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# Soil Health Management Practices among Smallholder Maize Growers in Gwagwalada Area Council of Federal Capital Territory, Nigeria

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## Abstract

The basis of successful, productive, and ecologically responsible agricultural systems is healthy soil. Examining the soil health management practices and their determinants would help in achieving Sustainable Development Goals 1 (no poverty) and 2 (no hunger). This study assessed the soil health management options among smallholder maize growers in Gwagwalada Area Council of Federal Capital Territory, Nigeria. It specifically examined the various soil health management options employed by the smallholder maize farmers. The multi-stage sampling technique was used to sample a total of 105 respondents. The result of the various soil health management options used by the smallholder maize farmers in the study area showed that 38.1% of the respondents used organic amendments. The result of the multinomial logit regression showed that the coefficients of the smallholder farmers' age (p<0.01) and cooperative membership (p<0.01) negatively influence the choice of the smallholder farmers to use cover cropping as opposed to using crop rotation. The result revealed that the major constraints militating against the maize farmers' choice of soil health management options are non-availability of labor; neighbourhood norms, customs, culture and traditional beliefs about soil health; and illiteracy and poor access to and control of land. The study concludes that there is a significant relationship between the maize farmers' choice of soil health management options and their socio-economic characteristics, farm-specific and institutional factors. The study suggests that policymakers can develop new financing options for smallholder maize farmers.

## Introduction

The bulk of economies in Sub-Saharan Africa (SSA) are based on the agricultural sector. More than 60% of the population depends on it for their major source of income, and it contributes between 30% and 50% of GDP and more than 40% of export earnings (Food and Agriculture Organization Statistics [FAOSTAT], 2022). Food insecurity is the main issue facing the people of Sub-Saharan Africa (SSA) (Khonje et al., 2015). Rainfed agriculture is vital for smallholder farmers, who produce over 90% of the food on the continent (Beyene & Kassie, 2015). Consequently, improving the agricultural sector by aiding small farmers may contribute to the alleviation of poverty and food insuffecency, which may then promote economic growth. FAO (2012) explained that in sub-Saharan Africa and Asia, 80% of the farmland is cultivated and managed by smallholders. Smallholding farms are referred to farms of up to 10 hectares.

Maize (*Zea mays* L.) is their main crop and source of nutrition. According to FAOSTAT (2022) and; Onumah et al. (2021), Nigeria is the foremost grower of maize in Sub-Saharan Africa (SSA), with over 48% of the region's total output coming from maize production in 2020. Therefore, growing maize is strategically crucial for boosting export revenue and bolstering food security at home. Notwithstanding its significance, maize productivity is still mostly inadequate, with yields substantially below potential (FAOSTAT, 2022). This is mostly because of recent climate change and decreasing soil fertility in developing nations (Yegbemey et al., 2014).

Continuous crop cultivation causes a loss of soil minerals, which subsequently deteriorates soil fertility and decreases soil in soil productivity (Ande et al., 2017). The primary stewards of the soil production resource base in many developing countries, such as Nigeria, are farmers with farm size of not more than five hectares, who typically work with marginal soils that have little to no nutrients for plant growth (Mgbenka & Mbah, 2016). It is clear that high-quality soil management raises soil value considerably (Lin et al., 2006). In Sub-Saharan Africa, declining soil fertility is a serious problem that permanently hinders agricultural output, especially in low-potential areas. This puts food security and rural livelihoods at serious risk (Vanlauwe et al., 2017).

Chukwuka and Omotayo (2009) state that the history, response to inputs, and chemical, physical, and biological characteristics of the soils in various parts of Sub-Saharan Africa (SSA) are very varied. The most prevalent soil types are Arenosols (21.5%), Cambisols (10.8%), Ferralsols (10.4%), and Leptosols (17.5%) (Tully et al., 2015). The absence of vital components including sulfur, phosphorus, nitrogen, and carbon sets these soils apart (Chianu et al., 2012; Krah et al., 2019). Due to their high phosphorus fixing ability, which forces resource-poor farmers to apply phosphorus fertilizers more frequently, their general shallowness (Leptosols), which allows soil moisture to evaporate quickly, and their lack of binding agents like humus, they are highly susceptible to erosion (Shepherd & Walsh, 2007).

Good soils are essential for healthy ecosystems and communities. They are also linked to biodiversity, water quality, food and nutrient availability, human health, and mitigating and adapting to climate change (Manter et al., 2017; National Academies of Sciences and Medicine [NASM], 2017). Preventing land degradation brought on by nutrient loss, soil erosion, and loss of ecological integrity is essential (The Intergovernmental Panel on Climate Change [IPCC], 2019). The widespread application of soil health management techniques, or the soil's continuous ability to support humans, animals, and plants as a vital living ecosystem (USDANRCS, 2019), is a viable countermeasure to the degradation of agroecosystems. Maintaining healthy soil is essential to the agricultural system's ability to produce food over the long run. Without a doubt, productive soil is necessary for crops to grow well enough for industrial, human, and animal usage (Bayu, 2020).

Kurgat et al. (2018) stated that soil health (SH) is a crucial part of any policy's thrust to address issues of food scarcity while ensuring sustainable environment even though the population is growing. As per Marenya and Barret's (2007) proposition, maintaining soil health requires the thoughtful application of many methods for managing soil fertility in an integrated manner, hence leveraging the synergies between management efforts.

No soil fertility management strategy can meet the requirements of enhanced SH on its own, and several techniques, such as fertilizer type, are site-specific (Adolwa et al., 2019). Researchers, business owners, policymakers, and the general public have all expressed interest in SH, and a number of public-private organizations, academic institutions, and business associations are collaborating to develop metrics and science related

to SH as well as policies that support it (NASM, 2017; Soil Health Institute, 2017; The Nature Conservancy, 2016).

Numerous studies have demonstrated the connections between SH and human health, as well as the vital role that SH plays in nutrition, food security, and food production. Increased agricultural productivity and improved dietary quality have also been associated with SH improvements in the literature (Brevik & Burgess, 2012; Brevik & Sauer, 2015; Bünemann et al., 2018; Pepper, 2013; Wall et al., 2015).

As reported by many studies in Africa, some soils are losing their capacity to provide food and other essential ecosystem services, particularly (Ajayi, 2007; Kiboi et al., 2019; Marenya & Barrett, 2007; Sileshi et al., 2019), due to inadequate soil management methods causing depletion of fertility and land degradation on about 83% of Africa's 874 million hectares of arable land, over-cultivation, and excessive population pressure. Farmers' adoption of technology appears to be influenced by a variety of demographic, biophysical, and institutional variables, as well as knowledge and skills in best agricultural practices (Asrat et al., 2004; Nigussie et al., 2017). Agricultural technologies used by smallholder farmers in SSA are generally limited due to a lack of supporting resources, including land (Adimassau et al., 2016). This is also true for livestock unit size (Adimassau et al., 2014; Asrat et al., 2004); agricultural extension services (Paudel & Thapa, 2004); and credit (Tiwari et al., 2008). According to Adimassau et al. (2014) and Asrat et al. (2004), other 2 variables also include household size and on-farm labor ratio. Adoption of soil management systems has been the subject of numerous studies, such as those conducted in Southern Africa by Mponela et al. (2016), Ethiopia by Adimassu et al. (2016), Southern Africa by Ajayi (2007), Malawi by Chinangwa (2006), and Kenya by Marenya and Barret (2007). Eze et al. (2021) also examined the indicators of soil health in the African highlands.

However, none of the aforementioned research was undertaken in Nigeria, and there is little or no attention on smallholder maize producers. As a result, understanding the soil health management options accessible to smallholder maize farmers, also the drivers of soil health management practices, has received minimal attention, particularly in Nigeria, where few of these studies have concentrated. Due to this lack of information, this study seeks to analyse the soil health management options by smallholder maize growers. It specifically examined the various soil health management options employed by the smallholder maize farmers in the study area, examined the determinants of soil health management options used by smallholder maize growers, and described the constraints militating against the maize growers' choice of soil health management options.

The null hypothesis guided the study to realize the objectives of examining the factors influencing soil health management options used by small-scale maize growers in the study area. The null hypothesis tested is that there is no significant relationship between the maize farmers' choice of soil health management options and their socio-economic characteristics, farm-specific and institutional variables.

## Materials and Methods

The Study Area

The research was done in the Gwagwalada Area Council of Nigeria's Federal Capital Territory. Gwagwalada is a local government area in Abuja, Nigeria's Federal Capital Territory (FCT). The geographical coordinates are 8.56° 29' North and 7.5° 31' East. Gwagwalada has an elevation of 210 meters above sea level. It has a total area of

1069.589km$^2$ and ten wards: Zuba, Dobi, Tunga-Maje, Ibwa, Kutunku, Ikwa, Paiko, Gwako, Staff Quarters, and Gwagwalada Central (Akoachere et al., 2019). Prior to the founding of the Federal Capital Territory, Gwagwalada was part of the Kwali District of the former Abuja Emirate. The climatic characteristics of the research region allow for agricultural operations such as crop cultivation, animal grazing, and fisheries production. The average annual rainfall ranges from 800 to 1,500mm, while the temperature ranges from 21°C to 35°C. Gwagwalada is well located, making it easier to visit other nearby local councils like Kuje, Abaji, and Abuja Municipal.

### Sampling Technique

The respondents for this study were sampled using a multi-stage sampling procedure. In the initial step, five (5) wards known for maize production were purposefully chosen from the Gwagwalada Area Council because of preponderance of farming activities especially maize farming. The second stage involved selecting three (3) farming villages at random from each of the five (5) selected wards, for a total of 15 farming villages. The sample frame for the study was made up of the 15 chosen farming villages. In the last stage, (seven) 7 smallholder maize growers were chosen at random from each of the 15 farming villages. As a result, the total number of participants for the study is 105 smallholder maize growers selected for the study.

### Method of Data Collection

The data used in this study was cross-section data obtained from primary source. The data collection instrument was a well-structured questionnaire developed by the reseachers and then validated by experts. One hundred and five (105) smallholder maize farmers were interviewed. The data was collected within two weeks (1st – 15th February, 2023). The data was based on 2022 cropping season. Smallholding farms are referred to farms of up to 10 hectares (FAO, 2012).

### Method of Data Analysis

Both descriptive and inferential statistics were used to analyse the data in this study. Percentages, frequencies, and mean were used to explain socio-economic characteristics of the respondents, soil health management strategies used by the respondents, and the constraints militating against choice of soil health management practices by the respondents. Multinomial logit model was used to unravel the factors influencing the smallholder maizer farmers' choice of soil health management practices.

## Model Specification

### The Multinomial Logit Model

The Multinomial Logit Model was used to assess the determinants of soil health management options used by the smallholder maize growers in the study area. Because the dependent variable is polychotomous, categorical, and unordered in nature, Multinomial Logit Model was used in the study to estimate the explanatory factors impacting the soil health management choices utilized by smallholder maize farmers. This affects the likelihood that a farmer would utilize one of the four types of soil health management options: tillage consideration, crop rotation consideration, cover cropping consideration, and organic amendment consideration. The model, as specified by Green, (2008) cited in Ezie & Ezie (2023), the main soil health management practices used by the smallholder maize growers were the ones that were fitted into multinomial logit as the dependent variable.

Other works that used multinomial logit model because of the polychotomous nature of the dependent variables were Otitoju (2013), Otitoju et al. (2021), Enete et al. (2015), however, Obeten et al. (2022) used multinomial probit model. But the choice of multinomial logit was deliberate because of it ease of interpretation and computation. The polychotomous dependent variable must be mutually exclusive, hence this study then assumed that the main soil health management strategy is attributed to each farmer.

The MNL model is expressed as follows:

$$prob\left(y = \frac{j}{x}\right) = \frac{e^{\beta i x i}}{\sum_{k=1}^{j-1} e^{\beta i x i}} \; for \; j = 1, 2, \ldots \beta o = 0 \tag{1}$$

Whereas "y" denotes a random variable with values (0, 1, 2,...J), for a non-negative integer J, and "x" denotes a set of conditioning variables, y in this study represents soil health management options used by smallholder maize farmers, and x represents farmers' socio-economic characteristics and farm-specific factors. The study assumes the Independence of Irrelevant Alternatives (IIA) holds in order to get unbiased and consistent estimations of the MNL model described in equation (1).

The specification of the multinomial logit probability model is given below:

$$Y_{i=0,1,2..J} = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \beta_3 x_3 + \beta_4 x_4 + \cdots + \beta_{12} x_{12} + U_i \tag{2}$$

Let j signify a specified soil health management option utilized by smallholder maize farmers, with a value ranging from 1 to 4, with Y0 (1) representing crop rotation as the reference category.

$Y_0$ = 1 for crop rotation

$Y_1$ = 2 for Cover Cropping

$Y_2$ = 3 for Organic Amendment

$Y_3$ = 4 for Soil Tillage

Let j represent a specific soil health management option used by smallholder maize farmers, with a value ranging from 0 to 3, and crop rotation as the reference category;

$X_1$ = Sex of farmer (Dummy 1 if male, 0 if female)

$X_2$ = Age of the household head (in years)

$X_3$ = Education level of household head (years of schooling)

$X_4$ = Membership of cooperative society (1 if belonging to cooperative societies, 0 otherwise)

$X_5$ = Off-farm income

$X_6$ = Extension contact (qualitative binary variable assigned 1 if yes, 0 if no)

$X_7$ = Farm size (hectares)

$X_8$ = Training in soil health management. (qualitative binary variables 1 if yes,0 if no)

$X_9$ = Access to credit (qualitative binary variable assigned 1 if have access, 0 if no access)

$X_{10}$ =Farming experience (in years)

$X_{11}$ = Participation in a funded project (1 if participating, 0 otherwise) Literacy ratio

$X_{12}$ = Literacy ratio

The tested hypothesis was done using a z-test as embedded in the multinomial logit model at various levels of significance.

## Results and Discussion

### Socioeconomic characteristics of the respondents

The socioeconomic features of the smallholder maize growers in the study area, as shown in Table 1, revealed that majority of the maize growers are married men with an average household size of eight people. The findings corroborated to the findings of Ashagidigbi et al. (2019) that men predominate in Nigerian arable farming. It is widely believed that male farmers are stronger and can withstand the demanding work needed in growing arable crops, whereas their female counterparts are typically engaged in less demanding production and processing tasks. Farmers can leverage household size to satisfy the farm labor needs. This can also enhance the use of soil health management techniques for enhanced crop yield.

Table 1 also indicated that the respondents' average age is 48 years. This suggests that smallholder maize farmers are still active and productive. Approximately 36.2% of the respondents had no formal education, while the remaining 63.8% had different levels of education, with secondary school education accounting for approximately 24.8%. The approximate mean number of school years spent demonstrates a degree of literacy among smallholder maize producers. The educational attainment of smallholder farmers is a key element that positively enhanced the adoption of integrated soil fertility management technologies (Mponela et al., 2016).

The average year of farming experience (28 years) indicates that the study's smallholder farmers have extensive expertise in maize cultivation. As a result, knowledge and skills gained through farming surely helped crop output of maize farms and the adoption of appropriate soil health management solutions. Mponela et al. (2016) found that inexperienced farmers are risk-averse and will attempt the fewest possible tactics. . It was also discovered that 89.5% of those polled had access to credit. Thus, access to finance improves farmers' ability to obtain critical inputs for maize crop production and the adoption of soil health management alternatives, ultimately enhancing agricultural output and productivity. According to Chianu et al. (2012), budgetary constraints limit the adoption of superior technology.

Furthermore, 94.3% of smallholder maize farmers received instruction in one or more soil health management measures, and 97.2% received extension contact twice or more throughout the cropping season. Moreover, 87.6% of the participants are members of one or more cooperative societies. According to Mponela et al. (2016), awareness creation training can make up for inadequate formal training when access to training from agricultural extension service providers is available. This information points to a level of interaction with extension agents and information packages about soil fertility management, crop and livestock husbandry, and soil testing. There has been high positive relationship between training, agricultural extension services and adotion of agricultural improved technologies.

The results show that 70.5% of the research region's smallholder maize farmers own farm with an average size of two hectares, ranging from 1.1 to 3.0 hectares. One important factor driving the use of soil health management techniques is a farm's land holdings. Chianu et al. (2012) also found that larger farmers have a greater inclination to invest in or adopt improved agricultural technology compared to smallholder farmers.

**Table 1:** Frequency Distribution of the Respondents according to Socio-economic and Farm-Specific Characteristics in the Study Area (n= 105).

| Variables | Frequency | Percentage | Mean (Standard Deviation SD) |
|---|---|---|---|
| Gender | | | |
| **Male** | 65 | 61.9 | |
| **Female** | 40 | 38.1 | |
| Marital status | | | |
| **Single** | 7 | 6.7 | |
| **Married** | 84 | 80.0 | |
| **Widowed** | 7 | 6.7 | |
| **Divorced** | 7 | 6.7 | |
| Level of Education | | | 9.2 years (SD ±5.94) |
| **No formal education** | 38 | 36.2 | |
| **Attended primary school** | 18 | 17.1 | |
| **Attended secondary school** | 26 | 24.8 | |
| **Attended tertiary** | 23 | 21.9 | |
| Household Size | | | 8.3 persons (SD ±1.88) |
| **1 – 5** | 5 | 4.8 | |
| **6 – 10** | 89 | 84.8 | |
| **11 – 15** | 11 | 10.5 | |
| Access to Credit | | | |
| **Access to credit** | 94 | 89.5 | |
| **No access to credit** | 11 | 10.5 | |
| Extension Visit | | | 1.98 (SD ±0.86) |
| **Extension Visit** | 102 | 97.2 | |
| **No extension visit** | 3 | 2.9 | |
| Land Ownership | | | |
| **Yes** | 74 | 70.5 | |
| **No** | 31 | 29.5 | |
| Age of farmers | | | 47.5 years (SD ±8.87) |
| **Less than or equal to 20** | 1 | 1.0 | |
| **21 – 30** | 7 | 6.7 | |
| **31 – 40** | 16 | 15.2 | |
| **41 – 50** | 40 | 38.1 | |
| **51 – 60** | 41 | 39.0 | |
| Training on soil health management options | | | 2.83 years (SD ±1.31) |
| **Training** | 99 | 94.2 | |
| **No training** | 6 | 5.8 | |

**Table 1:** *Continued...*

| Variables | Frequency | Percentage | Mean (Standard Deviation SD) |
|---|---|---|---|
| Membership of Cooperative society | | | |
| **Yes** | 92 | 87.6 | |
| **No** | 13 | 12.4 | |
| Farming Experience | | | 27.9 years (SD ±10.5) |
| **1 – 10** | 6 | 5.7 | |
| **11 – 20** | 31 | 29.5 | |
| **21 – 30** | 30 | 28.6 | |
| **31 – 40** | 27 | 25.7 | |
| **41 – 50** | 11 | 10.5 | |
| Farm Size | | | 2.0 hectares (SD ±1.18) |
| **≤ 1.0** | 30 | 28.6 | |
| **1.1 – 3.0** | 63 | 60.0 | |
| **3.1 – 5.0** | 12 | 11.4 | |

**Source:** Computed from field data, 2023.

**Main Soil Health Management Options Used by Smallholder Maize Growers**

Figure 1 indicates the outcomes of the main soil health management practices utilized by smallholder maize growers. According to the findings, 38.1% of the respondents mainly utilized organic amendments. The organic amendment (manure) employed by the greatest number of smallholder maize growers refers to the mixed crop-livestock farming method utilized by the bulk of small-scale corn farmers. According to Holden and Mangisoni (2013), and Chianu et al. (2012), it could also be attributed to their quick returns and the high cost of fertilizer in the market.

**Figure 1**. Frequency Distribution of Soil Health Management Options Used by the Smallholder Maize Farmers in the Study Area
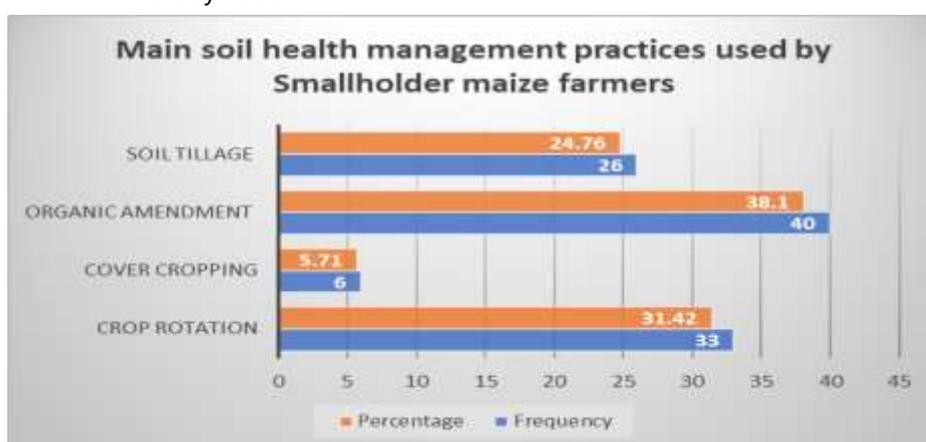


Source: Computed from field data, 2023.

However, the inadequacy of manure, as hypothesized by Nalivata et al. (2017), maybe the reason of 31.42% and 24.76% of smallholder maize farmer respectively practice crop rotation and soil tillage as main soil health management option, respectively. The adoption of crop rotation and soil tillage as soil health management options is a good example of smallholder farmers utilizing a specific technique to tailored towards certain soil needs. Because Gwagwalada Area Council has mainly rough soil topography, it is prone to soil and land degredation.

Cover cropping was utilized by 5.71% of the respondents as their main soil health management practices. According to Blaser et al. (2017), cover cropping is important in protecting the environment. Cover crop boost soil organic matter, limiting soil erosion and binding the soil together.

**Determinants of Soil Health Management Options Decisions by Small-scale Maize Growers**

Table 2 shows the multinomial logit regression results for the factors impacting the choice of soil health management options utilized by smallholder maize farmers in the study region. As the reference category, the influencing coefficients were computed using the crop rotation as the base category for the soil health management options. The choice of crop rotation as the reference category was autoselected as the iterations took place by the Stata software. The other 3 soil health management options were used differently for the estimation of the model as the reference category but the results of the analysis of crop rotation as the base category performed better following the necessary selection criteria (statistical and theoretical). The pseudo probability value in Table 2 is -88.529. This test validates that all of the coefficients are substantially different from zero, indicating a good fit and the preciseness of the estimated model. This high pseudo probability value obtained in this analysis indicates an xcellent fit of the multinomial logit model (Hosmer & Lemeshow, 2000) and equally supported by Burnham and Anderson (2002). In other words, the explanatory factors are statistically significant in explaining the soil health management practices chosen or employed by smallholder maize growers.

The use of soil health management options was impacted by a number of farm-specific and institutional factors, including access to credit, training in soil health management practices, and socioeconomic factors like the farmer's gender and household literacy rate. As a result, the null hypothesis is rejected since there is a significant association between maize farmers' choice of soil health management choices and some socioeconomic characteristics, farm-specific, or institutional variables in the research area. The selection of the significant variables using different thresholds (10%, 55 and 1%) is on the basis avoiding the pitfalls of dichotomous thinking of significant versus not significant (Gelman & Loken, 2014).

A shown in Table 2 the coefficients of the smallholder farmers' sex, (-18.02), age (-0.66) and educational level (-2.72) were significant and negatively influenced the choice of the

smallholder farmers to use cover cropping at 1% level of probability as compared to using crop rotation. The coefficients of the smallholder maize farmers' literacy ratio also negatively influenced the adoption of organic amendment (-4.00) at 1% level of probability as opposed to using crop rotation as a soil health management option in the study area. This implies that a unit increase in the age and education level of the smallholder maize farmers can probably lead to proportionate decrease in the probability of using cover cropping over using crop rotation in Gwagwalada Area Council, respectively. This means that older female smallholder maize farmers with higher levels of education in the study area are more likely to opt for the crop rotation option of soil health management. According to Mponela et al. (2016), literacy has an impact on farmers' adoption of new technologies because they are more likely to be able to comprehend and apply the technical knowledge that comes with certain soil health management technologies. The impact of gender on soil health management decisions could be related to disparities in resource accessibility between men and women (Njuki et al., 2008).

**Table 2:** Determinants of soil health management practices by the respondents in Gwagwalada Area, Nigeria.

| Variables | Parameter | Cover Cropping | | Organic Amendment | | Soil Tillage | |
|---|---|---|---|---|---|---|---|
| | | Coefficient | z-value | Coefficient | z-value | Coefficient | z-value |
| **Sex of the farmer ($X_1$)** | $\beta_1$ | -18.016 | 12.86[***] | -0.402 | -0.52 | -0.196 | -0.24 |
| | | (1.401) | | (0.772) | | (0.803) | |
| **Age of farmer ($X_2$)** | $\beta_2$ | -0.660 | -6.08[***] | -0.015 | -0.30 | -0.066 | -1.43 |
| | | (0.109) | | (0.049) | | (0.046) | |
| **Education level ($X_3$)** | $\beta_3$ | -2.723 | -15.62[***] | -0.055 | -0.90 | -0.053 | -0.78 |
| | | (0.175) | | (0.061) | | (0.068) | |
| **Membership of cooperative societies ($X_4$)** | $\beta_4$ | -10.347 | -10.31[***] | 0.551 | 1.15 | 1.884 | 2.97[***] |
| | | (1.004) | | (0.479) | | (0.635) | |
| **Off-farm income ($X_5$)** | $\beta_5$ | 4.07 | 21.72[***] | -1.36 | -0.83 | 1.73 | 1.05 |
| | | (2.16) | | (1.64) | | (1.65) | |
| **Extension contact ($X_6$)** | $\beta_6$ | -25.579 | -7.45[***] | -18.141 | -13.99[***] | -20.013 | -15.60[***] |
| | | (3.434) | | (1.297) | | (1.283) | |
| **Farm size ($X_7$)** | $\beta_7$ | 4.474 | 8.55[***] | 0.106 | 0.35 | -0.472 | -1.30 |
| | | (0.523) | | (0.301) | | (0.363) | |
| **Training in soil health management ($X_8$)** | $\beta_8$ | 2.495 | 6.00[***] | 0.100 | 0.36 | 0.376 | 1.24 |
| | | (0.416) | | (0.278) | | (0.303) | |
| **Access to credit ($X_9$)** | $\beta_9$ | -28.543 | -10.46[***] | -2.194 | -1.84[*] | -1.158 | -0.85 |
| | | (2.729) | | (1.194) | | (1.359) | |
| **Farming experience ($X_{10}$)** | $\beta_{10}$ | -3.129 | -3.64[***] | -0.239 | -0.71 | -0.614 | -1.34 |
| | | (0.859) | | (0.339) | | (0.459) | |
| **Participation in funded project ($X_{11}$)** | $\beta_{11}$ | 7.696 | 4.25[***] | 1.261 | 1.66[*] | 2.367 | 2.34[**] |
| | | (1.813) | | (0.758) | | (1.012) | |

**Table 2:** *Continued...*

|  |  | Coefficient | z-value | Coefficient | z-value | Coefficient | z-value |
|---|---|---|---|---|---|---|---|
| **Literacy ratio ($X_{12}$)** | $\beta_{12}$ | 5.172 | 1.32 | -3.995 | -3.00[***] | -0.601 | -0.31 |
|  |  | (3.926) |  | (1.331) |  | (1.913) |  |
| **Constant** | $\beta_0$ | 77.042 | 14.15 | 23.012 | 7.65 | 22.495 | 7.32 |
|  |  | (5.444) |  | (3.009) |  | (3.073) |  |

Crop rotation is the reference category. Figures in paretheses are the robust standard errors. *, **, and *** stand for 1%, 5%, and 10% levels of probability, respectively.

Source: Computed from field data, 2023.

The coefficient of membership to a cooperative society of smallholder maize farmers is negatively and positively influencing the use of cover cropping (-10.35) and soil tillage (1.884) as soil health management options, respectively; in relation to using crop rotation at a 1% level of probabilities for both soil health management options. This implies that membership of cooperative of the smallholder maize farmers in the area will increase their likelihood of making the choice of soil health management practices of using soil tillage and will decrease their likelihood of using cover cropping by the coefficients as opposed to using crop rotation. The results show that the more smallholder maize farmers belongs to cooperative societies, the more likely they are to employ soil tillage management options and the less likely they are to adopt cover cropping as a soil health management option relative to crop rotation. This result demonstrates a shared awareness of the advantages of crop rotation offers over monocultures in terms of yield enhancement, improved soil nutrient availability, and less pressure from weeds, insects, and diseases (Beal et al., 2019; Seifert et al., 2017).

The result also revealed that the coefficients of the smallholder maize farmers' off-farm income (4.07), farm size (4.47) and training in soil health management (2.50) positively influenced the use of cover cropping as opposed to using crop rotation at 1% level of probability. The coefficients of farming experience (-3.13) showed a negative influence on the use of cover cropping as opposed to using crop rotation as a soil health management option (p≤0.01). This implies that with more years of farming experience, the small-scale maize growers in the area tend to use cover cropping over crop rotation as a soil health management practices. This result also implied that training maize farmers on various soil health management options and increase in both their off-farm income and farm size would increase their likelihood of using cover cropping by 2.5%, 4.07% and 4.5%, respectively. This result confirms the findings of Asrat et al. (2004) and Nigussie et al. (2017), which found that a range of institutional factors, including farm size and experience, training, and proficiency with best agricultural practices, influence farmers' adoption of technologies.

The coefficients of the small-scale maize farmers' extension contact negatively influenced the soil health management options of cover cropping (-25.58), organic amendment (-18.14) and soil tillage (-20.01) as opposed to using crop rotation (p≤0.01). The findings imply that smallholder maize farmers in the research area who have access to extension contact are more likely to employ crop rotation soil health management options. According to Mponela et al. (2016), awareness creation training can serve as a substitute for inadequate formal training in agriculture by providing access to agricultural extension specialists' training.

The coefficients of maize growers' participation in the funded project positively influenced the use of cover cropping (7.70) (p≤0.01), organic amendment (1.26) at 10% level of probability and soil tillage (2.37) at 5% level of probability as opposed to using crop rotation. This indicates that the participation of smallholder maize growers in funded agricultural projects would enhance their use of cover cropping, organic amendment and soil tillage as compare to crop rotation.

The coefficient of the smallholder maize farmers' access to credit negatively influenced the use of cover cropping (-28.54) (p≤0.01), and organic amendment (-2.19) at a 10% level of probability as opposed to using crop rotation as a soil health management practice. This suggests that smallholder maize farmers' access to credit will reduce their likelihood of making the choice to use cover cropping and organic amendment as a soil health management option but will rather opt for the crop rotation option. According to Tiwari et al. (2008) opined that credit is a driver of agricultural techniques adoption among smallholder farmers.

Overall results have indicated that, sex of the farmer, age of the farmers, education level of the farmer, membership of cooperative societies, off-farm income, extension contacts, farm size, training in soil health management, access to credit, farming experience and participation in donor-funded project influenced cover cropping as soil health management practice. Organic amendement as a soil health management practice was influenced by extension contact, access to credit, participation in donor-funded project, and literacy ratio; while membership of cooperative societies, extension contacts, and participation donor-funded projects influenced soil tillage as soil health management practice.

**Constraint Militating Against the Maize Farmers' Choice of Soil Health Management Options**

The result in Table 3 revealed that the major constraints militating against the maize farmers' choice of soil health management options in the study area are the non-availability of labor with a mean value of 2.96, neighbourhood norms, customs, culture and traditional beliefs about soil health with a mean value of 2.69 and illiteracy of the farmer and poor access to and control of land with a mean value of 2.55, respectively. This finding underscores the importance of education, access to, and control over land resources. Comparably, data from throughout the Southern African continent has connected the low uptake of agricultural practices by smallholder farmers with a deficiency of resources that facilitate such adoption, including land (Adimassu et al., 2016), livestock unit size (Adimassau et al., 2014; Asrat et al., 2004), agricultural extension services (Paudel & Thapa, 2004), and credit (Tiwari et al., 2008).

**Table 3:** Distribution of constraints militating against the maize farmers choice of soil health management options.

| S/N | Constraints | Very Serious | Serious | Less serious | Not serious | Mean |
|-----|-------------|--------------|---------|--------------|-------------|------|
| **1** | Non-availability of credit facilities | 0 (0) | 23 (21.9) | 66 (62.9) | 16 (15.2) | 2.07 |
| **2** | Illiteracy of the farmer | 0 (0) | 30 (28.6) | 71 (67.6) | 4 (3.8) | 2.25 |
| **3** | Non-availability of organic amendment | 0 (0) | 14 (13.3) | 68 (64.8) | 23 (21.9) | 1.91 |

**Table 3:** *Continued...*

| S/N | Constraints | Very Serious | Serious | Less serious | Not serious | Mean |
|---|---|---|---|---|---|---|
| **4** | Inadequate/lack of extension programmes directed to meet the needs of the farmers in soil health management | 1 (1.0) | 8 (7.5) | 67 (63.8) | 29 (27.6) | 1.89 |
| **5** | Non-availability of labor | 27 (25.7) | 48 (45.7) | 29 (27.6) | 1 (1.0) | 2.96 |
| **6** | Insufficient knowledge of various soil health management options | 3 (2.9) | 32 (30.5) | 64 (61.0) | 6 (5.7) | 2.30 |
| **7** | Inadequate/lack of government policies to support soil health management | 0 (0) | 9 (8.6) | 57 (54.3) | 39 (37.1) | 1.71 |
| **8** | Neighbourhood norms, customs, culture and traditional beliefs about soil health | 12 (11.4) | 48 (45.7) | 45 (42.9) | 0 (0) | 2.69 |
| **9** | Poor access to and control of land | 8 (7.6) | 43 (41.0) | 53 (50.5) | 1 (1.0) | 2.55 |
| **10** | Lack of/or inadequate access to NGO programmes in soil health management options | 1 (1.0) | 12 (11.4) | 47 (44.8) | 45 (42.9) | 1.70 |
| **11** | Lack of/or inadequate support systems | 0 (0) | 6 (5.7) | 44 (41.9) | 55 (52.4) | 1.63 |
| **12** | Lack of/inadequate access to information on soil health management options | 12 (11.4) | 23 (21.9) | 29 (27.6) | 41 (39.0) | 2.06 |
| **13** | Low technical know-how of farmers in handling soil health management options | 0 (0) | 14 (13.3) | 49 (46.7) | 42 (40.0) | 1.73 |
| **14** | Lack of/or inadequate access to supporting institutional facilities | 0 (0) | 0 (0) | 36 (34.3) | 69 (65.7) | 1.34 |
| **15** | Inadequate facilities to facilitate soil health management options | 1 (1) | 1 (1) | 48 (45.7) | 55 (52.4) | 1.50 |
| **16** | Inadequate government policies in the input sector of soil health management practice | 0 (0) | 0 (0) | 40 (38.1) | 65 (61.9) | 1.38 |
| **17** | Tedious work required in soil health management practices | 0 (0) | 32 (30.5) | 61 (58.1) | 12 (11.4) | 2.19 |

Source: Computed from field data, 2023.

Other major constraints are insufficient knowledge of various soil health management options (2.30), tedious work required in soil health management practices (2.19), non-availability of credit facilities (2.07), lack of/inadequate access to information on soil health management options (2.06), non-availability of the organic amendment (1.91), inadequate/lack of extension programmes directed to meet the need of the farmers in soil health management (1.89), low tech-

nical know-how of farmers in handling soil health management options (1.73), inadequate/lack of government policies to support soil health management (1.71), lack of inadequate access to NGOs programs in soil health management options (1.70), lack of inadequate support systems (1.63).

The least constraining factors militating against the maize farmers' choice of soil health management options in the study area are inadequate facilities to facilitate soil health management options (1.50), inadequate government policies in the input sector of soil health management practice (1.38) and lack of/or inadequate access to supporting institutional facilities (1.34)

### Conclusion and Policy implications

This study examined the soil health management options among smallholder maize farmers in Nigeria. The study concludes that there is a significant relationship between the maize farmers' choice of soil health management options and some socio-economic characteristics, farm-specific and institutional factors. The following recommendations are made that can lead to policy formulations:

• Younger maize farmers are to be encouraged by appropriate Authorities and Ministries (Agriculture, Youth) into using soil health management practices especially cover cropping to realise improved production.

• Smallholder maize farmers can be encouraged to improve their farm size to be more commercialized.

• Smallholder farmers can be encouraged to diversify into non-farm enterprise(s) that can help them generate more income to support their farming activities especially soil health management.

• Participation in agricultural funded projects would be a good driver of implementing soil health management policies or technologies.

• Training in soil health management is a major driver of adopting soil health management practices.

• Appropriate authorities with the mandate of policymaking must foster an environment that would support the farmers ability to invest in soil health management solutions.

• Labour saving technologies should be more encouraged for uptake by maize farmers.

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### Conflict of Interest

There is no known conflict of interest.

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Appendix I

**Table 4: Description, Measurement and Expected Signs of the Dependent and the Independent Variables (Regressors) in the Multinomial Logit Regression Analysis**

| Explanatory Variables | Description | Unit of measurement | Parameters | Expected Design |
|---|---|---|---|---|
| **Soil health management options/practices** | $Y_0$ = 1 for crop rotation; $Y_1$ = 2 for Cover Cropping; $Y_2$ = 3 for Organic Amendment; $Y_3$ = 4 for Soil Tillage | Categorical data | | |
| **Sex of the farmer ($X_1$)** | The sex category of the farmer. | Dummy (measured as 1 for male, 0 otherwise) | $\beta_1$ | + |
| **Age of farmer ($X_2$)** | The number of years the farmer has been living. | Years | $\beta_2$ | + |
| **Education level ($X_3$)** | The number of years spent in formal schooling. | Number of years | $\beta_3$ | + |
| **Membership of cooperative societies ($X_4$)** | The farmer belonging to co-operative societies. | Dummy (measured as 1 if yes, 0 otherwise) | $\beta_4$ | + |
| **Off-farm income ($X_5$)** | The amount of money received from off-farm activities in the cropping season. | Naira | $\beta_5$ | + |
| **Extension contact ($X_6$)** | The extension contact in the cropping season. | Qualitative binary variables 1 if yes,0 if no | $\beta_6$ | + |
| **Farm size ($X_7$)** | The area of farm size the farmer cultivated to maize. | Hectares | $\beta_7$ | + |
| **Training in soil health management ($X_8$)** | The training in soil health management by the farmer. | Qualitative Binary Variables 1 If Yes,0 If No | $\beta_8$ | + |
| **Access to credit ($X_9$)** | Access to credit by the farmer. | Qualitative binary variable assigned 1 if have access, 0 if no access | $\beta_9$ | + |
| **Farming experience ($X_{10}$)** | The number of years the farmer has been into maize farming. | Years | $\beta_{10}$ | + |
| **Participation in funded project ($X_{11}$)** | If participating in funded agricultural projects. | Qualitative Binary Variables 1 If yes, 0 Otherwise | | |
| **Literacy ratio ($X12$)** | The ratio of the number of people that can read and write to the total number of people in the household. | | | |