility is a dimension of relationship management practices that influence relationship outcomes (**Heide and John, 1992**). Relationship flexibility is conceptualized as the willingness to go beyond the terms and conditions stated in contractual agreement as the need arises (**Johnson and Sohi, 2016**). The need for flexibility in contract arises due to limited information availability, changing state of the environment and the managers bounded rationality in decision making (**MacNeil, 1980**). Hence, it is hypothesized that flexibility in market transaction positively influence relational satisfaction of vegetable farmers.

Hypothesis 11: Opportunistic behaviour of the intermediary influences negatively the relational satisfaction of the farmer.

Opportunism refers to the disclosure of distorted and/or incomplete information to mislead or confuse the trading partner (**Williamson, 1985**). The incentive to engage in opportunistic behaviour arises because one party decides to maximize its benefit ignoring the interest of the trading partner (**Gundlach *et al*., 1995**). If the trading partner detects opportunism, he/she will engage in retaliatory behaviour further deteriorating the relationship. Hence, the detection of opportunism causes relational satisfaction in trade transaction to decrease.

## DATA AND METHODS

### *Description of the study area*

East Hararghe zone is one of the 18 zones found in Oromia National Regional State with a population size of 3,039,680 and with a population density of 151.87 persons/km$^2$ (**CSA, 2007**). The zone is characterized by mid latitude and lowland agro-climatic zones that range from 1600-2100 masl (meter above sea level) (**CSA, 2007**). The high inter-annual, spatial and inter-seasonal variations characterize the annual rainfall that range between 500-1200mm (**CSA, 2007**). The zone is bordered in the west with West Hararghe zone, Bale zone from the south, Somali Regional State from the east and south east and Dire Dawa council from the north. The three *woredas(districts)* randomly selected were Haramaya, Kombolcha and Kersa.

### *Sample Size Determination*

The study employed the sample size determination formula given by **Kothari** (**2004**) to obtain a representative sample size (Eq.1).

$$n = \frac{Z^2pq}{e^2} = \frac{(1.96)^2(0.5)(0.5)}{(0.05)^2} = 385 \quad (1)$$

### *Data collection and Sampling Procedure*

Structured questionnaire combined with guided interviews were used to collect information from vegetable farmers from the selected three *woredas* in East Hararghe zone namely Haramaya, Kombolcha and Kersa. Both primary and secondary data were collected from their respective sources. A set of prepared statements were used to collect information on the relationship between the farmer and his preferred intermediary on a 5-point scale from 1(strongly disagree) to 5(strongly agree). Information was collected on trust and trust determining factors.

Purposive and stratified sampling procedures were adopted to select the respondents. East Hararghe zone of Ethiopia was purposely selected as it is very well known in vegetable production. Then out of 9 potential vegetable producing *woredas* in the zone, three *woredas* were randomly chosen. The third stage involved the selection of sample vegetable producing *kebeles(wards)* from among the 34 potential vegetable producing *kebeles* of the randomly selected *woredas* while the fourth stage involved the random selection of 385 vegetable farmers from lists of names of households in the sampled *Kebeles*. The data was collected between June and August of 2018.

***Methods of data analysis***

Before conducting partial least square path modelling (PLSPM), the construct items for trust and trust determining factors were selected based on the literature and opinion of experts in vegetable marketing. For the theoretical verification of these constructs, exploratory factor analysis (EFA) was conducted (**Hair *et al*., 2013**). EFA identified eight factors with eigenvalues greater than one. Then determinants of trust were explored using partial least square path modelling (PLSPM). PLSPM was adopted for the following reasons: First, it does not require normality assumption (**Henseler *et al*., 2016**). Second, PLS accounts for the measurement errors and provides accurate estimates of the mediation effects (**Chin, 1998**). Third, it is possible to estimate path models using PLS for small sample sizes (**Chin and Newsted, 1999**). Fourth, it is possible to deal with complex causal models using PLSPM (**Hulland, 1999**). Fifth, the relationship among trust, relational satisfaction, relational investment, opportunism, collaborative communication, flexibility, power and price satisfaction needs further theoretical development.

PLS model is defined by two sets of linear equations: The inner model and the outer model. The inner model specifies the relationship between latent variables whereas the outer model specifies the relationships between a latent variable and its observed variables. The inner model can be written as Eq. 2.

$$\varepsilon = B\varepsilon + e \quad (2)$$

where ε is the vector of latent variables, B represent the matrix of coefficients of the relationship, and e denotes the inner model residuals.

The outer models are of two types: reflective (Mode A) and formative (Mode B) measurement models. The choice of the outer model is underpinned by theoretical reasoning (**Diamontopoulos and Winklhoter, 2001**). The causal relationship from latent variable to the manifest variables represent reflective model (Eq.3).

$$X_x = \varphi_x \varepsilon + e_x \quad (3)$$

where $\varphi$ represent the loading (pattern) coefficients. The formative model of a measurement has a causal relationship from the manifest variables to the latent variable (Eq.4).

$$\varepsilon = \pi_x X_x + e_x \quad (4)$$

## RESULT AND DISCUSSION

***Determinants of trust***

*Measurement model assessment*

The Cronbach alpha value of greater than 0.7 in Table 2 indicate the reliability of the blocks (**Mackenzie and Podsakoff, 2011**). Moreover, the blocks are considered homogenous if the DG.rho is larger than 0.7 (**Sanchez, 2013**). The Keiser rule states that the first eigenvalue should be greater than 1 and the second eigenvalue should be less than one based on **Sanchez (2013)**. When the stated criteria were applied to the results, it was discovered that almost all of the blocks of items were found to be unidimensional (i.e. between 0.76 and 0.83) except power which was 0.63. Similarly, the DG rho also lie between 0.80 to 0.88 for all the blocks. Moreover, the first eigenvalue is larger than 1 while the second eigenvalue is smaller than 1 further indicating the unidimensionality of the blocks.

Table 3 describes the results of the factor loading and communality estimates as the matrices for examining the correlation between indicators and their latent variables. The constructs are considered reliable if the factor loadings are greater than 0.7 for all items (**Chin, 1998**). The communality of a variable is the sum of the squared variance loadings of a variable and indicate how much latent constructs explain variance in measured variables (**Sanchez, 2013**). It is also indicated that the communality of above 0.49 and loadings of above 0.7 are considered acceptable (**Sanchez, 2013**). The obtained estimates from our result indicated that almost all values of the loading are greater than 0.7 except for an item power3R. The communality index for an item power 3R is 0.412 (i.e., 41.2%) which imply that it is possible to reproduce 41.2% of the variance of an item from its respective block (power). For this reason, the item was kept in the model.

The matrix of cross loadings are the loadings of each item in each block (**Sanchez, 2013**). The criteria stated imply that the loadings of items in each block should be larger than its loading in other blocks. Hence, as Table 4 shows, all the items belonged to their respective blocks and hence are considered reliable.

**Table 2:** Unidimensionality and validity measures of the model

| Blocks | Mode | MVs | C.alpha | DG.rho | eig.1st | eig.2nd |
|---|---|---|---|---|---|---|
| relinv | A | 3 | 0.784 | 0.875 | 2.101 | 0.588 |
| comcat | A | 4 | 0.783 | 0.860 | 2.425 | 0.594 |
| flex | A | 4 | 0.763 | 0.849 | 2.342 | 0.640 |
| power | A | 3 | 0.627 | 0.802 | 1.746 | 0.841 |
| prsat | A | 4 | 0.830 | 0.887 | 2.657 | 0.611 |
| opport | A | 3 | 0.764 | 0.865 | 2.042 | 0.593 |
| relsat | A | 3 | 0.741 | 0.853 | 1.976 | 0.530 |
| trust | A | 4 | 0.788 | 0.863 | 2.448 | 0.637 |

**Table 3:** Factor loadings and communality estimates

| | Items | Blocks | Weight | Loading | Communality | Redundancy |
|---|---|---|---|---|---|---|
| 1 | RI2 | relinv | 0.492 | 0.893 | 0.797 | 0 |
| 2 | RI3 | relinv | 0.285 | 0.712 | 0.507 | 0 |
| 3 | RI4 | relinv | 0.404 | 0.886 | 0.786 | 0 |
| 4 | Comcat2 | comcat | 0.332 | 0.777 | 0.604 | 0 |
| 5 | Comcat3 | comcat | 0.320 | 0.777 | 0.604 | 0 |
| 6 | PT1 | comcat | 0.339 | 0.809 | 0.654 | 0 |
| 7 | PT2 | comcat | 0.292 | 0.750 | 0.562 | 0 |
| 8 | Flex1 | flex | 0.322 | 0.742 | 0.550 | 0 |
| 9 | Flex2 | flex | 0.355 | 0.743 | 0.552 | 0 |
| 10 | Flex | flex | 0.314 | 0.766 | 0.587 | 0 |
| 11 | Joint | flex | 0.318 | 0.805 | 0.648 | 0 |
| 12 | power2R | power | 0.370 | 0.731 | 0.534 | 0 |
| 13 | power3R | power | 0.293 | 0.642 | 0.412 | 0 |
| 14 | power6R | power | 0.657 | 0.825 | 0.680 | 0 |
| 15 | PS1 | prsat | 0.348 | 0.837 | 0.700 | 0 |
| 16 | PS2 | prsat | 0.310 | 0.858 | 0.736 | 0 |
| 17 | PS3 | prsat | 0.309 | 0.841 | 0.708 | 0 |
| 18 | PS4 | prsat | 0.256 | 0.714 | 0.511 | 0 |
| 19 | noopport | opport | 0.493 | 0.900 | 0.810 | 0.126 |
| 20 | trust2R | opport | 0.298 | 0.728 | 0.529 | 0.082 |
| 21 | trust7R | opport | 0.407 | 0.834 | 0.695 | 0.108 |
| 22 | RS2 | relsat | 0.409 | 0.812 | 0.659 | 0.392 |
| 23 | RS4 | relsat | 0.412 | 0.806 | 0.649 | 0.386 |
| 24 | RS5 | relsat | 0.411 | 0.817 | 0.668 | 0.397 |
| 25 | Trust1 | trust | 0.305 | 0.758 | 0.575 | 0.373 |
| 26 | Trust3 | trust | 0.340 | 0.841 | 0.708 | 0.460 |
| 27 | Trust4 | trust | 0.321 | 0.759 | 0.576 | 0.375 |
| 28 | Trust5 | trust | 0.312 | 0.767 | 0.589 | 0.383 |

***Structural model assessment***

After examining and accepting the quality of the measurement model, the quality of the structural model was assessed by examining the redundancy index and $R^2$ determination coefficients. The result of the total effect estimates, the path coefficients and the regression equations were also calculated to test the proposed hypotheses. Finally, goodness of fit (GOF) was checked to examine the reliability of the whole model. The predictive accuracy index ($R^2$) measures the variance of the dependent variable as influenced by the independent variables (**Sanchez, 2013**). The value of $R^2$ of 0.25, 0.50 or 0.75 indicate weak, moderate and strong coefficient of determination (**Hair *et al*., 2013**).

Redundancy index shows the variance in the endogenous blocks as determined by the independent latent variables. The index shows the prediction ability. As the mean of the redundancy index gets higher, its prediction ability for the value of the indicators endogenous construct would also be higher (**Sanchez, 2013**). Moreover, the value of the average variance extracted (AVE) index should be greater than 0.5 for all blocks to be included in the structure and to yield a convergent validity which is acceptable (**Fornell and Larcker, 1981**).

In this study, the endogenous construct's (i.e. trust) $R^2$ value is 0.65 (Table 5). This indicate that 65% of the variance of the trust construct is attributed to the remaining constructs. Relational investment explains 15.6% of the variance of the opportunism construct. Moreover, 59% of the variance of relational satisfaction was determined by the constructs flexibility, opportunism and collaborative communication. The mean redundancy value of 10.6% for opportunism imply that relational investment predicts 10.6 % of the variability in opportunism indicator. Similarly, the mean redundancy value of 39.2% imply that flexibility, collaborative communication and opportunism predict 39.2% of the variability in relational satisfaction indicator. Moreover, 39.8% of the variability in trust indicator is predicted by the rest of the constructs. The last column is related to AVE indexes and for all the blocks the value range between 0.542 and 0.697 indicating convergent validity of the LVs.

The results of regression analyses (t value) and path coefficients in Table 6 showed that relational investment, collaborative communication, flexibility and price satisfaction influenced trust positively. This is supported by the findings of the study which indicated that specific asset investment by purchasers of agricultural products enhanced the trust of farmers in China (**Chuang and Jia, 2016**). Empirical studies also showed that communication improved trust between trading partners (**Fischer, 2013; Pusputwati, 2013**).

The study by **Pusputwati (2013)** in Indonesia also indicated that flexibility had positive impact on goodwill trust of Indofood (the largest food processing company in Indonesia) and GPF (General Potato Farmers) groups of farmers. The study in Ghana further showed that FFV (Fresh fruit and vegetables) exporting firms had more trust for importers who provided satisfactory price (**Gyau and Spiller, 2007**).

The result also indicated that relational investment negatively influenced opportunism. This finding is in agreement with the result of the study which indicated that information exchange, cooperation and relational satisfaction reduced the perception of opportunism in the buyer-supplier relationship in the cocoa industry in Ghana (**Glavee-Geo, 2020**). Moreover, both collaborative communication and flexibility also positively influenced relational satisfaction. This result confirms previous findings by **Agarwal and Naryana (2020)** which stated that relational communication positively influenced relational satisfaction in buyer supplier relationship. The study by **Ivens (2005)** further showed that customer satisfaction, trust and commitment were positively influenced by flexibility in the exchange between customers and their service providers.

Hence for all the aforementioned constructs, the hypothesis was supported. However, for the construct power, opportunism and relational satisfaction influencing trust, the hypothesis was not supported since they are not significant. Similarly, for the construct opportunism influencing relational satisfaction, the hypothesis was not supported as it is insignificant.

The relationship between exogenous and endogenous constructs are decomposed into direct and indirect effects (Table 7). The direct effect indicates that trust increases significantly with relational investment, collaborative communication, flexibility and price satisfaction. Similarly, collaborative communication and flexibility also directly increase with relational satisfaction. However, relational investment directly and negatively influence opportunism. The evaluation concerning the indirect effects show that all of the indirect effects are insignificant.

**Table 4:** Item cross-loading estimates

| | Name | Blocks | Relinv | Comcat | Flex | Power | Prsat | Opport | Relsat | Trust |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | RI2 | Relinv | 0.893 | 0.611 | 0.604 | 0.364 | 0.660 | 0.434 | 0.532 | 0.676 |
| 2 | RI3 | Relinv | 0.712 | 0.334 | 0.386 | 0.105 | 0.317 | 0.192 | 0.375 | 0.453 |
| 3 | RI4 | Relinv | 0.886 | 0.564 | 0.531 | 0.266 | 0.609 | 0.313 | 0.510 | 0.600 |
| 4 | Comcat2 | Comcat | 0.455 | 0.777 | 0.595 | 0.321 | 0.662 | 0.399 | 0.692 | 0.474 |
| 5 | Comcat3 | Comcat | 0.486 | 0.777 | 0.641 | 0.409 | 0.532 | 0.522 | 0.575 | 0.547 |
| 6 | PT1 | Comcat | 0.502 | 0.809 | 0.574 | 0.452 | 0.649 | 0.530 | 0.560 | 0.631 |
| 7 | PT2 | Comcat | 0.501 | 0.750 | 0.591 | 0.370 | 0.676 | 0.405 | 0.456 | 0.569 |
| 8 | Flex1 | Flex | 0.530 | 0.629 | 0.742 | 0.334 | 0.627 | 0.417 | 0.536 | 0.521 |
| 9 | Flex2 | Flex | 0.475 | 0.633 | 0.743 | 0.331 | 0.499 | 0.424 | 0.577 | 0.589 |
| 10 | Flex | Flex | 0.437 | 0.492 | 0.766 | 0.256 | 0.511 | 0.284 | 0.519 | 0.513 |
| 11 | Joint | Flex | 0.454 | 0.590 | 0.805 | 0.422 | 0.454 | 0.490 | 0.541 | 0.503 |
| 12 | power2R | Power | 0.188 | 0.302 | 0.269 | 0.731 | 0.225 | 0.355 | 0.278 | 0.244 |
| 13 | power3R | Power | 0.232 | 0.256 | 0.181 | 0.642 | 0.212 | 0.305 | 0.265 | 0.193 |
| 14 | power6R | Power | 0.273 | 0.476 | 0.438 | 0.825 | 0.383 | 0.701 | 0.348 | 0.434 |
| 15 | PS1 | Prsat | 0.577 | 0.705 | 0.537 | 0.349 | 0.837 | 0.445 | 0.531 | 0.626 |
| 16 | PS2 | Prsat | 0.575 | 0.687 | 0.635 | 0.402 | 0.858 | 0.442 | 0.595 | 0.557 |
| 17 | PS3 | Prsat | 0.549 | 0.698 | 0.583 | 0.372 | 0.841 | 0.446 | 0.574 | 0.555 |
| 18 | PS4 | Prsat | 0.437 | 0.522 | 0.471 | 0.141 | 0.714 | 0.174 | 0.499 | 0.460 |
| 19 | noopport | Opport | 0.385 | 0.567 | 0.492 | 0.633 | 0.432 | 0.900 | 0.466 | 0.486 |
| 20 | trust2R | Opport | 0.272 | 0.384 | 0.350 | 0.507 | 0.331 | 0.728 | 0.237 | 0.299 |
| 21 | trust7R | Opport | 0.304 | 0.500 | 0.451 | 0.535 | 0.400 | 0.834 | 0.401 | 0.398 |
| 22 | RS2 | Relsat | 0.516 | 0.595 | 0.586 | 0.357 | 0.541 | 0.389 | 0.812 | 0.447 |
| 23 | RS4 | Relsat | 0.501 | 0.601 | 0.547 | 0.264 | 0.560 | 0.361 | 0.806 | 0.524 |
| 24 | RS5 | Relsat | 0.380 | 0.597 | 0.603 | 0.374 | 0.542 | 0.380 | 0.817 | 0.447 |
| 25 | Trust1 | Trust | 0.506 | 0.537 | 0.533 | 0.363 | 0.487 | 0.349 | 0.431 | 0.758 |
| 26 | Trust3 | Trust | 0.501 | 0.613 | 0.627 | 0.348 | 0.553 | 0.435 | 0.501 | 0.841 |
| 27 | Trust4 | Trust | 0.516 | 0.531 | 0.525 | 0.395 | 0.496 | 0.434 | 0.483 | 0.759 |
| 28 | Trust5 | Trust | 0.687 | 0.545 | 0.495 | 0.245 | 0.592 | 0.312 | 0.404 | 0.767 |

**Table 5:** Communality, Redundancy and Average variance extracted

| Blocks | Type | R2 | Block Communality | Mean Redundancy | AVE |
|---|---|---|---|---|---|
| Relinv | Exogenous | 0 | 0.697 | 0 | 0.697 |
| Comcat | Exogenous | 0 | 0.606 | 0 | 0.606 |
| Flex | Exogenous | 0 | 0.584 | 0 | 0.584 |
| Power | Exogenous | 0 | 0.542 | 0 | 0.542 |
| Prsat | Exogenous | 0 | 0.664 | 0 | 0.664 |
| Opport | Endogenous | 0.156 | 0.678 | 0.106 | 0.678 |
| Relsat | Endogenous | 0.595 | 0.659 | 0.392 | 0.659 |
| Trust | Endogenous | 0.650 | 0.612 | 0.398 | 0.612 |

**Table 6:** Results of hypothesis testing

| Blocks | Path coefficient (β) | t value | Pr(>\|t\|) | Results |
|---|---|---|---|---|
| Relinv -> Trust | 0.351 | 8.179 | 0.000 | supported |
| Comcat -> Trust | 0.216 | 3.312 | 0.001 | supported |
| Flex -> Trust | 0.237 | 4.501 | 0.000 | supported |
| Power-> Trust | 0.075 | 1.771 | 0.077 | unsupported |
| Prsat -> Trust | 0.115 | 2.070 | 0.039 | supported |
| Opport -> Trust | 0.022 | 0.482 | 0.630 | unsupported |
| Relsat -> Trust | -0.065 | -1.338 | 0.182 | unsupported |
| Relinv -> opport | -0.395 | -8.404 | 0.000 | supported |
| Comcat -> Relsat | 0.462 | 8.465 | 0.000 | supported |
| Flex -> Relsat | 0.359 | 6.958 | 0.000 | supported |
| Opport -> Relsat | -0.002 | -0.054 | 6785.7 | unsupported |

**Table 7:** Total effect

| | Relationships | Direct | Indirect | Total |
|---|---|---|---|---|
| 1 | relinv -> opport | 0.395 | 0.000 | 0.395 |
| 2 | relinv -> relsat | 0.000 | -0.001 | -0.001 |
| 3 | relinv -> trust | 0.351 | 0.009 | 0.360 |
| 4 | comcat -> relsat | 0.462 | 0.000 | 0.462 |
| 5 | comcat -> trust | 0.216 | -0.030 | 0.186 |
| 6 | flex -> relsat | 0.359 | 0.000 | 0.359 |
| 7 | flex -> trust | 0.237 | -0.023 | 0.213 |
| 8 | power -> trust | 0.075 | 0.000 | 0.075 |
| 9 | prsat -> trust | 0.115 | 0.000 | 0.115 |
| 10 | opport -> relsat | -0.002 | 0.000 | -0.002 |
| 11 | opport -> trust | 0.022 | 0.000 | 0.022 |
| 12 | relsat -> trust | -0.065 | 0.000 | -0.065 |

**Table 8:** PLS path coefficient

| | Original | Mean.Boot | Std.Error | perc.025 | perc.975 |
|---|---|---|---|---|---|
| relinv -> opport | 0.395 | 0.400 | 0.048 | 0.309 | 0.496 |
| relinv -> trust | 0.351 | 0.346 | 0.054 | 0.249 | 0.451 |
| comcat -> relsat | 0.462 | 0.467 | 0.070 | 0.326 | 0.612 |
| comcat -> trust | 0.216 | 0.213 | 0.082 | 0.048 | 0.367 |
| flex -> relsat | 0.359 | 0.356 | 0.066 | 0.216 | 0.473 |
| flex -> trust | 0.237 | 0.235 | 0.057 | 0.133 | 0.360 |
| power -> trust | 0.075 | 0.077 | 0.037 | 0.010 | 0.174 |
| prsat -> trust | 0.115 | 0.128 | 0.062 | 0.020 | 0.251 |
| opport -> relsat | -0.002 | -0.002 | 0.044 | -0.099 | 0.079 |
| opport -> trust | 0.022 | 0.019 | 0.042 | -0.056 | 0.109 |
| relsat -> trust | -0.065 | -0.066 | 0.057 | -0.187 | 0.037 |

***Overall quality of the model***

The Gof index-pseudo goodness of fit- measures the quality of the measurement as well as the structural models. The index is a geometric mean of the average communality and corresponds to the average $R^2$ value (**Sanchez, 2013**). The GoF index value of the model was 0.542 implying the entire model's average prediction power is 54.2%.

***Bootstrap validation***

The fact that PLSPM is non parametric statistical procedure precludes the test of significance of parameter estimates based on normal distribution. Hence the precision of the estimates need to be checked using the standard errors obtained from bootstrap validation. The bootstrap procedure involved the drawing of 200 samples (with replacement) from the original data set of 385. So, 200 estimates for each parameter in the model as well as the standard deviation (standard errors) was obtained. Hence, 200 samples of 385 cases were drawn randomly for the original sample. Finally, the mean of the 200 estimates as well as their standard deviations were calculated. The result indicated that we accept seven hypotheses out of eleven hypothesis formulated.

The t-values of the parameters were calculated by dividing the original estimates of the parameter by the bootstrap standard error. The significance of the PLS parameters can be tested with the standard errors obtained from the bootstrap procedure. If parameters are at least twice their standard errors, they are considered significant. For example, as Table 8 shows, the effect of collaborative communication on trust is significant at $\alpha = 0.5$ as the original estimate (0.216) is at least twice its standard error ($t = 0.216/0.082 = 2.634$) whereas the effect of opportunism on trust is insignificant ($t = 0.022/0.042 = 0.524$). These results can also be confirmed from their respective confidence intervals. The confidence interval for collaborative communication -> trust does not contain zero indicating the significance of the parameter. However, the confidence interval related to opportunism -> trust does contain zero and thus statistically insignificant.

## CONCLUSION

The findings of the study showed that collaborative communication, engaging in relational investment, offering attractive price and demonstrating flexibility enhanced the trust of the farmer for the preferred intermediary. Similarly, collaborative communication and flexibility in trade transaction increased relational satisfaction of the farmer. Moreover, intermediary’s engagement in relational investment reduced the perception of opportunism.

Hence, the analysis suggests that to improve the farmers trust and increase relational satisfaction, intermediaries should use effective communication strategies with farmers. They should also promote relational investment by giving advice and assistance since these contribute to trust and reduce opportunism. Intermediaries must also attract farmers by offering fair and reasonable price as this strengthens the trust of the farmer. Flexibility must also be exercised by adjusting the contract arrangement and solving problems that might arise. The development of trust between the farmer and the intermediary reduces transaction cost and lead to increased trade.

Similar to other studies, this study has some limitations. The limitation is related with the number of measures used to operationalize the construct and the cross sectional nature of the data which doesn’t permit to study long term relationship. The data is also based on a one sided interview with producers which doesn’t take into account the perspective of intermediaries.

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# SPATIOTEMPORAL EVALUATION OF DRY BEANS AND GROUNDNUT PRODUCTION TECHNOLOGY AND INEFFICIENCY IN GHANA

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## ABSTRACT

**Research background**: A combination of technology and efficiency gains will drive future intensification programs aimed at fostering food and nutrition security in the developing world. Specifically, the adoption of improved varieties and use of quality seed alongside good agronomic practices will be critical.
**Purpose of the article:** Given the space-time availability of technology, this study investigates how production efficiency (technical efficiency, technology gap, and meta technical efficiency) has changed over time and assesses the possibility of heterogeneous technology adoption in Ghana.
**Methods:** The study constructs a rich nationally representative dataset of dry beans and groundnut farmers that constitutes 15 production seasons in Ghana. Using a sample of 10,518 farmers from 10,051 households, a Meta Stochastic Frontier (MSF) approach is used to access changes and determinants efficiency and technology adoption.
**Findings & Value added:** We find that farms are operating under heterogeneous technologies along ecological lines and that the technology gap has been reducing over time. Improvements in meta technical efficiency could be driven by the gains in the technology gap ratio. Technical efficiency levels across the two legumes averaged about 61% and did not significantly improve between 1987 to 2017. The key determinants for the observed trends were farmer education, mechanization, access to agricultural extension services, and land ownership. Holding ecological technologies constant, legume farmers generally performed poorly because of technical inefficiency, implying that a general improvement in farmer managerial skills could substantially improve farm output. The study recommends policies/programs be formulated on a case-by-case basis; to ensure specificity and wider impacts, if production is to improve.

**Key words:** efficiency; Ghana; dry bean; groundnut; technology gap
**JEL Codes:** D13; Q12; O55

## INTRODUCTION

Achieving ‘close to’ potential mean yields of staple crops in Sub-Saharan Africa remains elusive among small-scale farmers. Available evidence shows that adoption rates and national mean yields of several crops have remained low **(Alliance for a Green Revolution in Africa (AGRA), 2016; Binswanger-Mkhize and Savastano, 2017**). These disparities have been attributed to the extreme vulnerability of crops to biotic and abiotic stresses **(Feed the Future, 2013**) and the use of inefficient production practices and technology gaps **(Combary, 2017; Nishimizu and Page, 1982)**. This is against the backdrop that governments and non-governmental organizations have been promoting initiatives such as breeding and supplying yield-enhancing technologies (improved seeds, fertilizers, and pesticides) and extension services. However, the realization of the impacts of Ag investments takes time following adoption. A key policy question thus concerns how efficient farmers have been and how this has been changing overtime, whether technology adoption is heterogeneous, and what factors have influenced production efficiency.

This study examines the temporal and spatial dimensions of production efficiency of dry beans (cowpea (*Vigna unguiculata*) and Bambara beans (*Vigna subterranean*)) and groundnut (*Arachis hypogaea*) farmers in Ghana. The paper investigates how production efficiency has changed over time and assesses the possibility of heterogeneous technology adoption. Using the Meta Stochastic Frontier (MSF) approach, the study; (1) assesses factor contributions to ecology specific, national and meta-frontier efficiencies, (2) quantifies temporal pure Technical Efficiency (TE), Technology Gap Ratio (TGR), and Meta Technical Efficiency (MTE), and (3) evaluates farmer and institutional factors that have influenced technical inefficiency and adoption of superior technologies. The empirical strategy is implemented using a rich nationally representative dataset that covers 15 production seasons between 1987 and 2017 in Ghana. This data presents a unique opportunity to empirically assess the nature of observed legume production patterns in Ghana over time.

## LITERATURE REVIEW

Production efficiency can be categorized into technical or allocative efficiency, with the two combining to form economic efficiency (**Farrell, 1957**). Due to the paucity of reliable data on input prices at the farmer level, technical efficiency, which deals with how well farmers manage inputs to reach potential yields is the most commonly used measure. The literature presents two main orientations - i.e., output or input - in measuring technical efficiency. Output orientation compares the observed output to its potential given a set of input and technology while the input orientation measure compares observed input levels to its minimum potential necessary to produce a given output level **(Belotti, Daidone, Ilardi, and Atella, 2013).** These two orientations are empirically implemented either using the non-parametric Data Envelopment Analysis (DEA), or the Stochastic Frontier Analysis (SFA) methods. DEA ignores deviation outside the control of farmers (i.e. white noise) while SFA employs econometrics and as such incorporates randomness into the production process (**Belotti *et al.*, 2013**). Consequently, the SFA approach is used in this study because it incorporates randomness and fits the data best. The existence of a homogeneous production technology and management practices puts all farmers on the production frontier. However, deviations can be observed that can be attributed to technical inefficiency and/or production risk (**Bokusheva and Hockmann, 2005**).

Empirical evidence into smallholder production efficiency has mostly been static in time (single-season analysis) and limited in geographic scope. This kind of analysis, therefore, does not allow for spatial and temporal analysis of production efficiency and its dynamics. It has been noted that failure to account for technological differences could lead to falsely attributing production shortfalls due to technology gaps to inefficient input use **(Battese, Rao, and O'Donnell, 2004)** leading to suboptimal policy prescriptions. A handful of studies on Ghana have shown that low production levels for maize **(Owusu, 2016; Wongnasa and Awunyo-Vitor, 2019)**, rice **(Asravor, Wiredu, Siddig, and Onumah, 2019)**, vegetables **(Tsiboe, Asravor, and Osei, 2019)**, and cocoa could be attributed to ecological and regional technological gaps. Furthermore, some have shown that technology gaps could exist along gender differences of farm owners and managers **(Djokoto *et al.*, 2017)** or methods of production used by farmers, both conventional/organic **(Onumah *et al*., 2013)**. The only studies also on Ghana and focusing on leguminous crops do not consider technology gaps but they show that production could be improved by reducing technical inefficiency **(Avea *et al.*, 2016; Awunyo-Vitor, Bakang, Gyan, and Cofie, 2013; Etwire, Martey, and Dogbe, 2013).**

This study differs from earlier empirical studies conducted on legumes in Ghana on two fronts: First, the possibility for heterogeneous technology adoption is considered in explaining the nature of observed production. Secondly, production technologies and efficiencies were analysed over an extended period allowing the study to isolate trends and temporal dynamics. By putting the nature, dynamics, and spatial distribution of legume production on a solid empirical footing, the output from this study offers ground truth that informs the policy dialogue and supports crop improvement agendas.

## DATA AND METHODS

### *Data and Sample*

The data used comes from three sources; (1) all seven Ghana Living Standards Surveys (GLSSs); (2) the first and second waves of the Ghana Socioeconomic Panel Surveys (GSPS); and (3) the Ghana Africa Research in Sustainable Intensification for the Next Generation Baseline Evaluation Survey (GARBES). Detailed information on the harmonization of these datasets is published elsewhere. Except for GSPS, each round of data collection has a sample of new households. Thus, the study data is a pooled/repeated cross-section dataset of Ghanaian legume farmers. The sample used in this study was limited to farmers originating from the dry bean and groundnut producing households, with yield measured in kg/ha above the 5th and below the 95th percentile by survey, ecology, and legume. The final sample consists of 10,518 farmers originating from 10,051 households.

The data is nationally representative covering all but one ecology: Rain Forest, Semi-Deciduous Forest, Transitional Zone, Guinea Savanna, and Sudan Savanna, of Ghana. The farming systems are highly heterogeneous and supportive of many types of farming. Most of the cultivated lands and production are in Guinea Savanna and Sudan Savanna Zones. Ideally, given their balanced annual rainfall and modest temperatures, these two ecologies have the optimal conditions for growing legumes. Due to data limitations and problems associated with thin data, observations from Semi-Deciduous Forest and Rain Forest are combined and reported as the Forest Zone.

### *Empirical model specification, model selection and estimation*

Suppose environmental, farmer demographics, and factor usage in farms define the Stochastic Frontier Production (SF) function models for distinct groups. Then the SF function representing a group of farmers faced with similar circumstances (*j*) can be expressed as Eq. 1.

$$y_i = f^j(x_i)e^{\varepsilon_i}, \varepsilon_i = v_i - u_i \quad (1)$$

Where: $y_i$ is output and $x_i$ represent production inputs for the $i^{th}$ farmer. Deviations from the frontier are captured by $\varepsilon_i$ that is composed of production risk ($v_i$) and technical inefficiency ($u_i$). The distributional assumptions of the deviations ($v_i$ and $u_i$) underpin the estimation of Equation (1). Generally, $v_i$ follows a normal distribution with zero mean and variance $\sigma_{v_i}^2$ $[v_i \sim N(0, \sigma_v^2)]$, but $u_i$ has different distributions based on its negative skewness **(Belotti *et al.*, 2013)**.

Eq. 1 implies that production-output-increasing inputs simultaneously increase production variability **(Just and Pope, 1979)**. However, inputs may have varying effects on production output and its variability. The stochastic components ($v_i$ and $u_i$) could also be influenced by exogenous variables other than inputs **(Just and Pope, 1978, 1979)**. A better model should allow technical inefficiency increasing and decreasing effects. As such, technical inefficiency is redefined as $\sigma^2_{u_i} = \exp(\boldsymbol{w}_i\boldsymbol{\alpha})$, where $\boldsymbol{w}_i$ and $\boldsymbol{\alpha}$ are, respectively, vectors of explanatory variables and parameters **(Caudill, Ford and Gropper, 1995).** If the null hypotheses $H_o: \boldsymbol{\alpha} = 0$ is not rejected, then there is no statistical justification for the inefficiency increasing and decreasing effects **(Aigner, Lovell, and Schmidt, 1977).** Furthermore, the group specific TE of the $i^{th}$ farmer is calculated as $TE_i = E[\exp(-u_i)\,|\hat{\varepsilon}_i]$.

Following **Huang, Huang, and Liu (2014)**, under the Meta-Stochastic Frontier (MSF) approach, Eq 1. is first estimated separately for each group (*j*), and then in the second step, the predicted output levels from the group SFs are used as the observation for a pooled SF that captures all ecologies to estimate the MSF. In the second step, the conventional one-sided error term ($u_i^M$) serves as the estimate for any technology gaps amongst the diverse groups. The MSF which envelops all group-specific frontiers $[f^j(x_i)]$ is represented as Eq. 2.

$$f^j(x_i) = f^M(x_i)e^{-u_i^M},\ u_i^M \sim N^+\big(0, \exp(\boldsymbol{w}_i\boldsymbol{\alpha})\big), \quad (2)$$

Where: $u_i^M$ is strictly greater than zero, implying that $f^j(x_i) \le f^M(x_i)$. The ratio of group *j*'s frontier to the MSF is the technology gap ratio (TGR) that can be defined as Eq. 3.

$$TGR_i = \frac{f^j(x_i)}{f^M(x_i)} = e^{-u_i^M} \le 1 \quad (3)$$

The TGR depends on the accessibility and adoption level of the available MSF which in turn depends on farmer-specific circumstances. Each farmer's meta-frontier technical efficiency (MTE) is thus estimated as Eq. 4.

$$MTE_i = f^j(x_i)[f^M(x_i)e^{v_i}]^{-1} = TGR_i \times TE_i \quad (4)$$

Following **Avea *et al.* (2016) and Etwire *et al.* (2013)**, the empirical model in this study formulates the functional form of the production function as a Translog due to its relative flexibility over the Cobb-Douglas form **(Awunyo-Vitor *et al.*, 2013)**. Moreover, the Cobb-Douglas functional form is nested within the Translog, which allows us to evaluate it. We run a battery of model specification tests including functional form tests, skewness, likelihood ratio, variance, and inefficiency tests, and model significance to select a suitable model (Table 2). The empirical model used in this study is of the form of Eq. 5.

$$\ln y_{ijt} = \beta_{0r} + \textstyle\sum_k \beta_{kj} \ln x_{kijt} +$$
$$\tfrac{1}{2}\textstyle\sum_s \sum_k \beta_{skj} log \ln x_{kijt} \ln x_{sijt} + v_{ijt} - u_{ijt}$$
$$u_{ijt} \sim N^+\big[0, \exp(\boldsymbol{w}_{ijt}\boldsymbol{\alpha})\big],$$
$$v_{ijt} \sim N(0, \sigma_v^2) \quad (5)$$

Where: $y_{jit}$ is total production (kg) for the $i^{th}$ farmer in ecology $j$ at time *t*. The variable $x_{kjit}$ represent the $k^{th}$ input (total land, seed, family and hired labour, and pesticides) used by the $i^{th}$ farmer for production and a trend variable.

Whilst $u_{ijt}$ can take on varied distributions, the study assumes a half-normal distribution (i.e., $u_{ijt} \sim N^+\big[0, \exp(\boldsymbol{w}_{ijt}\boldsymbol{\alpha})\big]$) due to non-convergence in the case of other distributions. Following **Tsiboe *et al.* (2019)**, the covariates in $\boldsymbol{w}_{ijt}$ control for farmer characteristics (age, education, and gender), institutional factors (land ownership, credit, and extension), and a trend and constant term.

Based on the likelihood-ratio tests, the null hypothesis of the Cobb-Douglas out-performing the Translog functional form for the production function (i.e., $H_0$: $\beta_{skj} = 0$) was rejected for all models. This shows that the Translog is appropriate for our data. Furthermore, the **Coelli (1995)** and **Schmidt and Lin (1984)** skewness test for ordinary least squares residuals are negative for all the models, suggesting that the variation of production in these ecologies are negatively skewed. Similarly, the **Gutierrez *et al.* (2001)** test for the null hypothesis of no one-sided error is rejected across most of the models. This further validates the strength of estimating the model using SFA.

The parameters of the ecology- and Meta-frontiers were estimated via maximum likelihood, using the "*frontier*" command in Stata 16. The elasticity for each input is estimated as the first derivative of the frontiers with respect to that input, evaluated at the inputs means. Thus, production returns to scale (RTS) are estimated as the summation of all the input elasticities. The delta method is used to estimate the standard errors for all parameters. Point estimates of parameters and their standard errors were used to evaluate the null hypothesis that they were not different from zero. The only exception is the RTS, where the relevant null hypothesis was that of unity, indicating constant returns to scale.

## RESULT AND DISCUSSION

### *Descriptive statistics*

The average age of a legume farmer was 46 years, and women make up about 22% of legume farmers in the sample (Table 1). The farmers had an average of two years of schooling with the mean years of formal education increasing at a rate of 3% per annum. This is consistent with the improvement in education due to free basic education. The production area for dry beans and groundnut averaged one hectare with yields averaging 535, and 790 kg/ha, respectively. Though mean yields significantly improved over the study period, they are less than half the yield potential of available technologies **(Ministry of Food and Agriculture [MOFA], 2017)**. This signifies room for improvement. About 11% of farmers reported access to credit and the probability of accessing credit declined by 0.1% annually over the study period.

***Model specification tests***

The likelihood ratio test for the null hypothesis that the production frontiers for a given legume are similar across ecologies is rejected. This supports the fact that dry beans and groundnut farmers are operating under heterogeneous technologies along ecological lines. The total production variance for the model without the inefficiency effects for dry bean and groundnuts (Table 2), show that the empirical model explains the variation in output for the ecology frontiers and the Meta-frontier at varying levels.

***Input Elasticity, productivity, and technical change***

We found that land with input elasticities ranging from 0.42 to 0.53 for dry beans and 0.53 to 0.62 for groundnut, was the most important and significant factor in their production (Table 3). The highest contribution of land for dry beans was in the Guinea Savanna Zone, and the lowest was in the Transitional Zone. For groundnut, the highest was in the Transitional Zone and the lowest contribution was in the Forest Zone. While the contribution of seed, hired labour, and pesticides are also significant, their spatial heterogeneities are lower than that of land. For both legumes, the lowest contribution for hired labour was in the Sudan Savanna and highest in Transitional Zones, respectively. Finally, family labour is only important in the production of beans making the highest and lowest contribution in the Sudan Savanna and Transitional Zones, respectively. The elasticity estimates are in line with those of earlier studies **(Avea *et al.*, 2016; Awunyo-Vitor *et al.*, 2013)**. Because of the rising demand for land, coupled with declining farm size due to growing populations **(Jayne, Chamberlin, and Muyanga, 2012)**, improving productivity via the enhancements in the responsiveness of output to non-land inputs is inevitable.

Our estimates reveal that the production of both legumes is characterized by decreasing returns to scale (returns to scale values less than one) (Table 3). This implies that the output of both legumes will proportionately decrease if all inputs are increased by the same proportion. Though for a different legume crop, **Avea *et al.* (2016)** showed that soybean production in Northern Ghana is characterized by constant returns to scale.

Considering the productivity parameter (i.e., the constant term), dry beans, and groundnut farmers in the Guinea Savanna had the highest productivities estimated at 1.56 and 2.19, respectively (Table 3). Guinea Savanna's productivity was lower [higher] than the MSF for dry beans [groundnuts] but was closer to that of the MSF than their peers in other ecologies. Residing in these ecologies could partly be exerting a positive influence on observed efficiency levels. Thus, observed factor-specific variations in ecology frontiers could explain the different positive effects on meta-frontier ratios. Comparing the two legumes, ecology-specific frontiers and MSF are higher for dry beans than for groundnuts. Theoretically, this implies that dry bean farmers are performing better than groundnut farmers. The overall technical change parameter for the MSFs for both legumes is negative (- 0.02 for dry beans and -0.03 for ground nuts) and statistically significant implying that production technologies used have declined over the study period (Table 3).

**Table 1** Summary Statistics of Dry beans and Groundnut Farmers

| Variable | Mean (SD) | Trend (%) |
|---|---|---|
| *Farmer*[a] | | |
| Female (dummy) | 0.22†(0.415) | 0.39*†[0.047] |
| Age (years) | 45.87†(15.415) | 0.19*[0.044] |
| Education (years) | 2.23†‡(4.229) | 3.03*†[0.384] |
| Land owned (dummy) | 0.66†‡(0.475) | 0.63*†‡[0.043] |
| Land (ha)[a] | | |
| Dry beans | 1.05†(2.972) | 7.78†[53.566] |
| Groundnut | 1.08†(2.034) | -7.63*†[3.730] |
| *Yield (kg/ha)*[a] | | |
| Dry beans | 534.49†(1792.702) | 2.71*†[0.635] |
| Groundnut | 789.91†(1816.972) | 0.47*†[0.215] |
| *Input use*[a] | | |
| Seed (kg/ha) | 68.41†‡(631.867) | 9.19†‡[227.103] |
| Family labour (AE) | 3.49†(1.924) | 0.22*‡[0.066] |
| Hired labour (man-days/ha) | 15.07†‡(63.845) | 1.96†[4.972] |
| Pesticide (Litre/ha) | 4.99†‡(23.369) | -2.85†‡[343.158] |
| *Household*[b] | | |
| Size (AE) | 6.07†(3.469) | 0.24*[0.070] |
| Dependency(ratio) | 1.54(1.798) | -0.28[0.161] |
| Credit(dummy) | 0.11(0.313) | -0.09*†[0.032] |
| Mechanization(dummy) | 0.18†(0.382) | 1.19*†[0.059] |
| Extension(dummy) | 0.21†(0.407) | 0.57*†[0.049] |

Note: * Indicates significance at p<0.05; *†* and *‡* indicate significant (p<0.05) variation across ecology and crop, respectively.
[a] Farmer sample size; Dry beans [5,763], Groundnut [7,774], Pooled [10,518]
[b] Household sample size; Dry beans [5,626], Groundnut [7,497], Pooled [10,051]
Data Sources: GLSS, GSPS, and GARBES data.

**Table 2** Hypothesis Tests for Ecology- and Meta- Frontier Models for Dry beans and Groundnut Production

| Test/statistic | Ecology production frontier | | | | National frontier | Meta- |
|---|---|---|---|---|---|---|
| | Sudan Savanna | Guinea Savanna | Transitional Zone | Forest Zone | | Frontier (MSF) |
| *Dry beans* | | | | | | |
| Sample size | 3,083 | 1,653 | 420 | 334 | 5,614 | 5,614 |
| Log likelihood | -3,299 | -1,832 | -559 | -477 | -6,538 | 421 |
| Cobb-Douglas test | 545.73*** | 208.32*** | 78.76*** | 65.71*** | 691.94*** | 8039.94*** |
| Schmidt & Lin (1984) [a] skewness test | -0.05 | -0.21 | -0.15 | -0.35 | -0.26 | -0.07 |
| Coelli, (1995) [ab] skewness test | -3.25* | -8.27* | -1.47 | -2.22* | -15.94* | -117.39* |
| Gutierrez (2001) [a] LR test | 2.46 | 16.29*** | 4.77* | 12.96*** | 65.79*** | 18.19** |
| Inefficiency variance [$\sigma_u$] | 0.50 (0.106) | 0.83 (0.072) | 1.07 (0.159) | 1.50 (0.150) | 0.83 (0.037) | 0.19 (0.015) |
| Total production variance [$\sigma^2 = \sigma_u^2 + \sigma_v^2$] | 0.67 (0.071) | 1.00 (0.088) | 1.64 (0.252) | 2.57 (0.366) | 1.06 (0.045) | 0.09 (0.004) |
| Gamma [$\gamma = \sigma_u^2/\sigma^2$] | 0.38*** (0.120) | 0.69*** (0.063) | 0.69*** (0.106) | 0.87*** (0.057) | 0.64*** (0.032) | 0.38*** (0.047) |
| Inefficiency function test | 40.02*** | 23.01** | 50.71*** | 9.11 | 94.37*** | 497.69*** |
| Model significance | 4241.82*** | 1829.06*** | 395.80*** | 218.77*** | 6285.71*** | 82932.27*** |
| *Groundnut* | | | | | | |
| Sample size | 3,758 | 2,659 | 749 | 330 | 7,496 | 7,496 |
| Log likelihood | -3,627 | -2,921 | -937 | -456 | -8,318 | 178 |
| Cobb-Douglas test | 612.86*** | 298.19*** | 151.14*** | 48.84*** | 1016.62*** | 7785.75*** |
| Schmidt & Lin (1984) [a] Skewness test | -0.12 | -0.33 | -0.15 | -0.07 | -0.37 | 0.50 |
| Coelli, (1995) [ab] Skewness test | -11.26* | -16.45* | -2.74* | -0.44 | -31.44* | 1803.53 |
| Gutierrez (2001) [a] LR test | 11.83*** | 79.65*** | 6.57** | 2.70 | 167.74*** | - |
| Inefficiency variance [$\sigma_u$] | 0.57 (0.058) | 1.01 (0.040) | 0.99 (0.132) | 1.46 (0.277) | 0.88 (0.025) | 0.00 (0.072) |
| Total production variance [$\sigma^2 = \sigma_u^2 + \sigma_v^2$] | 0.63 (0.046) | 1.22 (0.064) | 1.36 (0.189) | 2.52 (0.598) | 1.06 (0.035) | 0.05 (0.001) |
| Gamma [$\gamma = \sigma_u^2/\sigma^2$] | 0.52*** (0.068) | 0.83*** (0.025) | 0.72*** (0.096) | 0.84*** (0.125) | 0.74*** (0.020) | 0.00 (0.005) |
| Inefficiency function test | 121.11*** | 87.39*** | 8.14 | 113.22*** | 119.01*** | 1016.82*** |
| Model significance | 5279.34*** | 2903.14*** | 696.75*** | 335.83*** | 8171.97*** | 84244.32*** |

Significance levels: * p<0.10, ** p<0.05, ***p<0.01

[a] Null hypothesis of no one-sided error (i.e. no inefficiency) was tested

[b] Values less than the critical value of 1.96 confirms the rejection of the null hypothesis.

Data Sources: Author rendering of GLSS, GSPS1, and GARBES data.

**Table 3.** Elasticities for Ecology- and Meta- Frontier Models for Dry beans and Groundnut Production

| | Ecology production frontier | | | | | |
|---|---|---|---|---|---|---|
| | Sudan Savanna | Guinea Savanna | Transitional Zone | Forest Zone | National frontier | Meta-Frontier |
| *Beans* | | | | | | |
| Land elasticity | 0.49***(0.017) | 0.53***(0.025) | 0.42***(0.047) | 0.47***(0.075) | 0.50***(0.013) | 0.50***(0.004) |
| Seed elasticity | 0.18***(0.010) | 0.09***(0.012) | 0.09***(0.019) | 0.03(0.035) | 0.12***(0.006) | 0.11***(0.002) |
| Family labour elasticity | 0.09***(0.028) | 0.02(0.040) | -0.20**(0.098) | -0.06(0.129) | 0.04*(0.023) | 0.03***(0.009) |
| Hired Labour elasticity | 0.02***(0.005) | 0.01(0.007) | 0.09***(0.023) | 0.11***(0.027) | 0.02***(0.003) | 0.02***(0.001) |
| Pesticide elasticity | -0.03**(0.010) | -0.02*(0.011) | 0.06***(0.019) | 0.00(0.049) | -0.01*(0.007) | 0.00(0.002) |
| Returns to scale | 0.75***(0.033) | 0.63***(0.046) | 0.47***(0.107) | 0.54***(0.165) | 0.68***(0.027) | 0.66***(0.010) |
| Productivity | 0.81***(0.181) | 1.56***(0.424) | 1.51**(0.768) | 1.11**(0.503) | 1.66***(0.218) | 2.05***(0.124) |
| Annual trend (%) | -0.01*(0.004) | -0.01*(0.006) | 0.03*(0.016) | -0.02(0.019) | -0.02***(0.003) | -0.02***(0.001) |
| *Groundnut* | | | | | | |
| Land elasticity | 0.56***(0.016) | 0.62***(0.022) | 0.54***(0.037) | 0.53***(0.058) | 0.58***(0.012) | 0.58***(0.004) |
| Seed elasticity | 0.17***(0.008) | 0.10***(0.007) | 0.06***(0.019) | 0.04(0.032) | 0.13***(0.005) | 0.11***(0.002) |
| Family labour elasticity | 0.02(0.023) | 0.01(0.030) | -0.11(0.072) | -0.03(0.140) | 0.00(0.018) | 0.00(0.007) |
| Hired Labour elasticity | 0.01***(0.003) | 0.03***(0.004) | 0.06***(0.019) | 0.10***(0.030) | 0.03***(0.003) | 0.03***(0.001) |
| Pesticide elasticity | -0.03***(0.010) | -0.01*(0.009) | 0.02(0.014) | 0.06**(0.031) | -0.01(0.006) | 0.01***(0.002) |
| Returns to scale | 0.74***(0.027) | 0.75***(0.035) | 0.57***(0.076) | 0.70**(0.138) | 0.73***(0.021) | 0.73***(0.007) |
| Productivity | 0.65***(0.087) | 2.19***(0.332) | 0.54*(0.317) | 0.96**(0.373) | 1.33***(0.131) | 1.82***(0.092) |
| Annual trend (%) | -0.01*(0.003) | -0.01***(0.004) | -0.03**(0.011) | 0.03**(0.012) | -0.02***(0.002) | -0.03***(0.001) |

Note: Significance levels: * $p<0.10$, ** $p<0.05$, ***$p<0.01$
[a] Null hypothesis of constant returns to scale was tested.
Data Sources: GLSS, GSPS, and GARBES data.

***Technology gap, Technical Efficiency, and Meta-frontier Technical Efficiency***

The TGR ranged between 0.81 to 0.93 for dry beans and 0.86 and 0.93 for ground nuts (Figure 1, panel a). On average, the TGR was 0.84 and 0.86 indicating a technology gap (required to match the best technology) of 15% and 14% for dry beans and groundnut farmers, respectively. Farmers growing temporal dynamics show that the TGR increased over the study period for both legumes (Figure 2, panel a). The TGR was highest in the Forest Zone for dry beans and the Guinea Savanna for groundnuts (Figure 1, panel a). These values are higher when compared to those of other crops grown in Ghana; 0.56 and 0.75 for okra and tomato, respectively **(Tsiboe *et al.*, 2019)**, 0.73 for rice **(Asravor *et al.*, 2019)**, and 0.79 for cocoa. These findings suggest that legume farmers, on average, perform better than those growing other crops for which TGR has been measured in Ghana. The high TGRs in this study are not surprising given the low range of variance due to the technical inefficiency parameter ($\gamma$). Changing the model specification could influence the size of $\gamma$ (Table 2), however, this was not the case in this study. Also, altering the production function form did not significantly improve the size of $\gamma$ nor the size of the TGRs. This implies that output variation across ecologies could also be due to idiosyncrasies such as biotic and abiotic shocks.

Overall, the best and worst performing farmers for dry beans were those from the Transition Zone and Forest zone with average TE of 0.72 and 0.45, respectively. For groundnuts, the highest TE (0.72) was in the Sudan Savanna and lowest in the Transitional Zone (0.52) (Figure 1, panel b). These variations can be explained by changes in production environments, available technologies and their usage. According to **Asravor *et al.* (2019),** TE with differentiated production technology varies along ecological lines. For instance, in rice production, TE decreases from northern to southern Ghana. These differences occur because of variations in weather, biotic conditions, and production practices across zones. Rainfall, for example, changes from being unimodal in the north to bimodal in the south of Ghana. Our fitted mean estimates across space and time for the study period reveal that dry bean TE has been stable over time while that of groundnuts have been declining (Figure 2 panel b). These findings are consistent with earlier estimates that show that legume farmers operated between 53-89% efficiency levels **(Avea *et al.*, 2016; Awunyo-Vitor *et al.*, 2013; Etwire *et al.*, 2013)**.

A major caveat about the TE scores we have discussed above is that they do not tell us how farmers perform relative to the broader legume-specific sector production frontier. Our legume-specific MTE compared to the TE of the farmers accounts for these variations. After accounting for the ecology-specific differences in production technologies, the mean MTE is 0.535 and 0.525 for dry bean and groundnut, respectively. The MTE improves from Southern to Northern Ghana. Specifically, the most technically efficient dry bean and groundnut farmers compared to their meta-frontier are those in the Sudan Savanna zone with MTE of 0.614 and 0.624 respectively (Figure 1, panel c).

***Determinants of Technical Efficiency and Technology gap***

In Table 4, negative coefficients imply that the variable has an increasing [decreasing] effect on technical efficiency [technology gap] and vice versa. Male-headed farms have the best technologies and are also more efficient. Except for the Transition and Forest Zone and MTE for groundnuts, the gender effect is important in all ecologies for both crops. Whilst the coefficient for farmer education does not affect technical inefficiency, the same pushes both dry bean and groundnut farmers away from the best production technology.

Land ownership improves TE and minimizes technology gaps for dry bean farmers. This effect is not only important at the national level but also in Sudan and Guinea Savanna Zones. For groundnuts, land ownership has the same effect as that of dry beans except in the Transitional Zone (with a technical inefficiency measure of 0.4) where it is associated with a decrease in TE. These findings suggest that changes in land tenure towards near ownership rights would enhance the efficiency of dry bean production. For both legumes, mechanization is associated with a reduction in technical inefficiency and technology gaps. The effect is significant at the national level for dry beans and Sudan and Guinea Savanna Zones and the national level for groundnuts.

The effect of credit availability is a reduction in the technological gap for the meta frontier of ground nut farmers. It is also associated with, an ambiguously positive technical inefficiency score which suggests a reduction in TE in the Guinea Savanna Zone for groundnuts (Table 4). While we will normally expect credit to improve TE if farmers invest the credit in TE enhancing techniques, we cannot tell for certain how they spent their credit in this sample. Access to agricultural extension services is associated with a significant improvement in TE in the production of dry beans at the national and Sudan Savanna Zone level. For groundnuts, extension services were positively associated with TE in Sudan and Guinea Savanna Zones and at the national level. For the most part, extension services reduced the technology gap in all zones but fell short in the Transition Zone where it was associated with a negative TE (an inefficiency score of 0.39).

Our study explores the importance of ecological variation in explaining differences in production by classifying farms based on ecologies. The study finds that pesticide, hired labour, mechanization, extension, and credit usage significantly varied across ecologies. As noted by **Antwi-Agyei, *et al.* (2012)** and **Armah *et al.* (2011),** ecological variations are important in explaining farm output, input usage, and crop production. Noting that such variations are caused by differences in climate, farming systems, and levels of social-economic development.

The study found significant variations in yields across ecologies with farmers in the Transitional and Forest Zone ecologies reporting the highest yields. The Transitional Zone is a major commercial food-producing zone in Ghana **(Amanor and Pabi, 2007)** and has the longest growing days and well-balanced annual precipitation **(MOFA, 2017)**. Even with this historical significance and conducive environment, operations in the Transitional Zone are labour-intensive with the highest average labour usage of 20 man-days worked per hectare and the lowest level of mechanization. Generally, the levels of mechanization remain low (18%) across Ghana with Sudan and Guinea Savanna Zones having the highest mechanization rates for groundnuts and the Guinea Savanna Zone for dry beans. Disparities exist in access to extension services across ecologies. About 30% of the farmers reported accessing extension services with the Transitional Zone having the highest levels of access followed by farmers in Guinea Savanna and Forest Zone.

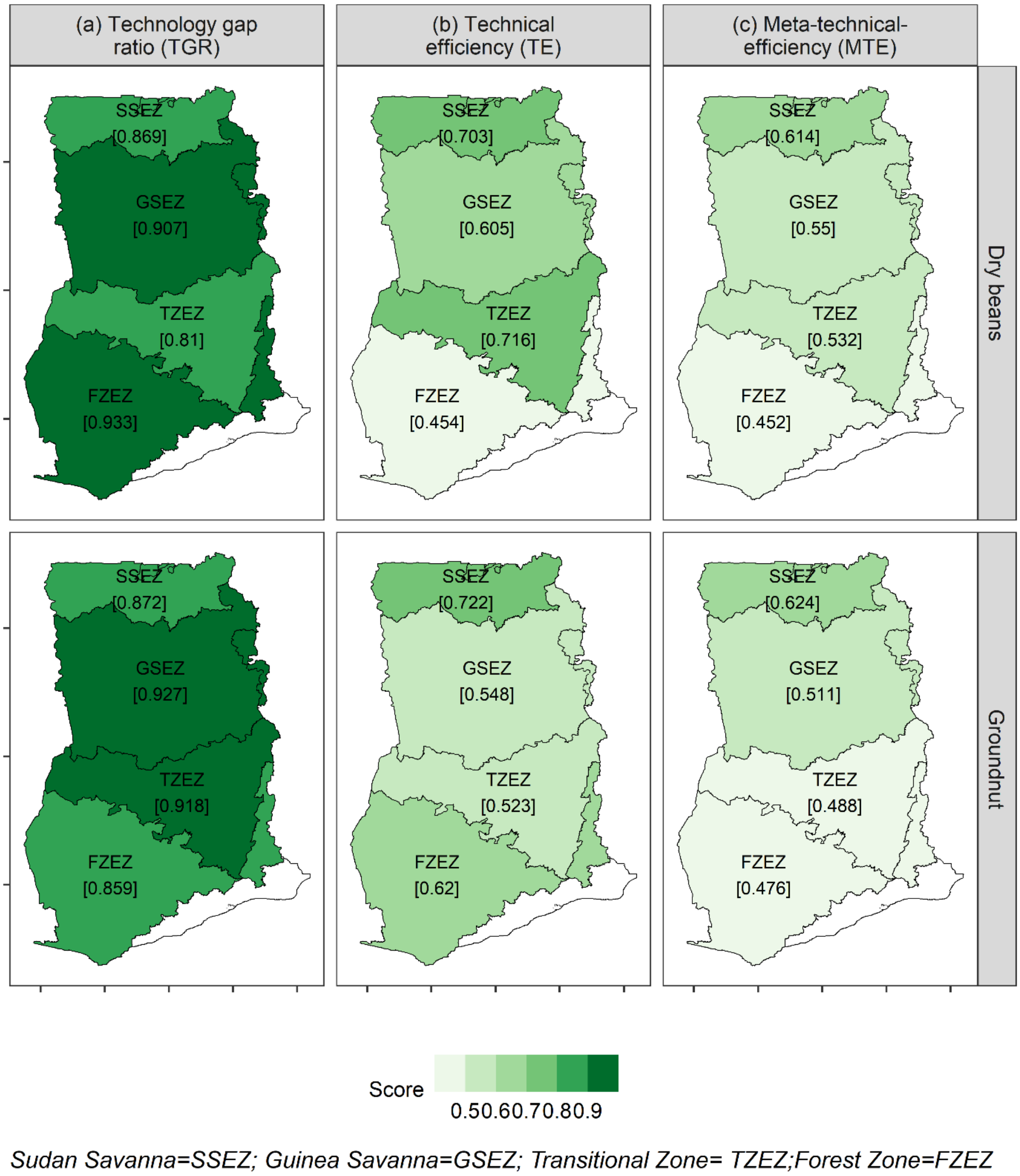


**Figure 1.** Dry beans and Groundnut Production Technology Level and Technical Efficiency Across Ecologies

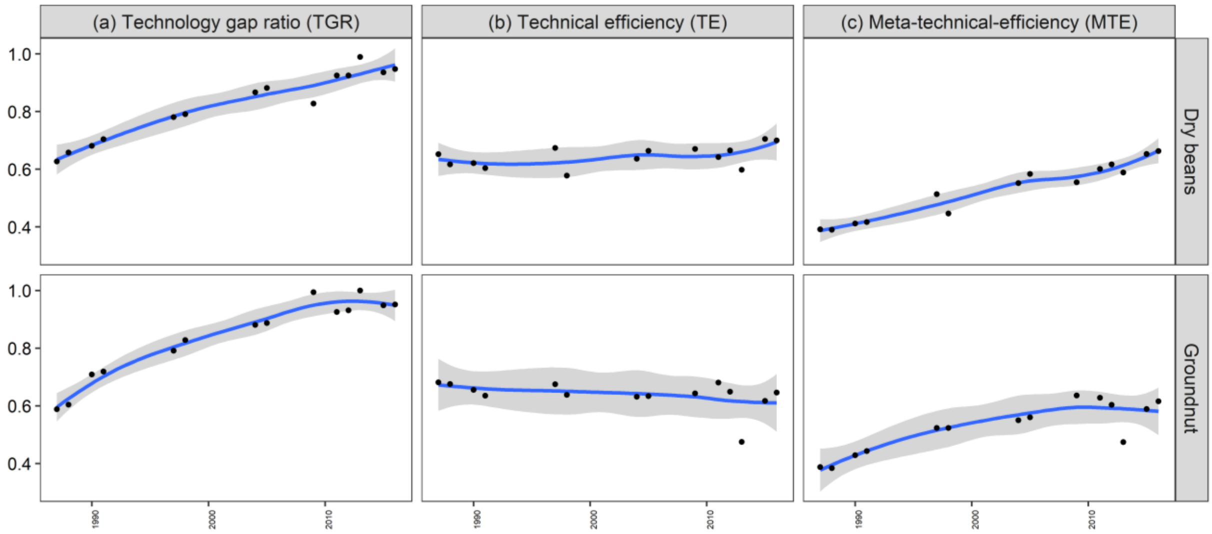


**Figure 2.** Temporal Dynamics in Dry beans and Groundnut Production Technology Level and Technical Efficiency

## DISCUSSION AND POLICY IMPLICATIONS.

The findings from this study have several implications that can be inferred at the national and ecology levels. Policies will thus have to be formulated on a case-by-case basis, for specificity and wider impacts, if production and efficiency are to improve. First, we found that holding ecological technologies constant, legume farmers generally performed poorly because of pure farmer technical inefficiency. Furthermore, mean yields obtained by farmers remain far below the attainable yields of available technologies. This will call for extensive and widespread popularization of available legume varieties whose adoption and use are still extremely low. Most importantly, there is a need to tailor the seed systems of different crops to meet supply gaps while staying responsive to farmer needs. The seed sector should, be bolstered right from the production of Early Generation Seed to the production of Quality Declared Seed. Also, easing access to agricultural inputs would go a long way in improving production.

Secondly, the observed performance heterogeneity across ecologies can be exploited to improve production. This can be through leveraging existing good practices and creating synergies between and across ecologies. For example, farmers could benefit from simple technology transfer. The most efficient but technologically disadvantaged farmers in the transition zone for beans could benefit from technology transfer from their peers in the Forest Zones. They could be targeted with yield-enhancing technologies like improved seed varieties, fertilizers, among others. Farmers who are better off in terms of technology (e.g., Forest Zone farms) but less efficient could benefit from interventions aimed at improving farmer managerial practices and skills via targeted extension, farmer field schools, and village agents peer training programs. The same logic could apply to groundnut farmers to improve their production.

Furthermore, ecological variations in TGR, TE, and MTE capture important stresses that may be associated with environmental and climatic changes. It is thus important that breeding efforts, aimed at producing high-yielding and productivity enhancing legume varieties and management options, take these into account. Specifically, breeding and agronomic research should be focused on ensuring that the ecological needs of regions are fully factored into the development of new and climate-smart technologies. The trade-off here is between developing ‘a one size fits it all’ and agroecological suited varieties and practices for maximum returns.

Finally, since land; both in terms of ownership and farm size, was the greatest contributor to legume production, policy should put more effort into the development of non-land-based interventions that allow legume intensification and yield improvements at the intensive margin. This is critical given that farm size in Ghana, just like in a host of other countries in sub-Saharan Africa is diminishing. Also, programs that hasten land ownership through formal documentation should be of strategic importance in delivering productivity gains.

## CONCLUSIONS

Renewed recognition of the historical role research, development, and technology transfer initiatives have had on technical and efficiency transformation has spurred interest in more focused research and outreach to ensure food security and income generation in developing countries. Developing tailored breeding and agronomic management systems to produce climate-smart, efficiency-enhancing, and high productive technologies is one such effort. However, given the heterogeneity in the production environment and farmer behaviour, it is hard to assess gains from such programs.

This paper employed the Meta-stochastic-frontier analysis to a rich nationally representative dataset of dry beans and groundnut farmers that spans over three decades in Ghana to quantify trends in technical efficiency, technology gap, and meta technical efficiency. Factors that have affected technical efficiency and technology gap are also documented.

**Table 4**. Determinants of Dry beans and Groundnut Technical Inefficiency/ Technology Gap

| | Ecology production frontier | | | | National frontier | Meta-frontier |
|---|---|---|---|---|---|---|
| | Sudan Savanna | Guinea Savanna | Transitional Zone | Forest Zone | | |
| *Dry beans* | | | | | | |
| Female(dummy) | 0.39**(0.155) | 0.48***(0.157) | 0.68*(0.405) | 0.59**(0.259) | 0.47***(0.085) | 0.45***(0.113) |
| Age(ln[years]) | -0.12(0.188) | -0.10(0.175) | 0.33(0.478) | 0.82**(0.387) | 0.06(0.101) | -0.02(0.124) |
| Education(ln[years]) | -0.02(0.020) | 0.03*(0.017) | 0.06(0.047) | 0.02(0.028) | 0.02**(0.010) | 0.06***(0.015) |
| Land owned(dummy) | -0.83***(0.157) | -0.30**(0.138) | 0.33(0.325) | -0.12(0.221) | -0.47***(0.074) | -0.34***(0.109) |
| Mechanization(dummy) | -0.27(0.220) | -0.21(0.145) | -0.45(0.557) | -0.21(0.239) | -0.21**(0.088) | -0.41***(0.154) |
| Credit(dummy) | 0.19(0.170) | 0.29(0.189) | 0.41(0.398) | 0.04(0.238) | 0.20**(0.098) | -0.18(0.172) |
| Extension(dummy) | -0.75***(0.227) | -0.16(0.164) | -0.04(0.361) | 0.17(0.306) | -0.24**(0.099) | 0.17(0.176) |
| Trend | -0.02(0.010) | -0.03***(0.011) | 0.35***(0.099) | -0.03(0.025) | -0.03***(0.006) | -0.16***(0.008) |
| Constant | -0.71**(0.335) | 0.40*(0.222) | -8.76***(2.714) | 0.96**(0.382) | 0.51***(0.131) | -0.28*(0.162) |
| *Groundnut* | | | | | | |
| Female(dummy) | 0.32***(0.112) | 0.58***(0.087) | 0.11(0.186) | 0.04(0.282) | 0.42***(0.059) | -0.05(0.077) |
| Age(ln[years]) | 0.29**(0.149) | -0.03(0.109) | -0.03(0.235) | 1.10***(0.418) | 0.13*(0.073) | -0.08(0.088) |
| Education(ln[years]) | -0.02(0.015) | 0.01(0.012) | -0.01(0.022) | 0.04(0.041) | 0.01*(0.007) | 0.02***(0.009) |
| Land owned(dummy) | -0.77***(0.143) | -0.23***(0.083) | 0.40**(0.182) | -0.17(0.247) | -0.25***(0.053) | -0.05(0.072) |
| Mechanization(dummy) | -0.51**(0.231) | -0.20**(0.101) | -0.04(0.228) | -0.05(0.350) | -0.26***(0.078) | -0.38***(0.120) |
| Credit(dummy) | -0.25(0.206) | 0.23**(0.106) | 0.11(0.205) | 0.20(0.372) | 0.01(0.074) | -0.46***(0.120) |
| Extension(dummy) | -0.40***(0.127) | -0.19**(0.092) | 0.39**(0.193) | -0.16(0.314) | -0.15**(0.064) | -0.27**(0.120) |
| Trend | 0.04***(0.010) | -0.04***(0.006) | 0.00(0.017) | 0.24***(0.067) | -0.01(0.005) | -0.16***(0.009) |
| Constant | -2.15***(0.294) | 0.77***(0.142) | -0.46(0.686) | -4.86***(1.857) | -0.06(0.126) | -0.54***(0.101) |

Significance levels: * p<0.10, ** p<0.05, ***p<0.01. Data Sources: GLSS, GSPS, and GARBES data.

Whilst causes of low legume yields have mostly been attributed to biotic and abiotic stresses, this study supplies more knowledge arguing that low legume yields are observed because of farmer inefficiencies in using available technologies and production resources. Earlier studies relying on data limited to single seasons and specific regions in Ghana show that this is likely to be true. Thus, by overcoming the limitation of its predecessors, this paper supplies a holistic insight to facilitate understanding of the spatial and temporal dimensions of legume production technology and technical inefficiency in Ghana.

The results show that across the study period, dry bean TE has been stable over time while that of groundnuts has been declining. MTE for dry beans has been increasing at an increasing rate while that of groundnuts has been increasing at a decreasing rate. Farmers use technology that is about 15% short of the best available technology. However, holding ecological technologies constant, the study finds mean efficiency levels of 62 and 60% for dry beans and groundnut, respectively. The overall trend shows that the improvement in MTE could be driven by the decline in the TGR. Most importantly, bean and groundnut farmers are using heterogeneous technologies along ecological lines.

Taken as a whole, achieving desired yield levels to meet supply shortfalls will require interventions specifically tailored to farm production abilities and production circumstances. Blanket interventions aimed at improving productivity and efficiency will perpetuate the status quo. Thus, a careful assessment of all intended interventions before dissemination will generate more optimal outcomes of policy.

Due to data limitation, this research did not identify the best technologies [managerial practices, inputs, and Varieties] used by farmers but only indicates where such technologies and practices could be located. The study thus recommends this for future research to ensure that specific technologies and managerial practices are fronted. Where modern technologies are limited, the output from this study could provide valuable information on where dry bean and groundnut productivity could be increased by reducing technical inefficiency and/or technological gaps.

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***Data availability***
Replication materials are available in GitHub at https://github.com/ftsiboe/Agricultural-Productivity-in-Ghana

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# DETERMINANTS OF ACCESS AND EXTENT OF USE OF AGRICULTURAL INSURANCE SCHEMES BY SMALL-SCALE FARMERS IN KOGI STATE, NIGERIA

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## ABSTRACT

**Research Background:** Although, insurance services are offered by the Nigerian Agricultural Insurance Corporation and other private companies in Nigeria; however, there has been a low level of involvement of farmers in the purchasing of insurance premiums in Kogi state. The empirical evidence on the factors accountable for the low patronage of the Nigeria Agricultural Insurance Schemes (AIS) in Kogi State are not known. The identification of these factors inhibiting the access and use of AIS by farmers and the provision of appropriate and efficient solutions by the relevant stakeholders can mitigate the catastrophic effects of risks and uncertainties on the farmers.
**Purpose of the article**: The research was carried out in order to ascertain the determinants of access and extent of use of AIS by farmers in the study area so as to of provide appropriate and efficient solutions capable of mitigating the catastrophic effects of risks and uncertainties inherent in agriculture on the farmers means of livelihood. This makes the analysis of the level of access and extent of use of and the factors influencing farmers' willingness to participate in the agricultural insurance scheme a compelling necessity.
**Methods**: Data for the study was collected through the help of a well-structured questionnaire administered to 150 farmers whom were selected through a multi-stage random sampling technique. Data collected were analysed using descriptive statistics and Heckman's two-stage model.
**Findings and value added:** Farmers in the study area were males, literate, and experienced farmers. The determinants of access to AIS were awareness of AIS, age, income, and marital status, while age, awareness of AIS, and income significantly influenced the extent of use of AIS by the farmers in the study area. Farmers in the study area can access and use more of AIS through increased awareness of the insurance scheme as well as increasing farmers' income level through affordable loan scheme or outright government grants.

**Key words:** insurance; Heckman model; risks; small scale farmers; Nigeria
**JEL Codes:** Q12; Q14; Q18

## INTRODUCTION

Insurance is a method of risk management used to protect against contingent loss. It is conventionally defined as a fair transfer of risk of loss from one entity to another in exchange for a premium or a guaranteed and quantifiable small loss to prevent a large and possibly devastating loss (**Schaffnit-Chatterjee, 2010**). Specifically, according to **Epetimehin (2012**), agricultural insurance is intended to cover financial losses incurred due to an unforeseen decline in agricultural production. The primary aim of any agricultural insurance policy is to act as cover for losses from natural disasters; it also serves as collateral for formal financial institutions' agricultural loans to farmers (**Pelka *et al.*, 2015**). Agricultural insurance policy is one of the prominent strategies used by farmers to reduce, share, or pass the risks and uncertainties inherent in their farming business. It encourages farmers to invest more in agricultural production, promotes their trust in the adoption of new and enhanced farming methods, enhances their access to credit through financial institutions as insurance cover, and ultimately provides financial support to farmers in the form of compensation that ensures the sustainability of their farming activities. (**Eleri. *et al.*, 2012)**. In cognizance of the need for a clear support program for agricultural growth which addresses the peculiar problems of risks and uncertainties, the Nigerian Agricultural Insurance Scheme (NAIS) was administered by the Nigerian Agricultural Insurance Company (NAIC) was introduced. The key goal of the scheme was to reduce to an acceptable minimum the catastrophic effects of agricultural risks as well as natural disasters and ensuring payment of adequate compensation to keep farmers in business. **(Aina and Omonona, 2012).** Many private insurance firms have also arisen in Nigeria over the years, integrating agricultural insurance into their policies (**Aina and Omonona, 2012**). However, there is still a very limited provision of agricultural insurance across rural banking networks, including microfinance institutions **(Mahul and Stutley, 2010**). In a report by the Nigerian

Agricultural Insurance Scheme; **Aina and Omonona ( 2012)** reported that though the scheme has been beneficial to the few farmers that keyed into the insurance program, ,there exist some bottlenecks which includes but not limited to lack of fund, lack of trained personnel, low penetration of the scheme, low participation of commercial banks in agricultural finance, lack of interest in the scheme by insurance companies and difficulties in developing new agricultural insurance products. **Mahul and Stutley** (**2010**) reported, in agreement with Yusuf's findings, that government-sponsored agricultural insurance programs and farmers' participation were disappointing. Therefore, the consequences in the absence of risk management tools such as insurance may lead farmers out of production. Also, the successive government has introduced various incentives programs to ensure the patronage of agricultural insurance, sustained and beneficial to the insurer; this effort, however, has not made much impact (**Akinola, 2014)**. Similarly; in India, **Chhikara and Kodan, (2012**) observed that the majority of rural farmers were hindered from accessing the national agricultural insurance scheme, and as a result, they are compelled to cope with the use of conventional methods for risk minimization which were not so effective and reliable. Furthermore, **Mahul and Stutley** (**2010**) noted that from the perspective of most subsistence farmers, agricultural insurance is seen as a luxury in which few farmers could only afford; hence, farmers seek effective and efficient government intervention to make agricultural insurance more affordable through premium subsidies. **Sikibo *et al.* (2018)** agreed that while awareness of agricultural insurance is a crucial precursor to its use, only a few farmers understand how it works; this prohibits their ability to make decisions on its use. The adoption was also impeded by the unaffordability of premiums and inaccessibility of insurance services **(Chantarat *et al.*, 2013).**

Although, insurance services are offered by the Nigerian Agricultural Insurance Corporation and other private companies in Nigeria, however, there has been a low level of involvement of farmers in the purchasing of insurance premiums and, consequently, there is a need to analyse limiting factors to the use of agricultural insurance scheme. Furthermore, even though Kogi State is predominantly an agrarian state, researches on agricultural insurance and its accessibility by farmers are limited in the literature. Previous studies, by **Adah *et al.*** (**2016**), centred on the evaluation of rural farmers' attitudes towards the agricultural insurance scheme as a risk management tool in Kogi State while **Ibitoye** (**2012**) concentrated on assessing the level of knowledge and use among rural farmers of the agricultural insurance scheme. However, little or no work has addressed the determinants of access and extent of usage of agricultural insurance schemes by small-scale farmers in Kogi State.

The broad objective of this paper is to examine the determinants of access and extent of use of agricultural insurance schemes by small-scale farmers in Kogi state, Nigeria. The specific objectives are to:
*i*. describes the socioeconomic characteristics of the small-scale farmers,
*ii*. examines the socio-economic factors that influence access to Agricultural Insurance Scheme by small-scale farmers and iii. identify factors that determine extent of use of Nigerian Agricultural Insurance Scheme by small scale farmers Based on the stated objectives, two hypotheses were drawn; i. $H_{01}$: Socio-economic characteristics of farmers have no influence on access to Nigerian Agricultural Insurance Scheme by farmers, and ii. $H_{02}$: Socio-economic factors have no influence on the extent of use of Nigerian Agricultural Insurance Scheme by farmers.

## LITERATURE REVIEW

Small scale farmers in most developing counties especially those in Sub Saharan Africa are particularly vulnerable to climate shocks; but unfortunately, have little or no access to agricultural insurance **(Sibiko *et al.*, 2018)**. Formal insurance contracts are seldom available for the small-scale resource- poor farmers in the rural areas of low - income countries **(Chantarat *et al.*, 2013).** The high risk associated with agriculture which includes but not limited to flood, drought, pest infestation and diseases, price and policy volatility among others, which results in crop failure and sometimes in total loss of the source of livelihood. Many smallholder farmers in Kogi state, Nigeria face these risks, and thus, it has become increasingly necessary that these farmers take formal insurance to mitigate the risks and uncertainties that come with farming.

Agricultural insurance is designed to provide covers for financial losses incurred due to variability in the expected outputs. Insurance is a vital part of the risk management task, as it helps to determine who carries, which part and how much of a risk. This enables equitable risk-sharing and also ensures that correct levels of cover are taken out by the right parties, based on ability to pay. Premium is the price the farmer pays monthly or per annum. **Skees (2008)**, as well as **Nnadi *et al.* (2013),** affirmed that traditional risk minimization strategies are unfavourable to some extent and cannot adequately absorb the resultant economic shocks; hence, can lead to a poverty trap. Therefore, risk transfer using insurance works best where and when other complimentary services are in place, such as access to credit, improved seeds and inputs, markets and functioning supply chains, and advisory services.

Several empirical works of literature on agricultural insurance indicated that socio-economic characteristics of farmers generally affect their awareness, access and also use (participation) of agricultural insurance schemes. **Nnadi *et al.* (2013),** focused on the socio-economic differentials of participants and non-participant. The result revealed that there were socio-economic differentials in the age, education, farming experience, social organization membership, the status of participants and non-participants in the scheme. The study further revealed that the socio-economic and farm enterprise characteristics of age, education, marital status, farming status, farming experience, farm size and credit opportunity were significant in determining the farmers that participated in the scheme. **Sherrick *et al.* (2004)** in the Midwestern states of Illinois, Iowa and Indiana, United States oriented on the factors influencing farmers' crop insurance decisions indicated that farm size, age, perceived yield risk, and income of the household were among the major variables that significantly influenced farmers' decision to use agricultural insurance. Similarly**,** **Falola *et al.* (2013)** examined willingness to take agricultural insurance by cocoa farmers in Nigeria, the study also identified age of household head, educational level, and access to extension service and farm income as the various socio-economic factors that significantly influenced willingness to take agricultural insurance. **Kumar *et al.* (2011)** analysed farmers' perceptions and awareness towards crop insurance as a tool for risk management using Tobit and Probit models. The result of the survey showed that 65% of the farmers were aware of risk mitigation measures. **Chikaire *et al.* (2015)** studied rural farmers' perception, awareness and use of agricultural insurance as a hedge against climate change, the study revealed that the majority of the farmers (87.3%) had no knowledge of agricultural insurance opportunity in the study area, and 75% indicated interest if they can access it. The result further revealed that only 7.7% and 5% were very much aware and partially aware as well, the study concluded that the majority in the study area who are farmers were not aware of the agricultural insurance scheme in Nigeria and that could be due to low level of education and lack of publicity/campaign on insurance among the rural dwellers. The study further posed that the farmers had a positive perception for agricultural insurance, that if made available, would reduce risk and set back, cushion shock arising from losses, increase credit worthiness and reduce vulnerability as well and such indicated interest. Furthermore, **Nwani (2019)** revealed that the farmers had an unfavourable perception of agricultural insurance, as a result of the obstacles arising from their low level of education, lack of awareness and also communication gaps that existed between these farmers and appropriate stakeholders.

The conclusion drawn from these researches could imply that a relationship exists between farmers' awareness and perception of agricultural insurance which can be positive or negatively significant. For instance, in research in Eastern Ghana, **Ellis (2017)** found a positive and significant association between farmers' awareness and perception of agricultural insurance. Similarly, **Akinola (2014)** in his study on determinants of farmers' adoption of agricultural insurance in Ogun State Nigeria noted that only 46% of farmers had knowledge of agricultural insurance policy and only 44% adopted the practice. The author concluded that rate of farmers' adoption of agricultural insurance practice would increase if there is an increase in both the formal and extension education, an improved awareness of agricultural insurance policy, more perception and concern for experience with risk and less indifference resulting from too much confidence in their years of farming experience and alternative risk management strategies.

**Chantarat *et al.* (2013)** noted that the number of smallholder farmers taking crop insurance is marginally small. The study further revealed that the insurance pattern was complicated by the fact that the majority of households did not understand the insurance concept, partially because of the complex nature of insurance or because there was not sufficient awareness on the side of the farmers. This supports the study by **Mahul and Stutley (2010),** that the general population views insurance coverage as a privilege of the rich, which is particularly true for agricultural insurance, which, by definition, pays only when infrequent events occur. The poor in developing countries are the most exposed to and affected by natural hazards and they have limited or no access to insurance and financial services and in most cases have to manage weather risks by their means **(Hallegatte *et al.*, 2020)**. **Sibiko *et al.* (2018)**, similarly observed that the majority of smallholders are precluded from accessing agricultural insurance services and as a result, they are pushed to cope with disasters using traditional risk minimization strategies, yet they cannot adequately cushion them from the effects of reduced productivity and income losses. Despite substantial research efforts to enhance smallholder access to formal insurance services through innovation in financial derivative insurance products, emerging evidence globally **(Cole *et al.*, 2013**). **Tsikirayi *et al.* (2014)** demonstrate that the uptake of index insurance has been generally low, though there are promising results concerning its demand and impacts on key household indicators. Thus, ease of access to farming clients by insurers is key to the diffusion of agricultural insurance **(Tsikirayi *et al.*, 2014)**. Their study indicated that partnership with agricultural financial institutions and farm visits were noted as the key means of access to the farmers by insurers to create new business and maintain the existing one, and also that through the insurer/financial institutions partnerships, farmers were able to pay their insurance premiums.

A commonly cited reason for the low demand for agricultural insurance in developing countries is the limited understanding of its benefits and insurance is often perceived as a non-viable investment because premiums are collected every year but indemnities are paid much less frequently **(Chantarat *et al.*, 2013)**. **Sikibo *et al.* (2018)** in a study on the determinants of agricultural insurance uptake decisions in the face of climate change among smallholder farmers in Kenya, revealed that some of the major predictors that that significantly influenced the decision to buy crop weather index insurance are crop insurance awareness, training on crop insurance, cooperative membership, farm size, off farm income, education, proximity to both the nearest farm produce market and the weather station. **Chikaire *et al.* (2015),** revealed that only 3. % were using insurance, 21.7% indicate that if insurance is available, they would not use it and this was due to the low income of farmers. From the study, the majority (75.3%) indicated readiness to use it once it becomes available and they showed them readiness by their response. According to **Cole *et al*. (2013)** even with numerous efforts to avail formal insurance to farmers in low-income rural settings through pilot programmes, to date, very little success has been achieved to move index insurance beyond the piloting phase and hence the uptake levels remain low.

Generally, factors that affect the uptake of agricultural insurance are yet to be fully understood, partly because of lack of sufficient data and over-reliance on hypothetical evidence that seem to underscore the theoretical viability of insurance yet the empirical evidence from several insurance programmes showed mixed results on the performance of agricultural insurance. Empirical studies showed that in the access and use of agricultural insurance packages, both insurers and farmers face several distinct challenges which hinders the practice. **Tsikirayi *et al.* (2014)**, analysed the uptake of agricultural insurance services by the agricultural sector in Zimbabwe, from the result, the constraints cited by insurers and farmers as preventing high uptake of farm insurance were: limited knowledge on insurance; unaffordability of insurance; low-income levels; and low agricultural production; remoteness of farms from service providers; and negative perceptions about insurance in general. Similarly, **Ogunmefun and Achike (2015**), revealed that the majority of the farmers (61%) identified their major problems with the use of informal insurance measures as entry constraints which were grouped into lack of credit, lack of credit facilities, lack of working capital (assets like land) and lack of skills (education), and also high costs of inputs as problems they encountered, thus constrained the access and use of such insurance programme in the study area. Therefore, agricultural insurance is expensive to service, particularly to small and marginal farmers scattered across the countryside **(Mahul and Stutley, 2010).**

## DATA AND METHODS

### *Study Area*

The study was carried out in Kogi State, Nigeria. It is located between latitude $7^0$ 49ˈN and longitudes $6^0$ 45ˈE. Kogi state has 21 local Government Areas (LGAs), about 2.1 million inhabitants **(FRNOG, 2009),** and four agricultural zones designated as zone A, B, C, and D.

The climate is divided into two major seasons - dry and wet seasons. The wet season begins towards the end of March and ends towards the end of October. Occasionally, rainfall may not start until the month of April especially in a very dry. Dry season begins in the month of November and lasts until late February. The harmattan wind is experienced during the dry season between December and January. The average annual rainfall is between 850 and 2000 millimetres. During the rainy and dry seasons, the daily mean temperature is 280°C and 350°C, respectively. High humidity is also a common occurrence **(KADP, 2011).** The vegetation of the state is made up of rainforest in the south and woody derived savannah and Guinea savannah in the north. The land mass is generally flat or gently undulating, and it lies between 50 and 700 meters above sea level. Generally, the land mass is flat or gently undulating and lies at 50m to 700m above sea level.

The two largest rivers in Nigeria Rivers Niger and Benue, which are the two major rivers in Nigeria form a confluence at Lokoja, the state capital. The rivers predispose the farm lands to occasional flooding especially during the rainy season. The effects of the flooding are usually severe and destroy many farm lands, leading to the loss of livelihood on the part of the farmers.

### *Sampling Techniques*

Multi-stage sampling techniques were used in selecting respondents. Stage one involved a random selection of two LGAs from each of the four agricultural zones. Five communities were chosen randomly from each of the eight LGAs in stage two; while in the third stage, four small–scale farmers from each of the 40 communities were randomly selected. A total of 160 respondents were therefore chosen for the study.

### *Data Collection*

Data were obtained from a primary source using a well-structured questionnaire. The questionnaire was designed in such a way as to capture the specific objectives of the study. However, the questionnaire recovery rate was 94%; therefore, 150 respondents were analysed out of the 160 chosen for the study.

### *Data Analysis*

The objectives were realized using descriptive statistics such as mean, frequency, percentage, and Heckman two-stage model. The Heckman two-stage model was used to determine the factors that influence access and extent of use of AIS. The access to and the extent of use of AIS are dependent on some variables which were estimated independently. For such independent estimation of two equations; the first was whether a farmer had access to AIS or not and the second was the extent of use of AIS. The model was divided into two steps; first, the selection equation was calculated using a probit model, and second, the outcome equation was calculated using OLS regression. A probit model predicts the probability of whether a farmer had access to AIS (Eq. 1).

$$\Pr(Z_i = 1/\omega^{\backprime}\alpha) = \boldsymbol{\phi}\,(\boldsymbol{\eta}(\omega^{\backprime},\alpha)) + E_i \qquad (1)$$

Where: $Z_i$ is an indicator variable equivalent to unity for a farmer who had access to AIS, $\boldsymbol{\phi}$ is the regular normal cumulative distribution function, $\omega^{\backprime}$ is the vector of co-efficient to be calculated, and $E_i$ is the error term presumed to be normally distributed with a mean of zero and variance $\sigma^2$. If the marginal utility obtained by the farmer from accessing AIS is greater than zero, the variable $Z_i$ takes the value of 1, and zero otherwise. This was illustrated as Eq. 2.

$$Z_i = \alpha\omega^{\backprime} + U_i \qquad (2)$$

Where: $Z_i$ is the latent level utility the small-scale farmers get from accessing AIS,

$U_i \sim \mathrm{N}\,(0{,}1)$ and

$Z_i = 1$ if $Z_i > 0$

$Z_i = 0$ if $Z_i \leq 0$

In the second step, to correct possible selection bias, an additional regressor in the equation was included. The inverse mills rational (IMR) was computed as Eq. 3.

$$IMR = \frac{\emptyset(\boldsymbol{\eta}(\omega^{\backprime},\alpha))}{\emptyset(\omega^{\backprime},\alpha)} \qquad (3)$$

Where: $\emptyset$ is the normal probability density function. The second stage was given by Eq. 4.

$$E = \frac{Y_i}{Z} = 1 = f(X_i, \beta) + \lambda \frac{\phi(\eta(w^\iota, \alpha))}{\phi(w^\iota, \alpha)} \quad (4)$$

Where: E, is the expectation operator density, Y is the (continuous) extent of Use of Agricultural Insurance Scheme (AIS), X is a vector of independent variables, affecting the extent of Use of AIS and $\beta$ is the vector of the corresponding coefficients to be estimated. Therefore, $Y_i$ can be expresses as Eq. 5.

$$Y_i^* = \beta^1 X^\iota + y\lambda^\iota + U_i \quad (5)$$

$Y_i^*$ is only observed for those farmers who have access to AIS
Where:
$U_i \sim$ N (0, 6u)
$(Z_i = 1)$, in which case $Y_i = Y_i^*$
Therefore, the model can thus be estimated as follows:
The first step of either access to AIS or not was specified as Eq. 6.

$$P(0,1) = \beta_0 X_0 + \beta_1 X_1 + \beta_2 X_2 + \cdots \beta X_n + e \quad (6)$$

Where: Access was denoted by 1 and Non - access was denoted by 0, $\beta_0$ is a Constant, $\beta_{1\ldots n}$ are parameters to be estimated, $X_{1\ldots n}$ are vectors of explanatory variables.
The second step which was the extent of Use of AIS was estimated by the use of an OLS as Eq. 7.

$$Y = \beta_0 X_0 + \beta_1 X_1 + \beta_2 X_2 + \cdots \beta X_n + e \quad (7)$$

Where: Y denotes the extent of Use of AIS, $\beta_0$ is a constant, $\beta_{1\ldots n}$ are parameters to be estimated, $X_{1\ldots n}$ is a vector of explanatory variables.
The two equations are explicitly specified as Eq. 8 –9.

Step 1: Selection equation

$$\Pr(Y = 1 / X) = b_0 + b_1 X_1 + b_2 X_2 + b_3 X_3 + b_4 X_4 + b_5 X_5 + b_6 X_6 + b_7 X_7 + b_5 X_5 + b_6 X_6 + b_7 X_7 + b_8 X_8 + b_9 X_9 + b_{10} X_{10} + e \quad (8)$$

Step 2: Outcome equation

$$Y_i = f(b_1 X_1 + b_2 X_2 + b_3 X_3 + b_4 X_4 + b_5 X_5 + b_6 X_6 + b_7 X_7 + b_5 X_5 + b_6 X_6 + b_7 X_7 + b_8 X_8 + b_9 X_9 + b_{10} X_{10} + e \quad (9)$$

Where:
Pr denotes probability;
Y is the extent of Use of AIS;
$X$ is a vector of regressors which are assumed to influence the outcome $Y$
$Y_i$ conditional probability estimate with 1 as positive extent of use by farmers as regard the use of AIS, otherwise 0;
$Y_i$ 0 for non-access to AIS;
$b_0$ intercept parameter;
$b_i \ldots b_n$ coefficients of independent variables;
$e$ stochastic error term;
$X_1$ age;
$X_2$ gender;
$X_3$ awareness of AIS (yes = 1, otherwise 0);
$X_4$ farming experience (years);
$X_5$ household size (number);
$X_6$ access to credit (Access = 1, otherwise 0);
$X_7$ marital status (married = 1, otherwise 0);
$X_8$ cooperative membership (membership = 1, otherwise 0);
$X_9$ past experience with risk (Positive = 1, otherwise 0);
$X_{10}$ monthly income (NGN).

## RESULT AND DISCUSSION

### *Socio-economic characteristics of the respondents*

The result in Table 1 showed that 73.33% of respondents were males while 26.67 % of the respondents were females. This implied that male-dominated the farming activities in the area. The result could be attributed to the stressful and demanding nature of farming in developing countries where mechanical farming is not common. The marital status of the respondents showed that the majority of farmers (68%) were married, while only a few (8%) were single. This implied that more married people are engaged in farming in the study area. This may be because agriculture is labour intensive, requiring direct and indirect labour contributions from the members of the family to minimize the cost of paid labour. The majority (58.01%) of respondents were between 41 and 60 years of age. The average age of the farmers was 47, which indicates that the typical farmers studied were in the economically active age group. The results showed that farmers are young and energetic and can cope with farming demands, so they can bear the stress and take the risks involved in the farming business. The educational status of the respondents showed that the majority (81.33%) of the respondents had formal education while only 18.67% had no formal education. The result indicated that the respondents were literate, an advantage which according to **FAO** (**2006**), could translate to higher farm management and business acumen in terms of profit rate. The result corroborates the findings of **Ukwuaba *et al.*** (**2020**) who reported a high educational status among crop farmers in the Enugu Ezike Agricultural Zone of Enugu State, Nigeria. The majority (63.33%) of the respondents engaged in crop production while a few (9.33%) were involved in livestock production in the study area. About 27 % of the respondents combined both crop production and animal farming. This could be attributed to the fact that crop production is comparatively less risky, cheaper, and easier to manage compared to livestock production. As regards their farming experience, the majority (46%) of the respondents had between one to 15 years of farming experience while about 41% of the respondents had 16 to 30 years of farming experience; few of the respondents (13.3%) had farming experiences above 30 years. The average years of experience were 19. This suggested that most of the people involved had been in farming for years and that agriculture was their main livelihood in the area.

**Table 1:** Socio-economic characteristics of the respondents

| Socio-economic characteristics | Frequency | Percentage | Mean |
|---|---|---|---|
| *Gender* | | | |
| Female | 40 | 26.67 | |
| Male | 110 | 73.33 | |
| *Marital Status* | | | |
| Single | 12 | 8.00 | |
| Married | 102 | 68.00 | |
| Divorced | 20 | 13.33 | |
| Widowed | 16 | 10.67 | |
| *Age* | | | 46.67 |
| 20-40 | 51 | 34 | |
| 41-60 | 85 | 58.01 | |
| 61 -75 | 12 | 8.02 | |
| *Educational Status* | | | 8.5 |
| No formal education | 28 | 18.67 | |
| Primary education | 35 | 23.33 | |
| Secondary education | 55 | 36.67 | |
| Tertiary education | 32 | 21.33 | |
| *Farm Type* | | | |
| Crop farming | 95 | 63.33 | |
| Livestock farming | 14 | 9.33 | |
| Livestock and crop | 41 | 27.33 | |
| *Farming experience (years)* | | | 19.14 |
| 1-15 | 69 | 46 | |
| 16-30 | 61 | 40.67 | |
| 31 - 40 | 20 | 13.34 | |
| *Farm size (Ha)* | | | 3.03 |
| 0.5-2.0 | 61 | 67.34 | |
| 2.1-3.5 | 44 | 29.34 | |
| 3.6-5.0 | 32 | 21.34 | |
| 5.1- 8.5 | 43 | 8.66 | |
| *Household size* | | | 5.43 |
| 1-5 | 76 | 50.67 | |
| 6-10 | 73 | 48.66 | |
| 11 | 1 | 0.67 | |
| *Monthly income (NGN)* | | | 67,572.22 [1] |
| 0-50,000 | 11 | 7.32 | |
| 50,001-100,000 | 35 | 23.33 | |
| 100,001 -200,000 | 104 | 69.34 | |
| *Total* | 150 | 100 | |

Note: [1] 177.35 USD. Exchange rate: 381 NGN = 1 USD as at March, 2021.
Source: Field Survey, 2018

The mean farm size of the respondents was 3.03 hectares, implying that most of the farmers were smallholders and subsistence farmers. The limited farm size may be due to the land tenure system in the study area, which makes mechanize farming unprofitable and uneconomical to employ.

About 50% of the respondents had a household size between one to five while few (0.67%) had a household size above 11 members. The mean household size of the respondents was five persons and implied that the respondents had an available labour force to assist in the farming business. Thus, the more the household size, the greater the labour force available for farm works. However, **Prager *et al.* (2018)** reported that large households can limit the net return from the agricultural business by diverting potential investment funds to increase household expenditure. The mean monthly income of the respondents was 67,572.22 NGN (Nigerian currency Naira), (117.35USD). The result showed that an average farmer in the study area earns at least twice above the national minimum wage of 30,000 NGN (78.74 USD) and thus improved standard of living.

***Determinants of Access to the Agricultural Insurance Scheme***

On the determinants of access to AIS in Kogi state, Nigeria, the result showed that awareness of agricultural insurance, age, and income was significant and positively influenced access to agricultural insurance while marital status negatively influenced access to agricultural insurance. The awareness of the scheme was significantly positive and implied that the more one is informed and aware of the existence of AIS, the more one is likely to purchase or access more of the agricultural insurance. The findings showed that an increase in the awareness campaign will likewise increase respondents' access to agricultural insurance. The result is consistent with the results of **Akinola (2014)** who reported the awareness of insurance as an important factor in accessing formal agricultural insurance in Southwest, Nigeria. The age of the respondents was significant and positively increased access to agricultural insurance. The result suggests that older respondents had more access compared to younger farmers. This may be because the older one becomes the more risk-averse one becomes. Results also showed that the total income received by the respondents also played a major role in determining access to agricultural insurance in the study area; the higher the income received by the respondents the higher the access to agricultural insurance. This implied that farmers with high-income levels tend to access more agricultural insurance compared to farmers with low income. This is understandable as the higher income farmers had a surplus income to invest in the purchase of AIS. The result is consistent with the findings of **Afroz *et al.* (2017)** in Malaysia; who reported that the farm income of a farmer is essential in accessing formal agricultural insurance as a way of mitigating the effects of climate change. However, marital status was negative and significantly influenced respondents' access to agricultural insurance. The result implied that respondents who are not married will have more access to agricultural insurance compared to married farmers. This is attributed to the fact that the married farmers have more other family responsibilities which limit the amount of money or farm income needed to purchase formal agricultural insurance.

Consequently, the results in Table 2 showed that the socio-economic characteristics significantly influenced access to Nigeria's agricultural insurance scheme by farmers. Hence, the null hypothesis was rejected and the alternative accepted. The null hypothesis 1 is rejected because the $chi^2$ value of 61.92 at 0.05 level of probability was higher than the tabular value of 3.845.

***Determinants of the Extent of Use of Agricultural Insurance Scheme***

The result in Table 3 showed the factors that influenced the extent of agricultural insurance purchased by the respondents. Agricultural insurance awareness boosted the amount of agricultural insurance purchased. Thus, farmers who had adequate information on agricultural insurance and understand its importance will buy more agricultural insurance compared to respondents that knew little or nothing about agricultural insurance. As regards the marginal effect unit increase in the level of awareness of agricultural insurance will lead to an additional purchase of 256,893 NGN agricultural insurance. Age was also positive and significantly increase the amount of insurance purchased. In other words, the older farmers invested more in agricultural insurance than the relatively younger ones. The result shows that a unit increase in age will increase the amount of agricultural insurance purchased by 10,057 NGN (24.54 USD). The findings agree with that of **Okoffo *et al.* (2016)** in Ghana who indicated that age was among the significant variables in the decision to pay premium for agricultural insurance among cocoa farmers. The result also showed that farmers with higher incomes purchased more agricultural insurance. This is understandable as income is an important determinant of the amount of insurance purchased. Therefore, the higher the income received the higher the amount of agricultural insurance purchased. The result is in agreement with the findings of **Afroz *et al.* (2017)** in Malaysia; as well as **Chikaire *et al.*** (**2015)** in Imo State, Nigeria who reported that the farm incomes or savings of a farmer are vital factors in accessing and using formal agricultural insurance.

The overall result of the analysis implied that the socio-economic factors significantly influenced the extent of the use of the Nigeria Agricultural Insurance Scheme by farmers. Hence, the null hypothesis was rejected and the alternative accepted. The null hypothesis was rejected since the $Chi^2$ value of 45.26 at 0.05 level of probability was higher than the tabular value of 16.919.

**Table 2:** Socio-economic factors that influenced access to agricultural insurance scheme by small-scale farmers

| Variables | Coefficient | Standard error | t-value | p-value |
|---|---|---|---|---|
| Age | 0.0243705** | 0.0111108 | 2.19 | 0.028 |
| Gender | 0.322401 | 0.2014236 | 1.60 | 0.109 |
| Awareness of AIS | 0.6224981** | 0 .303463 | 2.05 | 0.040 |
| Farming experience | 0.0098537 | 0.0090574 | 1.09 | 0.277 |
| Household size | 0.2032411 | 3.212203 | 0.063 | 0.999 |
| Access to credit | 0.323401 | 0.2014736 | 1.61 | 0.108 |
| Marital status | -.2562593** | 0.1234254 | -2.08 | 0.038 |
| Cooperative membership | 0.1390038 | 0.1117625 | 1.24 | 0.214 |
| Past experience with risk | -0.0683328 | 0.2046652 | -0.33 | 0.738 |
| Income | 1.51e-07** | 6.33e-08 | 2.39 | 0.017 |
| Constant | -1.785279*** | 0.5310414 | -3.36 | 0.001 |

LR $chi^2$ (1) = 61.92***
Prob > $Chi^2$ = 0.0000
** and ***variables significant at10% and 5% probability level respectively
Source: Field Survey, 2018

**Table 3:** Factors that determine the extent of use of Nigeria agricultural insurance scheme (NAIS)

| Variables | Coefficient | Standard error | t-value | p-value |
|---|---|---|---|---|
| Age | 10057.22** | 4561.468 | 2.20 | 0.027 |
| Gender | -28199.61 | 84491.08 | -0.33 | 0.739 |
| Household size | 0.006496 | 5.924305 | 0.00 | 0.739 |
| Marital status | -105753.3** | 50572.56 | -2.09 | 0.999 |
| Awareness of AIS | 256893** | 125512.1 | 2.05 | 0.041 |
| Extension contact | 57364.2 | 45983.25 | 1.25 | 0.212 |
| Membership in coop. | 133461 | 83250.8 | 1.60 | 0.109 |
| Distance to the NAIS office | 4066.418 | 3722.32 | 1.09 | 0.275 |
| Income | 0.0624458** | 0.0259563 | 2.41 | 0.016 |
| Constant | -736750.6*** | 216918 | -3.40 | 0.001 |

Wald chi2 (9) = 45.26***
Log likelihood = -1612.88
Prob > chi2 = 0.0000
** and*** significant variables at 10% and 5% probability level respectively
Source: Field Survey, 2018

## CONCLUSION AND RECOMMENDATION

Agricultural risk is a global phenomenon; however, the magnitude of its negative impacts on small holder farmers varies depending on farmers' awareness, perception, access and the ultimate subscription to agricultural insurance. Investment in agriculture in the area of agricultural insurance especially among the smallholder farmers cannot be emphasized considering the uncertain and risky nature of the enterprise. Smallholder farmers' risk minimization through affordable insurance schemes is one of the surest ways of boosting farmers' confidence in their farming enterprise as well as enhancing the food security status of the nation and the overall agricultural development especially in the developing countries. The major findings of this study are in tandem with the available global evidence particularly in the developing countries that show limited awareness and access to affordable agricultural insurance packages among small scale farmers. Government policies should be directed towards absorbing and reducing the shocks of the smallholder farmers. Also, Government and other state actors should intensify efforts towards increased farmers' awareness of the insurance scheme and also increase farmers' participation through input subsidy provision, so as to free more farm income for agricultural insurance subscription and its sustainability.

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# CROP DIVERSIFICATION, PRODUCTIVITY AND DIETARY DIVERSITY: A GENDER PERSPECTIVE

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## ABSTRACT

**Research background:** Strengthening agriculture and food systems have a critical role to play in achieving the sustainable development goals of eliminating hunger and poverty; and increasing resilience to climatic shocks. Crop diversification has been recognized as a way of increasing resilience and reducing agricultural risk. Closing the gender gap could boost agricultural productivity and enhance welfare. Effects of crop diversification in enhancing dietary diversity amidst gender gap in agricultural productivity among smallholders have not been well established in Nigeria.
**Purpose of the article:** The study was conducted to provide empirical evidence on crop diversification, productivity and dietary diversity of male and female-headed farming households in Nigeria. This has policy implications on development of inclusive and efficient agrifood system towards achieving the SDGs of eradicating poverty, hunger and gender equality.
**Methods:** Secondary data from the 2015/16 Living Standard Measurement Survey-Integrated Survey on Agriculture (LSMS-ISA) was used for this study. Tobit regression model was employed to investigate the factors influencing crop diversification and dietary diversity while Oaxaca-Blinder decomposition method was used to decompose gender differentials in agricultural productivity.
**Findings and value added:** Crop diversification index of male farmers is 0.10 ($P<0.05$) higher than female farmers. The Tobit regression results showed that farm income, education, household size, farm size and use of inorganic fertilizer increased crop diversification ($P< 0.01$). However, household expenditure ($p< 0.05$), non-farm income ($p< 0.1$), age and credit access ($P< 0.01$) reduced crop diversification. Less than half (45.22%) of the rural households consumed at least nine out of the 12 food groups in the previous week of the survey period. Crop diversification among other factors has a positive ($P<0.01$) effect on households' dietary diversity. The results of the Oaxaca-Blinder decomposition showed a gender productivity gap of 10.87% in favour of male farmers. The structural and endowment disadvantages of female farmers in land size and credit access are key drivers of gender differentials in agricultural productivity. The study suggests improvement in land tenure system and female farmers' access to financial services in order to ensure gender productivity equality, women empowerment and efficient agrifood system.

**Key words:** Agrifood; Food Security; Gender equality; Inclusive; Resilience
**JEL Codes:** R52; R58; H41

## INTRODUCTION

Agriculture is a significant value-added contributor to the national food self-sufficiency in most rural developing economies which account for over 90% of total food consumption requirements. The sector has been recognized as an established pathway to prosperous economy (**Alliance for a Green Revolution in Africa (AGRA), 2017**). Nonetheless, there is higher growth-poverty elasticity for agricultural development than non-agriculture although the extent varies across countries considerably (**Christiaensen and Martin, 2018; Dorosh and Thurlow, 2016; Christiaensen and Demery, 2007**). In Africa, over 70% of the population depends on agricultural foods and income-based livelihoods such that agriculture-sector growth is a significant driver in achieving the Sustainable Development Goals (SDGs) 1 and 2 of eradicating poverty and hunger, respectively. Despite the fundamental objective of SDG 2 to end hunger, achieve food security and improved nutrition and promote sustainable agriculture by 2030, it is however, a developing burden still that with about a decade left to meet the targets, multiple countries especially in the sub-Saharan Africa (SSA) presently record higher levels of hunger than in 2010 (**von Grebmer *et al.*, 2019**). This situation has been attributed to poverty, inequality and ravaging effects of climate factors, among other factors.

Africa is well endowed with a resource base that is capable of turning the continent into a net large agricultural exporter, if more intensively farmed. This potential is evidenced by reduced yield currently experienced in Africa compared with continents with similar agro-ecological Zones and best practices (**Jistrom, Andersson and Djufeldt, 2011; Food and Agriculture Organization (FAO) *et al.*, 2017**). **Adesina (2017**) expressed that Africa is more dependent on food import, for instance, Nigeria's aggregate annual food import bill is expected to increase from US $35 billion to above US$110billion by 2025. Furthermore, the SSA has the world's lowest agricultural productivity attributed to high poverty level which implies that household's access to food is constrained by poor own production and low purchasing capacity (**World Bank, 2019**).

It is important to strengthen agriculture and food systems at local scale in order to achieve the SDGs targets of eliminating hunger and poverty; and enhances resilience to climatic shocks. The sub-Sahara can overcome the challenge of meeting its 2050 Food Security Agenda should millions of smallholder engaged in productivity-enhancing strategies (**Herrero *et al.*, 2017, Dioula *et al.*, 2013**). Crop diversification has been recognized as a way of increasing resilience and reducing agricultural risk especially among smallholders. This strategy enhances biodiversity and yield stability, improves soil fertility, controls pests and diseases, and capable of positive effects of farming households' welfare (**Di Falco and Chavas, 2009; Lin, 2011; Bezabih and Sarr, 2012; Njeru, 2013**). Crop diversification is fashioned as a way of developing climate resilient agricultural system, reducing food and nutrition insecurity, especially in the rural areas as more diverse production system could contribute to more diverse diets for farming households.

Food insecurity keeps rising in Nigeria regardless of abundant human resources, natural capital, agricultural programmes, and interventions. The country ranks 94$^{th}$ of the 113 countries with food security index score of 48.4 (**The Economists, 2020**). This rank is due to declining agricultural productivity. Dietary parameters further reveals that about 37% of Nigerian children are stunted, 29% are underweight, and 18% are wasted. The country's Global Hunger Index (GHI) score rose from 15.5 in 2011 to 25.5 in 2015 then to 27.9 in 2019 reflecting a serious hunger situation (**von Grebmer *et. al*., 2019**). Majority of the undernourished people live in rural areas and are predominantly smallholder farmers. Hence, the consideration of making agriculture and food systems more nutrition-sensitive is of great importance for agricultural development and policy.

Gender bias in agriculture is crucial to sustaining economic growth and ensuring food security, particularly in countries where most of the populations earn their incomes from agriculture-based activities (**Bizzari, 2017; Mukasa and Salami, 2016; Kenan, 2014; Deschutter, 2013**). Thus, closing the gender gap could boost agricultural productivity and income by ensuring equality in access to productive resources in raising agricultural output in developing countries and help reduce hunger (**Giroud and Huaman, 2016**). International Food Policy Research Institute (IFPRI) (2019) opined that agricultural growth and sustainability further hinges on addressing gender inequality. Inequalities make it more difficult to achieve better productivity, reduce poverty and hunger. For instance, in countries where incomes are highly unequal between female and male wages, lower levels of land productivity and higher food insecurity have been witnessed, on the average. These inequities are slowing progress towards SDG 2. The discriminating factors generally encompass land constraints, property rights, low application of modern resources, limited access to advisory services, low stocks of human and physical capital and exclusion from credit and financial markets (**Backiny-Yetna and McGee, 2015; Ali *et al.*, 2015; Aguilar *et al.*, 2014**). There is a very strong positive linear correlation between socio-economic variables and gender inequality. It was concluded that gender inequalities is very high in the Nigerian agricultural sector and it is hampering economic growth (**Ijieh *et al*., 2015**).

**Oseni *et al.* (2014), Aguilar *et al.* (2014), Backiny-Yetna and McGee (2015) and Mukasa and Salami (2015**) previously analysed gender differentials in agricultural productivity in Nigeria, Ethiopia, Niger and Nigeria respectively. These studies measured productivity in monetary values, and considered farm plot managers. However, our study employed 2015/16 LSMS-ISA dataset to measure land productivity in terms of crop yield (kg/hectare) and considered farming households. This approach was moved by the assumption that household heads are mainly responsible for their economic well-being, the gender of the households' head affects the manner in which households' resources are utilized and disbursed, and the manner in which households are networked for exchange of resources with other households. Furthermore, it removes the problem of misidentification in the households and overlaps along gender lines (**Gebre *et al.*, 2019; de la O Campos *et al.*, 2016; Lloyd and Gage-Brandon, 1993**). Nevertheless, effects of crop diversification in enhancing dietary diversity have not been well established in Nigeria.

This study investigates effect of crop diversification on dietary diversity amidst gender gap in agricultural productivity among smallholders in Nigeria. This study complements previous studies on gender differentials in agricultural productivity in Nigeria with policy implications on development of inclusive and efficient agrifood system towards achieving the SDGs of eradicating poverty and hunger and gender equality. Arising from the foregoing, the general objective of this study is to investigate gender inequality in crop diversification, productivity and dietary diversity among farming households in rural Nigeria. The specific objectives are to: Estimate crop diversification index and identify the socioeconomic factors influencing crop diversification among male and female headed households in Nigeria; Estimate dietary diversity of male and female headed households; Examine the effect of crop diversification and other socio-economic factors on dietary diversity of Nigerian households and Investigate gender differentials in agricultural productivity among Nigerian farming households.

## LITERATURE REVIEW

Studies have observed that farmers can achieve resilient agricultural systems that contribute significantly to household food security through crop diversification (**Ojo**

***et al*., 2014; Makate *et al.* , 2016; Rajendran *et al*., 2017; Mango *et al*. , 2018).** The literatures emphasized crop diversification as a means of overcoming the adverse effect of weather shocks and climate change. These studies have also drawn attention to range of socio-economic and institutional factors affecting crop diversification and dietary diversity among small-holder farmers in Africa. For instance, **Ojo *et al.* (2014)** opined that farming experience, extension contact, farm size and land ownership positively and significantly affected diversification among farmers. Crop diversification had positive and significant effect on food crop outputs. According to **Sichoongwe (2014)**, landholding size, fertilizer quantity, distance to market, and the type of tillage mechanism adopted have a strong influence on crop diversification in Zambia. The studies suggest the need for government to consider undertaking policies that will enhance farmers' access to and control over land. Furthermore, households that diversify their crop production tend to increase their food consumption and dietary diversity (**Rajendran *et al*., 2017; Mango *et al*., 2018).** In Central Malawi, **Mango *et al*. (2018)** asserts that crop diversification, cattle ownership, access to credit and attainment of education have positive and significant effect on the households' food consumption score.

Decomposition methods have been employed to analyze differences in agricultural productivity between male and female land managers in Africa (**Aguilar *et al*., 2014; Oseni *et al*., 2014**; **Backiny-Yetna and McGee, 2015; Mukasa and Salami, 2015).** The Oaxaca-Blinder decomposition method allows for decomposing the unconditional gender gap into (i) the portion caused by observable differences in the factors of production (endowment effect) and (ii) the unexplained portion caused by differences in returns to the same observed factors of production (structural effect) or (iii) even in differences in both the levels and returns of these observables (interaction effect). This methodology identifies the factors that explain productivity gap both at the aggregate and detailed levels. Analysis along the productivity distribution reveals that gender differentials are more pronounced at mid-levels of productivity and that the share of the gender gap explained by the endowment effect declines as productivity increases (**Aguilar *et al*., 2014)**. Most studies have observed that women have access to less productive resources and plots managed by women produce less than plots managed by men (**Oseni *et al*., 2014**; **Backiny-Yetna and McGee, 2015; Mukasa and Salami, 2015)**. Endowment and structural disadvantages of female managers in land size, land quality, labor inputs, and household characteristics are the main drivers of gender gaps. However, closing gender productivity differentials is expected to yield production gains, to raise monthly consumption and to help households with female-managed lands climb out of poverty in Africa **(Mukasa and Salami, 2015)**.

Despite the previous studies, there is still paucity of information on crop diversification and dietary diversity among rural households in Nigeria. Also, there is limited information on gender differentials in agricultural productivity based on the 2015/16 LSMS-ISA data set. Therefore, this study contributes towards bridging the gap and complements previous studies on crop diversification and dietary diversity in Nigeria by using a nationally representative data. The study examines progress in closing gender gaps in agricultural productivity by using the 2015/16 LSMS-ISA dataset. Furthermore, unlike previous studies, it considers the households instead of plot managers in investigating gender differentials in agricultural productivity.

## DATA AND METHODS

### *Data*

The study used secondary data from the 2015/16 Living Standard Measurement Survey-Integrated Survey on Agriculture (LSMS-ISA) which comprises 5,000 rural and urban households in Nigeria. This study focuses on the rural households' aspect of the data, given that the rural sector harbors the highest percentage of farm families where agricultural livelihood is predominant. The data comprises 3,172 rural households, however, due to the incompleteness of the data, data on 1,226 maize farming households were used for analysis. The data used for the study include socio-economic/demographics such as: age, sex, household size, farm size, credit access, education, income, farm size, income sources, crops production and income, among others.

### *Methods of data analysis*

The analytical techniques employed in this study include descriptive statistics, Z-test, Tobit regression model and Oaxaca-Blinder (OB) decomposition. Descriptive analysis was used in estimating crop diversification while Tobit regression model was used to examine major drivers of crop diversification among smallholders. Crop diversification index was computed indicating whether a farmer cultivates more than one crop or not. A zero value would indicate specialization, revealing a farmer's decision to cultivate only one food crop while a value greater than zero shows crop diversification, conditioned on choice, explaining the intensity of diversification. It is therefore easy to identify those farming households practicing crop diversification, and intensity of their diversification.

Tobit regression model is a censored regression model which captures both the propensity to diversify and the intensity of diversification, hence most appropriate for this study **(McDonald, 1980**).

Tobit regression model was used to analyse factors influencing food crop diversification, following **Maddala, (1992); Johnston and Dandiro, (1997) and Negash, (2007**), the Tobit model for the continuous variable decision level can be expressed as Eq. 1.

$$Y_i = Y_i^* = \beta_0 + \beta_i X_i + \mu_i \quad if \quad Y_i^* > 0, \qquad Y_i = 0 \quad otherwise \tag{1}$$

Where:

$Y_i^*$ Latent variable and solution to utility maximization problem of level of crop diversification, subject to a set of constraints per household;

$Y_i$ Crop diversification index for an i[th] farmer;

$X_i$ Vector of factors affecting crop diversification;

$\beta_i$ Vector of unknown parameters;
$\mu_i$ Error term.

The explanatory variables specified as determinants of crop diversification are defined as:
$X_1$ Sex (female=1, 0 otherwise); $X_2$ Age (years); $X_3$ Education (years); $X_4$ Household size (number); $X_5$ Self-employment income (1= self-employed, 0 otherwise); $X_6$ Agricultural wage employment (1= yes, 0 otherwise); $X_7$ Farm size (hectare); $X_8$ Credit access (1= yes, 0 otherwise); $X_9$ Extension service access (1= yes, 0 otherwise); $X_{10}$ Improved seeds cultivation (1= yes, 0 otherwise); $X_{11}$ Use of inorganic fertilizer (1= yes, 0 otherwise); $X_{12}$ Labour (Man-days); $X_{13}$ Crop yield (kg/ha); $X_{14}$ Production costs (Nigerian currency Naira – NGN); $X_{15}$ Crop income (NGN); $X_{16}$ Total income (NGN); $X_{17}$ Commercialization index.

***Estimating dietary diversity and crop diversification effect***

Dietary diversity is a quantitative measure of food consumption that reflects household access to a variety of food. The household dietary diversity score was generated based on the number of different food groups consumed over a given reference period (7 days in the case of this study). This was constructed based on the 12 food groupings from the FAO's food balance sheet: cereals, roots/tubers, pulses/legumes, dairy, eggs, meat, fish and sea foods, oils and fats, sugar/honey, fruits, vegetables and other foods (**FAO, 2011**). The effect of crop diversification on dietary diversity was captured by applying Tobit regression which controls for variables such as individual, household, and institutional characteristics, etc. Tobit regression model for the continuous variable can be expressed as Eq. 2.

$$Y_i = Y_i^* = \beta_0 + \beta_i X_i + \mu_i \quad if Y_i^* > 0$$
$$Y_i = 0 \quad otherwise \qquad (2)$$

Where,
$Y_i^*$ Latent variable and solution to utility maximization problem of level of dietary diversity, subjected to a set of constraints per household;
$Y_i$ Dietary diversity for an i[th] household;
$X_i$ Vector of factors affecting dietary diversity;
$\beta_i$ Vector of unknown parameters;
$\mu_i$ Error term.

The explanatory variables specified as determinants of dietary diversity are defined as:
$X_1$ Sex (female=1, 0 otherwise); $X_2$ Age (years); $X_3$ Education (years); $X_4$ Household size (number); $X_5$ Self-employment income (1= self-employed, 0 otherwise); $X_6$ Agricultural wage employment (1= yes, 0 otherwise); $X_7$ Farm size (hectare); $X_8$ Credit access (1= yes, 0 otherwise); $X_9$ Extension service access (1= yes, 0 otherwise); $X_{10}$ Improved seeds cultivation (1= yes, 0 otherwise); $X_{11}$ Use of inorganic fertilizer (1= yes, 0 otherwise); $X_{12}$ Labour (Man-days); $X_{13}$ Crop yield (kg/ha); $X_{14}$ Production costs (NGN); $X_{15}$ Crop income (NGN); $X_{16}$ Total income (NGN); $X_{17}$ Commercialization index; $X_{18}$ Crop diversification index.

***Gender differentials in productivity***

Following **Kilic *et al.* (2013), Aguilar *et al.* (2013), Oseni *et al.* (2014), Backiny-Yetna and McGee (2015) and Mukasa and Salami (2015**), Oaxaca-Blinder decomposition was employed to decompose gender differentials in agricultural productivity.

Let $y$ be the natural log of crop yield per unit land (kg/ha as measure of productivity), $g$ the gender of the farmer, and $x$ a $K+1$ dimension vector including the set of covariates of farming household's characteristics, farm size, inputs used etc.

The determinants of agricultural productivity can then be modelled using the following production function (Eq. 3).

$$y = \sum_{j=0}^{k} \alpha_j x_j + \beta_g + \mu \qquad (3)$$

Where $\alpha_j$ and $\beta$ are unknown parameters to be estimated and $u$ is a random error term assume to be independently and identically distributed with mean zero and $\sigma^2$variance. The presence of gender productivity gap can then be assessed by checking the significance of the coefficient $\beta$ in Equation (3). A negative and significant estimated coefficient indicates productivity differential at the expense of female-headed households and vice versa. Equation (3) was also estimated separately for male and female-headed households to identify any significant differences in the impact of various covariates on agricultural productivity. This approach helps to isolate the impact of the gender of the household head on the level of agricultural productivity after controlling for differences in other observed characteristics.

However, due to inability of this model to identify the fundamental drivers of productivity differences between male and female headed households, a decomposition procedure is necessary. This helps clarify whether the estimated productivity gaps are due to differences in the levels of observable characteristics between male and female-headed households (endowment effect) or due to the differences in the returns of these characteristics between both groups (structural effect), or even in differences in both the levels and returns of these observables (interaction effect). The decomposition starts with Equation (3) which is estimated for the pooled sample as well as by gender of the household heads as in Eq.4.

$$y_g = \sum_{j=0}^{k} \alpha_{gj} x_{gj} + \mu_g \qquad (4)$$

With $g = \{m; f\}$ and $\mu_g$ is the gender-specific random error term assumed independently and identically distributed, with mean 0 and variable $\sigma^2$. The rationale behind the OB decomposition approach is therefore to show how much of the mean productivity difference, $E(y_m) - E(y_f)$, $E(y_m)$ and $E(y_f)$ denoting the expected values of agricultural productivity by male and female headed households, is accounted for by gender differences in the levels and returns of covariates X. Following **Daymont and Andrisani (1984) and Jann (2008),** the gender productivity differential G can also be written as Eq. 5.

$$G = E(y_m) - E(y_f) = [E(X_m) - E(X_f)]\,\beta_f + E(X_f)(\beta_m - \beta_f) + [E(X_m) - E(X_f)] - (\beta_m - \beta_f) \quad (5)$$

According to Equation (5) gender productivity differential can be explained by three factors:

i. Differences between male and female managers in the levels of observable covariates X. Accordingly, the first component in Equation (5), $[E(X_m) - E(X_f)]\,\beta_f$ gives the proportion of the estimated productivity gap explained by male and female differences in the levels of those covariates and is called the endowment effect.

ii. Differences in the returns of the covariates X. The second term, $E(X_f)(\beta_m - \beta_f)$ called the structural or coefficient effect, measures the part of the productivity differential attributable to differences in the returns of covariates (including the estimated coefficient of the intercept).

iii. Finally, the last component, $[E(X_m) - E(X_f)] - (\beta_m - \beta_f)$ the interaction effect, captures the portion of productivity gap coming from simultaneous differences in both the predictors and their estimated coefficients. A positive value of the second component will imply that male headed households will have a structural advantage over female headed households in regards to the specific covariate while a negative value suggests a female structural advantage. The same reasoning holds for the other partial effects in Equation (5).

## RESULT AND DISCUSSION

### *Descriptive analysis of socio-economic profile of the respondents*

The gender-disaggregated descriptive results on Table 1 observe that male-headed households dominated the distribution by 84.99%. The average age of the household heads is 53.09 years across both gender with an average of 4.67 years of schooling, and about 8 household members. These differ significantly between Female-Headed Households (FHH) and Male-Headed Households (MHH) as indicated that farm size of male-headed households is significantly (p>0.05) higher than that of the female headed households by 0.77 hectares. Few households have access to formal credit services while the adoption of improved seeds is similar between MHH and FHH. Further results show that there is no significant difference in the use of improved seeds between the two groups. In overall, about 57% of the respondents use inorganic fertilizers. The number is higher for MHH than FHH. In the same vein, total labour used on farm by MHH is significantly higher than FHH. Likewise, households' incomes generated from various sources by MHH was also found to be significantly higher than FHH incomes.

### *Crop diversification and its determinants*

Over half of the respondents cultivated more than one crop while 47% specialized on a single crop. Farm income was significantly higher among farmers that diversified their crop production. The Crop Diversification (CD) index was 0.42. The crop diversification index of male farmers was 0.10 significantly (P>0.05) higher than females' as expressed in Table 2. The results of the Tobit estimates on the determinants of crop diversification showed that nine of the seventeen variables included in the model significantly influenced the extent of crop diversification. Household size, crop income, farm size, total household income, extent of commercialization, crop yield and use of inorganic fertilizer increase crop diversification significantly while age and sex of household heads significantly reduce crop diversification as observed in Table 3. From the results, a unit increase in age of household head will reduce crop diversification by 0.0018, hence as farmers' advance in age, they tend to specialize on production of a particular crop based on their long production experiences. Farmers' risk bearing capacity was also found to reduce as age increases which support previous findings of **Ojo *et al.* (2014)** that farmers' age negatively influences CD in North-Central Nigeria. Farm size was found to have positive and significant effect on CD which indicates that access to land resources gives room for easy practice of CD which also agrees with findings from **Rahman and Chima (2016), Sichoongwe *et al.* (2014) and Benin *et al.* (2004)** that farm size has significant and positive effect on CD in Southeastern Nigeria, Zambia and Ethiopia respectively.

A gender outlook further explained that belonging to a FHH reduces the extent of crop diversification significantly at 1%. Thus, male farmers are more diversified in crop production than their female counterparts. This is evidently supported by more male farmers' access to agricultural production resources than females which enhanced their extent of diversification. This result is consistent with **Dube (2016)** findings that having a male household head increased crop diversification in Manicaland and Masvingo provinces in Zimbabwe. Application of inorganic fertilizer has positive and significant influence on CD. Fertilizers are important input in crop production which improves soil fertility for high yield. Although costly, the costs can be offset by high yields. This agrees with the findings of **Sichoongwe *et al.* (2014)** that the quantity of fertilizer used increased the probability of engaging in crop diversification in Southern province, Zambia. Differences were observed in the correlates of CD between MHH and FHH. All the nine significant variables were found to influence CD among MHH but only three namely farm size, use of inorganic fertilizer and extent of commercialization were found to significantly influence CD among FHH.

### *Effect of Crop Diversification on Dietary Diversity*

The study found that less than half (45.22%) of the rural households consumed at least nine of the 12 food groups in the previous week of the survey period. The mean dietary diversity index of the households is 0.71. The results in Table 4 further shows that diet is more diverse among FHH than MHH with a significant difference of 0.06 which implies that FHH spend more on high quality foods than MHH.

**Table 1:** Descriptive statistics and mean differences tests by gender of household heads

| Variable | Definition | Pooled | FHH (%) | MHH ( %) | Difference |
|---|---|---|---|---|---|
| Age | Age of the household head (Years) | 53.09 | 57.60 | 52.15 | 5.45*** |
| Education | Household head's education (Years of schooling) | 4.67 | 3.59 | 4.86 | 1.27*** |
| Extension contact | Household reached by extension services (Number) | 14.03 | 3.80 | 15.83 | 12.03*** |
| Household size | Total household size (number) | 7.82 | 5.74 | 8.11 | 2.59*** |
| Farm size | Total farm size cultivated | 0.99 | 0.52 | 1.29 | 0.77** |
| Access to formal credit | Dummy=1 if respondent has access to formal credit | 27.57 | 34.24 | 26.39 | 7.84*** |
| Improved seeds | Dummy=1 if respondent cultivated improved varieties | 19.33 | 16.30 | 19.87 | 3.06 |
| Inorganic fertilizers | Dummy=1 if respondents used inorganic fertilizer | 57.10 | 38.04 | 60.46 | 22.41*** |
| Labour demand | Total labour days for farm | 880.82 | 658.99 | 861.09 | 250.79*** |
| Crop yield | Crop yield (kg/ha) | 7993.39 | 7640.72 | 8055.67 | 414.94*** |
| Crop income | Crop income (NGN) | 160764.50 | 75754.28 | 175775.90 | 99501.0*** |
| Agric.Wage income | Agricultural wage income employment (NGN) | 120861.20 | 90522.83 | 126218.50 | 35695.66 |
| Self-employment income | Income from self-employment (NGN) | 103679.40 | 74018.83 | 108917 | 34898.20* |
| Total income | Total household income (NGN) | 376855.30 | 238767.50 | 401239.40 | 162471.9*** |

Source: Estimated by Authors
Note: ***, **,* represent 1%, 5% and 10% significant levels respectively

**Table 2:** Gender disaggregated crop diversification index

| Gender of household head | Crop diversification index | Standard error | Difference | T-value |
|---|---|---|---|---|
| Male | 0.4376 | 0.0045 | 0.102*** | 8.6387 |
| Female | 0.3356 | 0.0087 | | |
| Pooled | 0.4236 | 0.0041 | | |

Source: Estimated by Authors
Note; *** represents 1% significant level

**Table 3:** Tobit estimates of the determinants of crop diversification

| Variable | Pooled Data | | MHH | | FHH | |
|---|---|---|---|---|---|---|
| | Coeff. | Std. Error | Coeff. | Std. Error | Coeff. | Std. Error |
| Age | -0.002** | 0.001 | -0.002*** | 0.000 | -0.004 | 0.003 |
| Extension contact | 0.031 | 0.023 | 0.035 | 0.023 | -0.056 | 0.169 |
| Education | -0.004 | 0.003 | -0.003 | 0.002 | -0.005 | 0.013 |
| Household size | 0.007*** | 0.002 | .007*** | 0.003 | 0.002 | 0.011 |
| Sex | -0.116*** | 0.025 | | | | |
| Credit access | -0.094 | 0.019 | -0.110 | .02017 | 0.026 | 0.072 |
| Total income | 3.18e-08** | 1.44e-08 | -3.17e-08** | 1.44e-08 | -1.07e-08 | 6.73e-08 |
| Commercialization | 0.201*** | 0.030 | -0.204*** | 0.032 | -0.238** | 0.124 |
| Production expenses | -7.90e-08 | 5.69e-08 | -8.59e-08 | 5.69e-08 | 3.05e-08 | 3.27e-07 |
| Crop income | 2.41e-07*** | 4.61e-08 | 2.40e-07 *** | 4.57e-08 | 1.63e-07 | 2.86e-07 |
| Self-employment | 3.75e-09 | 3.82e-08 | 8.99e-09 | 3.84e-08 | -1.37e-07 | 1.83e-07 |
| Ag. wage income | -7.20e-06 | 8.81e-06 | -4.90e-06 | 9.02e-06 | -1.37e-07 | 1.83e-07 |
| Farm size | 0.043*** | 0.005 | 0.041*** | 0.005 | 0.093** | 0.045 |
| Total labour | 5.12e-06 | 0.000 | 3.81e-06 | 0.000 | 0.000 | 0.000 |
| Inorganic fertilizer | 0.034** | 0.016 | 0.052*** | 0.017 | -0.135** | 0.066 |
| Improved seed | -0.009 | .021 | -0.008 | 0.021 | -0.008 | 0.021 |
| Crop yield | 1.56e-06*** | 5.46e-07 | 1.10e-06** | 5.62e-07 | 5.19e-06 | 2.23e-06 |
| Constant | 0.458*** | 0.043 | 0.449 | 0.042 | 0.392 | 0.218 |
| Prob > chi$^2$ | 0.000 | | 0.000 | | 0.0518 | |
| LR Chi$^2$(17) | 309.20 | | 309.20 | | 24.86 | |
| Log likelihood | -407.02 | | -306.99 | | -84.17 | |
| Pseudo $R^2$ | 0.4753 | | 0.3734 | | 0.3287 | |

Source: Estimated by Authors
***,**,* represent 1%, 5% and 10% significant levels respectively

**Table 4:** Household's dietary diversity by gender

| Gender of household head | Dietary Diversity | Std. Error | Difference | T-value |
|---|---|---|---|---|
| Male-headed | .6995677 | .1644632 | 0.055*** | 4.238 |
| Female-headed | .7549819 | .1578187 | | |
| Pooled | .7078912 | .1646152 | | |

Source: Estimated by Authors

Note: ***,**,* represent 1%, 5% and 10% significant levels respectively

The Tobit estimates further explained that crop diversification among other factors such as sex, credit access, non-farm income, cultivation of improved seeds and extent of commercialization have significant positive correlations with households' dietary diversity as indicated in Table 5. On the other hand, age and use of inorganic fertilizer have negative correlation with dietary diversity of farming households in rural Nigeria. Crop diversification increases the diversity of food crops that can be consumed by the household. Crop diversification was found to significantly (P<0.01) increase dietary diversity by 0.217. This result is consistent with similar findings of **Pellegrinni and Tasciotti (2014), Makate *et.al.*. (2016)** and **Mango *et al.* (2018**) which found out that CD increases DD, especially in the developing countries. Crop diversification have positive correlation with DD in the gender-disaggregated results for both MHHs and FHHs, however, gender differences are observed in the factors influencing households' DD. Tobit estimates presented in Table 5 found that extension services, credit access, commercialization, self-employment, agricultural wage income, use of inorganic fertilizers and improved seeds significantly influence DD among MHHs but farm size, credit access and CD significantly influenced DD among the FHHs. Crop yield (a proxy for productivity) has positive correlation with DD in both gender groups though not significant. This also supports previous findings of **Bouis (2007**) that there is positive correlation between nutrition improvement and household's agricultural productivity.

A significant reduction in dietary diversity was obtained in male-headed households which agrees with **Taruvinga, Muchenje and Mushinje (2013)** that male-headship would have negative correlation with household's DD. Credit has positive and significant coefficient at 1%. Credit improves household financial capacity to purchase productivity-enhancing inputs and to smoothing consumption. More so, households with credit access are opportune to invest in off-farm activities/enterprises that could increase households' incomes. This is in line with **Mango *et al*. (2018)** which noted better income enhances access to varieties of food, hence there was a positive influence of credit on dietary diversity in Central Malawi. The extent of commercialization was found to significantly increase dietary diversity because improvements in extent of commercialization among farming households will lead to increase in farm income which in return enhances household's economic access to food.

***Gender differentials in agricultural productivity***

Gender differences in productivity between MHHs and FHHs in rural Nigeria assist to understand determinants of gender gaps in farm productivity and controlling for the variations. The study explains the productivity gap due to variations in characteristics of both genders and due to discrimination against women. The results of the Oaxaca-Blinder decomposition revealed existence of gender productivity gaps in Nigerian food crop agricultural production as shown in Table 6. These results follow previous studies by **Kilic *et al*. (2013) in Malawi; Aguilar *et al.* (2013) in Ethiopia, Oseni *et al.* (2014) in Nigeria, and Mukasa and Salami (2015**) in Nigeria, Tanzania and Uganda. Observed factors responsible for the gender gaps were further investigated with policy implications on reduction or closing of gender gaps.

Gender productivity differentials of 10.87% was obtained which is a lower gap compared to results of previous studies. For instance, **Oseni *et al*. (2014**) estimated gender productivity gap of 28% and 23.9% in Northern and Southern Nigeria respectively based on LSMS-ISA data of 2010/11 while **Mukasa and Salami (2015**) estimated a gap of 18.6% in Nigeria based on LSMS-ISA 2012/2013 data. These estimates revealed the existence of gender productivity gap in Nigeria which is common to African agriculture whereby female farmers are less productive compared with their male counterparts **(Kilic *et al*., 2013; Aguilar *et al*., 2014).** Furthermore, the study considers the sources of productivity gap and their contributions to overall gender differentials. The OB decomposition results revealed that discrimination explains 0.46 points of the lower productivity of female compared with male while endowment reasons 0.42 points of the lower productivity of female farmers compared with their male counterparts. The relative contribution of the sources of gaps to the estimated gender productivity differentials shows that more of the productivity differentials are attributed to discrimination. The endowment effect and the structural effect (discrimination) are of opposite signs. The percentage of the productivity differentials attributed to the differences in the level of observables between male and female farmers (endowment effect) was found to be responsible for 384.82% (negative) of the total gender gap while the share of the gap attributed to the returns of the observables (discrimination/ structural effect) was 430.81%. Therefore, there is discrimination or structural advantage in favour of male farmers over female farmers. Improvement in endowments, however, will benefit female farmers more than their male counterparts. The interaction of endowments and discrimination was found to favour male farmers over female farmers.

**Table 5:** Tobit estimates of correlates of household's dietary diversity

| Variable | Pooled | | MHH | | FHH | |
|---|---|---|---|---|---|---|
| | Coeff. | Std. Error | Coeff. | Std. Error | Coeff. | Std. Error |
| Age | -0.000** | 0.000 | 0.000 | 0.000 | 0.001 | 0.001 |
| Extension contact | 0.033*** | 0.011 | 0.035*** | 0.012 | -0.012 | 0.049 |
| Education | 0.002 | 0.001 | 0.001 | 0.001 | -0.001 | 0.003 |
| Household size | -0.001 | 0.001 | -0.001 | 0.001 | 0.002 | 0.003 |
| Sex | 0.029** | 0.012 | | | | |
| Credit access | 0.092*** | 0.009 | 0 .089*** | 0.010 | 0.101 *** | 0.022 |
| Total income | 4.92e-09 | 6.35e-09 | 3.90e-09 | 0.000 | 1.87e-08 | 1.97e-08 |
| Commercialization | 0.060*** | .0150873 | 0.064*** | 0.016 | 0.034 | 0.036 |
| Production costs | -2.09e-08 | 4.14e-08 | -6.05e-09 | $4.32^{e-08}$ | 4.03e-08 | 1.62e-07 |
| Crop income | 9.35e-08 | 7.05e-08 | 8.41e-08 | $7.30^{e-08}$ | -4.55e-08 | 2.96e-07 |
| Self-employment | 9.18e-08*** | 1.83e-08 | 9.59e-08*** | $1.92^{e-08}$ | 4.65e-08 | 5.80e-08 |
| Ag. wage income | 5.05e-06 | 4.13e-06 | 8.70e-06* | $4.54^{e-06}$ | -0.000 | 0.000 |
| Farm size | -0.001 | 0.002 | -0.002 | 0.002 | -0.052*** | 0.016 |
| Total labour | 4.94e-08 | 5.13e-06 | 6.72e-07 | $5.39^{e-06}$ | 6.92e-06 | 0.000 |
| Inorganic fertilizer | -0.022** | 0.008 | -0.020** | 0.009 | -0.025 | 0.020 |
| Improved seed | 0.020** | 0.010 | 0.022** | 0.010 | 0.009 | 0.024 |
| Crop yield | 4.25e-07 | 2.76e-07 | 2.96e-07 | $2.96^{e-07}$ | 1.01e-06 | 7.57e-07 |
| Crop diversification | -0.064*** | 0.021 | -0.058** | 0.023 | -0.121** | 0.060 |
| Constant | 0.652*** | 0.024 | 0.652*** | 0.025 | 0.663*** | 0.073 |
| Prob > $chi^2$ | 0.0000 | | 0.0000 | | 0.0000 | |
| Log likelihood | 690.09 | | 582.89 | | 123.18 | |
| Pseudo $R^2$ | -0.4592 | | -0.4459 | | -0.3855 | |

Source: Estimated by Authors
Note: ***,**,* represent 1%, 5% and 10% significant levels respectively

**Table 6:** Gendered decomposition of sources of productivity gaps and their contributions

| Gender differentials | Male | Female | Gap |
|---|---|---|---|
| Mean productivity | 7.879*** | 7.770*** | 0.108* |
| | (0.048) | (0.124) | (0.056) |
| *Aggregate Decomposition* | Endowment effect | Structural effect | Interaction effect |
| Total | -0.418** | 0.468** | 0.103 |
| | (0.198) | (0.209) | (0.139) |
| Share of total gender gap | -384.82% | 430.81% | 94.39% |
| *Detailed Decomposition* | | | |
| Age | 0.778 | 0.755 | -0.080 |
| | (0.077) | (0.745) | (0.079) |
| Extension Contacts | -0.081 | 0.047 | 0.149* |
| | (0.074) | (0.029) | (0.078) |
| Household size | 0.034 | 0.105 | 0.048 |
| | (0.112) | (0.254) | (0.117) |
| Land size | -0.603*** | 0.163 | 0.348** |
| | (0.164) | 0.077) | (0.163) |
| Labour | 0.062 | 0.093 | -0.035 |
| | (0.035) | (0.144) | (0.055) |
| Crop diversification | 0.157 | -0.187 | -0.067 |
| | (0.098) | (0.282) | (0.102) |
| Fertilizer | -0.001 | 0.114 | 0.028 |
| | (0.010) | (0.051) | (0.028) |
| Improved seed | -0.003 | 0.062 | 0.013 |
| | (0.012) | (0.056) | (0.016) |
| Credit access | -0.062* | -0.267** | 0.062* |
| | (0.036) | (0.097) | (0.037) |

Source: Estimated by Authors
Note: Figures in parentheses are standard errors
***,**,* represent 1%, 5% and 10% significant levels respectively.

**Table 7:** Estimates of Oaxaca-Blinder Productivity Decomposition

| Productivity Decomposition components | Males | Females |
|---|---|---|
| Mean land productivity (kg/ha) | 8055.67 | 7640.72 |
| Productivity gap (kg/ha) | 414.94 | |
| Endowment effect | | -1596.39 |
| Discrimination effect | | 1788.02 |
| Productivity without discrimination | | 9428.74 |

Source: Estimated by Authors

Further insights revealed detailed decomposition of sources of gender gap in Table 6 which explains the contribution of different factors to the sources of gender gap. A positive coefficient widens the gap while a negative coefficient reduces the gender gap. The endowment effect was explained by the difference in land size between male and female farmers. Land was a major factor with the highest contribution (negative) to endowment effect, reducing the gap. Credit access has significant negative contribution to the endowment effect, accounting for 14.83% of the total endowment effect. This reveals that improvement in women's endowments in terms of access to land and credit facilities is very strong in closing gender productivity gap in Nigeria. Quantity of fertilizer has significant positive contribution to the structural disadvantage, thereby widening gender gap. This affects the magnitude of structural effects on male farmers' productivity. Access to credit further has significant negative relationship for female structural disadvantage which tend to generate higher returns in agriculture for women than men, thus result into a strong structural effect on female farmers' productivity.

Given characteristics of the female farmers, model estimates explained that without discrimination against women, their land productivity should be 9428.74 kg/ha as expressed in Table 7. This implies that due to discrimination, female farmers recorded 1,788.02 kg/ha less than male farmers. The value of discrimination represents 23.39% of their actual productivity.

## CONCLUSION

The study investigated crop diversification, productivity and dietary diversity of male-and female-headed farming households in Nigeria. Male farmers' crop diversification index was 0.10, significantly higher than female farmers. Diet is more diverse among female-headed than male-headed households. Crop diversification, sex, credit access, non-farm income, improved seeds cultivation, and extent of commercialization have positive and significant correlation with households' dietary diversity. The study found a presence of gender productivity gap in rural Nigeria due to variations in characteristics of both genders and discrimination against women. The overall gender productivity gap is 10.87%, female farmers are less productive compared to male farmers in rural Nigeria. Discrimination in terms of structural advantages favour male farmers while improved endowments benefits female farmers more than male farmers. Yet, the negative interactions of endowments and discrimination favour male farmers over female farmers in Nigeria. Without discrimination, the productivity of women farmers would increase by 23.39%. Structural disadvantages against women continue to unlock their agricultural productivity potentials. Endowment and structural disadvantages of female farmers in land and credit facilities are key drivers of gender productivity gaps. Policy interventions should focus on factors that enhance crop diversification especially access to land resources and credit facilities as key drivers of dietary diversity and closing gender productivity gaps. Hence, fast-tracking achievement of gender productivity equality, women's empowerment and inclusive agrifood system in Nigeria.

Suggestion for further research: A regular investigation of gender differentials especially at the national level is worth undertaking to ensure achievement of gender equality especially in African agricultural sector.

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