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Land tenure, land use antecedents, and willingness to embrace resilient farming practices among smallholders in Nigeria

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Introduction: Shifting to Resilient Farming Practices (RFPs) is crucial in building resilience to climate change and reducing greenhouse gas emissions. This study seeks to assess how land tenure and land-use antecedents affect the willingness of smallholder farmers (SHFs) to embrace RFPs in Nigeria.

Methods: The respondents were selected in a multi-stage random sampling process across 16 States and 192 farming communities, yielding a final sample of 1,344 SHFs that cultivate maize and/or rice. The RFPs include a set of good agricultural practices (GAPs), GAPs with manure application and GAPs with agroforestry as against the status quo of conventional agricultural practices. Data were analyzed using descriptive and regression methods.

Results and discussion: The results show that 20% of the respondents were willing to adopt agroforestry while 25% and 37% were willing to adopt GAPs with and without manure application respectively. On the other hand, about 18% preferred to stick to the status quo. The multinomial logit result shows that RFPs were significantly influenced by age, education and gender of the household head, membership of the cooperative, household size, land acquisition through inheritance and purchase, newly deforested land, mechanical clearing, and bush burning. The study suggests that land titling and some level of perceived tenure security are necessary conditions for smallholder farmers to embrace RFPs in Nigeria.

KEYWORDS

land tenure, land-use antecedents, resilient farming practices, multinomial logit, Nigeria

1. Introduction

Numerous reports (Foley et al., 2011; Seufert et al., 2012) have emphasized the need to address the challenges of a rapidly growing population, urbanization and rising challenge to meet domestic food requirements in Africa and the whole world at large while simultaneously minimizing the global environmental impacts (Godfray et al., 2010; Aggarwal, 2014). Early attempts to address the need to produce enough food to feed a rapidly growing World population led to the invention of synthetic materials and genetically modified organisms, including chemical fertilizers, pesticides, plant growth regulators, hormones, livestock feed additives and antibiotics, aiming to improve crop yield and livestock productivity. The use of these synthetic materials was promoted in extension messaging and policy support that emphasize mechanization (heavy tillage), irrigation, and cultivation of improved varieties of mostly internationally traded crops in monoculture, in pursuit of the so-called *green revolution* in Africa. Consequently, fertilizer use in Africa rose steadily from barely about 0.7 million tons in early 1960's to 3.3 million tons by 1980, 4.3 million tons by 2005 and 6.8 million tons by 2019. Similarly, pesticide use doubled within the last two decades, rising from 0.66 million tons in 1990 to about 1.1 million tons by 2019. In Nigeria, fertilizer use rose steadily from 183,000 tons in 1995 to 259,104 tons in 2005 and stood at 686,200 tons by 2019.

Ironically, while agrochemical use is growing rapidly in Africa, the impact on crop yield is mixed! For example, while the average yield of cereals as well as pulses in Africa increased by 20 and 34% respectively between 2005 and 2019, those of roots and tubers as well as vegetables declined by 4.2 and 3.4% respectively over the period (FAOSTAT data, 2022a). In Nigeria, yields of most crops have largely been on declining trends since 2010. For example, average yields of vegetables, roots and tubers, pulses and cereals declined by 51.2, 37.3, 33.6, and 10.5% between 2010 and 2019 despite the fact that fertilizer use during the period became almost double (FAOSTAT data, 2022a). This calls to question the appropriateness of the rising reliance on fertilizer use in Nigeria, more so that this has been at the center of a controversial fertilizer subsidy programme. Moreover, there are growing concerns that rising dependence on agrochemicals and synthetic materials among smallholder farmers in Africa exert huge negative impacts on the environment and human health. This includes an increase in Greenhouse Gases (GHGs) emissions that contribute to global warming and climate change (IPCC, 2022), and pollution that lead to air quality issues as well as contamination of food products, groundwater, fresh water, and oceans, among others (Tal, 2018). The consequence has been rising incidences of gastroenteritis and non-communicable diseases (NDCs) such as cancer and chronic respiratory diseases, which account for about 31.4 million premature deaths annually in the developing countries (WHO, 2022).

At the foundation of the rising agrochemical dependence among smallholder farmers in Nigeria, and Africa at large, is an excessive reliance on traditional slash and burn farming systems that expose farmland to erosion agents (Ubuoh et al., 2017). This land exposure to erosion agents coupled with rising resort to heavy tillage, monoculture farming, and continuous cropping have been a major cause of loss of soil health in Africa. The consequences have been massive deforestation, loss of soil fertility, land degradation, loss of ecosystems health and declining agricultural productivity (MEA, 2005; FAO, 2016a). The combined effects of these include low and declining yields leading to low income and poverty, food and nutrition insecurity, and growing dependence on fertilizer and plant growth hormones to address the declining soil fertility. Unfortunately, excessive and/or improper use of agrochemicals tends to deliver unsafe foods and negatively affects human health as well as the environment.

Another dimension to the low and declining yield associated with Africa's smallholder agriculture is the fact that most increases in food production over the years are achieved mostly through area expansion. A close examination of Nigeria's agricultural data, for example, shows that the agricultural area, which was about 50.4 million hectares in 1980, rose steadily to 66.2 million hectares by 2,000 and stood at 69.1 million hectare by 2019 (FAOSTAT data, 2022b). This shows that an average of 0.48 million hectare of forest area are being converted to agricultural land on an annual basis to meet the growing demand for food in Nigeria. This forest conversion is contributing to agricultural GHGs emissions that cause global warming and climate change. It is associated with an estimated 46.0 megatons of CO_2 equivalent GHGs emissions annually with chemical fertilizer use also contributing 2.2 megatons of CO_2 equivalent GHGs emissions in 2019. Beyond GHGs emissions, forest conversion to agricultural land destroys wildlife habitats and leads to loss of ecosystems health, which negatively affect associate livelihoods options. Unfortunately, smallholder farmers are those most adversely affected by climate change in Africa, while women and other vulnerable groups in local communities are the worst affected by livelihood losses due to deforestation and loss of ecosystem health (Morton, 2007).

It is against the above background, and a desire to reposition agriculture and food systems in Africa to meet the growing food needs of its rapidly growing population in the face of climate change and rising resource scarcity, that adoption of resilient farming practices (RFPs) is being promoted. By RFP, reference is made to farming practices aimed at enhancing agricultural productivity with minimal harm to ecosystems, animals, or humans. For sub-Saharan Africa (SSA) and most developing countries, the need for a shift to RFPs cannot be overemphasized because it has greater potential to withstand stressful events that are climate change-related. Despite this potential, adoption of RFPs remains generally low, particularly in SSA, Nigeria inclusive. This may, however, not be unconnected with insecure land tenure and property rights, which is often cited as one of the barriers to the adoption of improved technology and investment in land development in Africa (Liniger et al., 2011; Byamugisha, 2013). It is pertinent to note that without secure tenure, farmers often do not have the emotional attachment to the land they cultivate and would thus, not invest in land improvement that can enhance their productivity in the long run and promote sustainable development (Deininger, 2003). Thus, farmers' socioeconomic and institutional factors—Land tenure and land-use antecedents are important factors in agricultural production.

The RFPs are contextualized in this study as a set of good agricultural practices (GAPs), GAPs with manure application, and GAPs with agroforestry. Good agricultural practices are bundles of farming operations that seek to address the issue of food safety and quality of agricultural products during the on-farm and post-production processes, as well as, to enhance environmental and socioeconomic sustainability (FAO, 2016b; Lotz et al., 2018). The GAPs include combined use of zero/minimum tillage, early maturing and/or drought-tolerant varieties, mulching, crop rotation, mixed cropping, retaining refuse on the soil rather than burning, cover cropping, manuring (green manuring, application of farmyard manure, and compost), micro-dosing of fertilizer where absolutely necessary, integrated weed and pest management, improve water use efficiency, water harvesting, among others.

Gleaning through the literature, we found that only a few studies (Owombo et al., 2015) have been conducted to investigate whether or not tenure security has effects on willingness to embrace

RFPs in Nigeria. The paucity of information on the effects of land tenure and land-use antecedents on RFPs necessitates the study. Therefore, this study seeks to answer this research question: What are the socioeconomic factors, land tenure, and land-use antecedents that drive the willingness to embrace the RFPs among the smallholders in Nigeria? Arising from the foregoing, the goal of this study is to determine the influence of land tenure and land-use antecedents on the willingness to embrace resilient farming practices among smallholders in Nigeria. The results show that land tenure and land-use antecedents play very crucial roles in farmers' choices to embrace resilient farming practices. In the next section, we describe the method in which we have the study area and study design. Section three presents the analytical framework that comprises key variables measurement and method of data analysis. Section four describes and discusses the results; then we conclude with the implications of our findings in the final section.

2. Methodology

2.1. Study area

The study was conducted in selected farming communities reputed for maize and rice production across the six geopolitical zones, and covering five of the seven Agro-ecological zones (AEZs) of Nigeria (Figure 1). Nigeria is situated in the West African sub-region and lies between longitudes 3and 14 and latitudes 4 and 14. It has a landmass of 923,768 sq. km. Nigeria shares a land border with the Republic of Benin in the west, Chad and Cameroon in the east, and Niger in the north. Its coast lies on the Gulf of Guinea in the south and it borders Lake Chad to the northeast.

Administratively, it is made of 36 States and the Federal Capital Territory (FCT). The States are commonly grouped into six (6) geopolitical zones: Northeast, Northwest, North-central, Southeast, Southwest, and South-south geopolitical zones. Nigeria is covered by three types of vegetation: forests (where there is significant tree cover), savannahs (insignificant tree cover, with grasses and flowers located between trees), and montane land; and is commonly divided into seven agro-ecological zones; namely the Sahel Savannah, the Sudan Savannah and the Northern as well as Southern Guinea Savannahs. Other AEZs include the Derived Savannah, the Mid-Altitude and the Humid Rainforests, all of which are suitable for the cultivation of maize and rice, among several other crops like cassava, yams, etc.

2.2. The study design

The study was part of the FUNAAB-RAAF-PASANAO project implemented by the Federal University of Agriculture, Abeokuta (FUNAAB) in partnership with the National Cereals Research Institute, Baddegi, and funded by the Economic Community of West African States (ECOWAS). The central focus was on incentivising adoption of climate-smart agricultural practices in cereal production in Nigeria. The data were collected in a Nationwide Farm Household Survey conducted across the six geopolitical zones in Nigeria, focusing on maize and rice farmers. The respondents were selected in a three-stage sampling process, described as follows:

Stage I: Purposive selection of 16 States (Figure 1) that have been the leading rice and/ or maize producers in Nigeria (excluding conflict-prone areas), based on production statistics from NBS (2016).

Stage II: Purposive selection of three (3) Agricultural Blocks per State per crop from the main rice and maize producing areas of the State, and two (2) Extension Cells per block—that is, six (6) blocks per state, 12 Cells per State and 192 Cells in all.

Stage III: Proportionate stratified random selection of seven (7) Rice and maize farmers from members of Rice/Maize farmers' association in each of the selected Cells.

This process yielded 1,344 households of rice and maize farmers, from which a complete dataset was collected through personal interviews of the farmer and other farming members of their households. Data were collected on a wide range of issues, including the households' socio-economics, resilient farming practices, land-use choices, land titling, and tenure type on farmland cultivated during the 2016/17 farming season.

3. Analytical framework

Analysis of farmers' choice of RFP was analyzed within the framework of a multinomial logit (MNL) regression model, following Greene (2012) and Danso-Abbeam et al. (2017). The theoretical foundation is cast within the utility maximization framework in which the smallholder farmers, which in Africa are both producers and consumers of farm produce, seek to maximize their utility in their resource allocation choices subject to the usual constraints relating to available production technology and budget.

Suppose a smallholder farmer i is to make a choice among j unordered alternatives, and the utility of choice j is given as:

$$U_{ij} = \mathbf{Z}_{ij}^{'}\beta_j + \varepsilon_{ij} \ldots \tag{1}$$

Where

U_{ij} represents the latent variable defining the level of expected utility that farmer i derived from choice j;

$\boldsymbol{Z}$ is a vector of regressors that influence the level of the utility, which may include attributes of the choice set ($\mathrm{A_j}$) and the farmers' characteristics ($\mathrm{X_i}$);

β is a set of parameters that reflect the impact of changes in Z_{ij} on U_{ij}, and

ε_{ij} is the stochastic term that is assumed to be independently and identically distributed.

If the farmer makes a particular choice j, then it follows that U_{ij} is the maximum among the J utilities. Hence, the statistical model for analysis of the decision problem is driven by the probability that choice j is made, which is:

$$\text{Prob}\left(\mathrm{U_{ij}} > \mathrm{U_{ik}}\right) \text{forallotherk} \neq \mathrm{j} \ldots \tag{2}$$

Following (Greene, 2012), if Y_i is a random variable that indicates the choice made and the attributes are embedded in the

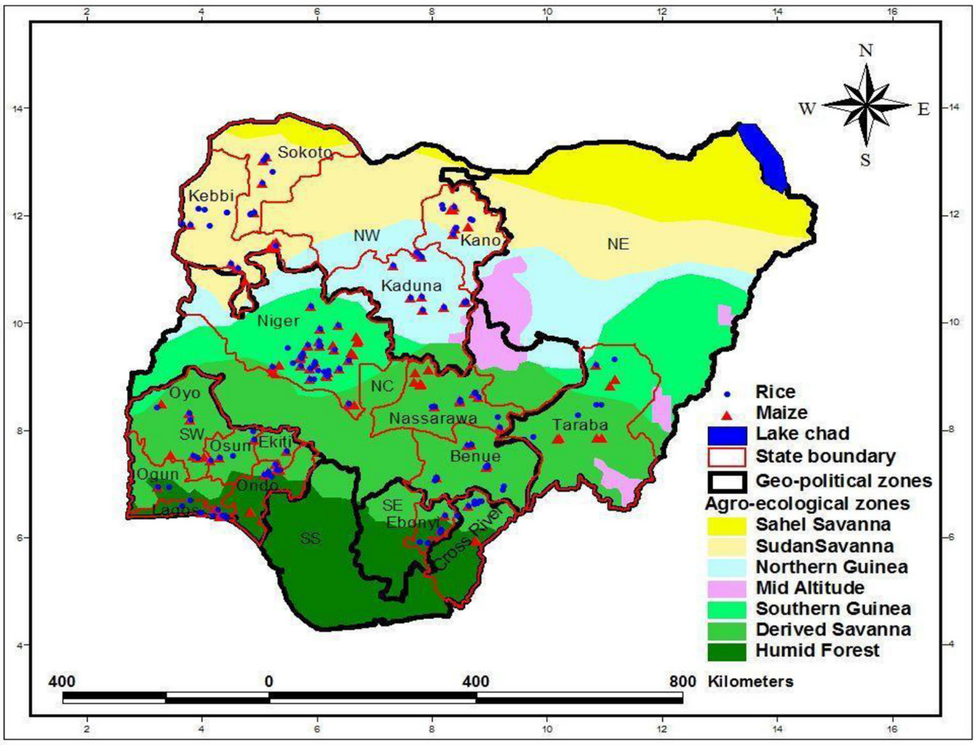


FIGURE 1
Map of Nigeria showing the study locations across the agro-ecological and geopolitical zones. Source: Field survey; 2017.

choice set, then the probability of that choice can be defined within the framework of MNL model as:

$$\mathrm{Prob}\left(\mathrm{Y_i} = \mathrm{j}\middle|\mathrm{X_i}\right) = \mathrm{P_{ij}} = \frac{e^{\beta_i' X_j'}}{1 + \sum_{k=1}^{J} e^{\beta_i' X_k'}} (\mathrm{j} = 0, 1, ..., \mathrm{J}) \quad (3)$$

This yields a set of J + 1 probabilities that must necessarily sum up to unity. Therefore, one of the J + 1 parameters is redundant, since only J parameters are needed to estimate the full set of the model parameters in Equation 3. Hence, Greene (2012) proposed a normalization by setting the coefficient vector, $\beta_0 = 0$. In this application, j = 0 where a farmer chooses to maintain the status quo: that is, decline to adopt any of the J RFPs.

Applying this normalization[1], the probability that a farmer will maintain status quo is:

$$\mathrm{Prob}\left(\mathrm{Y_i} = 0\right) = \mathrm{P_{i0}} = \frac{e^{\beta_0' X_j'}}{1 + \sum_{k=1}^{J} e^{\beta_i' X_k'}} = \frac{1}{1 + \sum_{k=1}^{J} e^{\beta_i' X_k'}} \quad (4)$$

Similarly, the probability that a farmer will choose one of the J bundles of RFPs as against maintaining a status quo will be given as:

$$\mathrm{Prob}\left(\mathrm{Y_i} = \mathrm{j}\right) = \mathrm{P_{ij}} = \frac{e^{\beta_i' X_j'}}{1 + \sum_{k=1}^{J} e^{\beta_i' X_k'}} (\mathrm{j} = 1, ..., \mathrm{J}) \quad (5)$$

1 Because $\beta_0 = 0$: $e^{\beta_0' X_j'} = 1$ and $\beta_j - \beta_0 = \beta_j$.

Therefore, setting j = 0 as the reference category and combining equations 4 and 5, the logs of odd ratios will be given as:

$$\ln\left[\frac{P_{ij}}{P_{i0}}\right] = X_i'\left(\beta_j - \beta_0\right) = X_i'\beta_j (j = 1, ..., J) \quad (6)$$

Equation (6) is the estimating equation in a MNL model of unordered choice set (Greene, 2012; Danso-Abbeam et al., 2017). In this application, we have three RFP options (j = 1, 2, 3) and maintain the status quo (j = 0) as the unordered choice set. The dependent variable in the MNL is the log of the odds of choosing one of the bundle of RFPs alternatives relative to the base or reference alternative, which is to maintain the status quo.

The MNL model assumes that the odds of choosing one option over another is Independent of the presence or absence of other Irrelevant Alternatives (IIA) in the choice set. This assumption is called the Independence of Irrelevant Alternatives (IIA). If the IIA assumption is not violated, it allows the choice of $_j$ alternatives to be modeled as a set of *j-1* independent binary choices, in which one alternative is chosen as a reference category and the other $_{j\text{-}1}$ compared against it, one at a time. The MNL model allows farmers' socioeconomic characteristics to have different effects on the relative probabilities between any two choices.

3.1. Measurement of key variables

The main outcome variable for this study is the choice of RFPs, including GAPs, GAPs with manure and GAPs with Agroforestry as against the status quo (conventional agricultural practices), while land tenure, land-use antecedents, and a number of traditional socio-economic predictors of adoption of RFPs are the explanatory variables.

Hence, the outcome variable is described as follow:

$Y_i = 0$ if a farmer chose to maintain the status quo ($j = 0$);
$Y_i = 1$ if a farmer chose GAPs with agroforestry ($j = 1$);
$Y_i = 2$ if a farmer chose GAPs with manure application ($j = 2$); and
$Y_i = 3$ if a farmer chose GAPs ($j = 3$).

Land tenure, on the other hand, was measured in the form of tenure type and tenure security.

3.1.1. Tenure type

This refers to the mode of land acquisition, categorized into four—Personally inherited lands, purchased lands (both of which exclusive use and transfer rights apply), leasehold (land leased from a third-party), and communal (land jointly owned/controlled by extended family or other community members, to which only use right is accorded). Meanwhile, communal land was dropped as the reference tenure-type variable.

3.1.2. Tenure security (legal)

In view of provisions of Nigeria's Land Use Act (2004), a tenure is *de jure* secure, if it is duly registered with the land registry and/or the Governor of the State where it is located issues the holder a certificate of occupancy. Holders of inherited and/or purchased lands that are not in dispute, even though commonly perceived as *de facto* secure, may be affected by unfair expropriation of such lands.

Evidence from the result of previous research (Nkamleu and Manyong, 2005; Teklewold et al., 2013; Nkegbe and Shankar, 2014) indicated that factors that affect the decision of farm households to choose new innovations are socioeconomic, demographic, institutional, and plot-level characteristics. A range of explanatory variables that influence the choice of resilient farming practices by a farmer was identified based on the review of related literature. Accordingly, the descriptions of explanatory variables were indicated in Table 1.

4. Results and discussions

Table 2 presents the socioeconomic distribution of smallholder farmers in Nigeria by geopolitical zones. The result revealed that the average age of a typical respondent was 45 years. The distribution of respondents by marital status has shown that 91% of the respondents were married at an average. Farm households in the study area had an average of nine persons; this may be due to their literacy level and the number of wives or extended family members residing with a typical nuclear family.

Similarly, the distribution of the farmers by education has shown that respondents in the Southern Geopolitical Zone (GPZ) had more formal years of education as compared to those in the Northern GPZs with respondents in the Northwest GPZ having the lowest (6 years) level of formal education. This implies that smallholder farmers in the southern GPZs are more likely to be willing to embrace RFPs when compared to their northern GPZs counterparts. The result from the distribution of respondents by farm size has shown that an average respondent in the country has a farm size of 2.46 ha. In the same vein, the distribution by land fragmentation and crop diversity has shown that about 27% of the respondents' farmland is fragmented while about 12% of the farmers diversified their crops.

4.1. Resilient farming practices among the smallholder farmers

The result showing the preference for resilient farming practices among smallholder farmers in Nigeria is presented in Figure 2. The smallholder farmers made their choices from the three RFPs options; GAPs, GAPs with manure application, and GAPs with agroforestry as well as the status quo of conventional agricultural practices for those who are not willing to choose any of the RFPs. As shown in Figure 2, the majority (37%) of the respondents were willing to adopt GAPs; this can possibly be due to the bulky nature of farmyard manure and/or animal dung coupled with the fact that large quantities might be required which may not be readily available. On the other hand, about 25 and 20% of the smallholder farmers were willing to adopt GAPs with manure application and GAPs with agroforestry, respectively while only 18% of the farmers were conservative and preferred to continue with their conventional farming practices. The relatively low value for agroforestry can be a result of its capital-intensive nature.

4.2. Land-use antecedents among the smallholder farmers

Figure 3 presents the result of land-use antecedents used by farmers across all the GPZs in Nigeria. Out of the six land-use antecedents considered in this study, application of inorganic fertilizer was used by 69.44% of the farmers across the GPZs. The run-off from the soil after heavy rains runs into rivers and other waterways, which pollute the aquatic life form and drinking sources. This was closely followed by mono-cropping (69.11%). Persistence cropping of a single crop on a piece of land has the implication of depleting the soil nutrient and ultimately leading to poor yield (Reynolds et al., 2015). The least land-use antecedents used by farmers were newly deforested forests for agricultural expansion. The implication of deforestation and the loss of trees that serve as windbreaks is that it results in the loss of the topsoil thus exposing the soil to harsh weather conditions (Borrelli et al., 2017).

TABLE 1 Definitions of study variables and their descriptive statistics.

Explanatory variables	Nature	Mean	Std dev
Land-use antecedents			
Newly deforested land (1 if done; 0 otherwise)	Dummy	0.03	0.14
Mechanical clearing (1 if done; 0 otherwise)	Dummy	0.40	0.42
Bush burning (1 if done; 0 otherwise)	Dummy	0.36	0.40
Herbicide use (1 if used; 0 otherwise)	Dummy	0.65	0.41
Fertilizer application (1 if used; 0 otherwise)	Dummy	0.69	0.39
Land tenure and land-related variables			
Lowland (1 if lowland; 0 if upland)	Dummy	0.45	0.49
Registered freehold (1 if registered; 0 otherwise)	Dummy	0.08	0.23
Land on inheritance (1 if inherited; 0 otherwise)	Dummy	0.55	0.47
Land on purchase (1 if purchased; 0 otherwise)	Dummy	0.14	0.32
Land on leasehold (1 if leased; 0 otherwise)	Dummy	0.21	0.39
Land on communal (1 if communal land; 0 otherwise)	Dummy	0.10	0.28
Farm size (ha)	Dummy	2.46	4.30
Simpson index of land fragmentation[a]	Continuous	0.27	0.28
Simpson index of crop diversity	Continuous	0.12	0.16
Socio-economic characteristics			
Age in years	Continuous	44.75	11.95
Age squared	Continuous	2145.63	1130.78
Gender (1 if Female; 0 otherwise)	Dummy	0.09	0.28
Household size (Number of persons	Continuous	9.08	6.39
Education (years)	Continuous	7.79	5.86
Institutional variables			
Extension service (1 if Access; otherwise 0)	Dummy	0.64	0.48
Belongs to cooperative society	Dummy	0.45	0.49
Location variables			
Location is Southwest	Dummy	0.22	0.41
Location is South-south	Dummy	0.04	0.21
Location is Southeast	Dummy	0.07	0.25
Location is Northeast	Dummy	0.09	0.28
Location is North central	Dummy	0.28	0.45
Location is Northwest	Dummy	0.31	0.46

[a]Simpson index of land fragmentation $\left[SI = 1 - \frac{\sum a^2}{(\sum a)^2}\right]$ has a value between 0 and 1. SI = 0 indicates complete land consolidation, i.e., the farm operates with only one parcel. Increase in SI value implies the farmland becomes more fragmented.
Source: Field survey; 2017.

4.3. Tenure types and tenure security

As shown in Figure 4, the proportion of parcels acquired by inheritance is higher in the northern part of the country as opposed to the southern GPZs with northeast, north central and northwest having 68, 67, and 60%, respectively. The proportion of parcels acquired by outright purchase was extremely low in the southwest (9%) and north central (7%), pegging the average for the whole country at 14%.

This corroborates the findings of Adeniyi (2013) who found that 24.0% of the households were on leasehold while 10.0 and 14% were cultivating communal and purchased lands, respectively. The proportion of parcels held on leasehold and a communal agreement was found to be extremely (8.0 and 3.0%, respectively) lower among farmers drawn from northwest and northeast while farmers held

TABLE 2 Socioeconomic distribution of farmers in Nigeria by geopolitical zones.

Variables	SS	SE	SW	NC	NW	NE	All
Age (years)	45	46	48	43	45	42	45
Marital status	0.93	0.93	0.92	0.86	0.95	0.88	0.91
Household size (No)	7	7	6	10	11	10	9
Education (years)	8	9	9	8	6	9	8
Gender	0.11	0.05	0.17	0.07	0.06	0.04	0.09
Farm size (ha)	1.71	1.99	3.28	2.81	1.94	1.87	2.46
Land fragmentation	0.23	0.18	0.36	0.22	0.28	0.22	0.27
Crop diversity	0.11	0.13	0.12	0.12	0.13	0.12	0.12

Source: Field Survey; 2017.
NC, North central; SS, South-South; SE, Southeast; SW, Southwest; NE, Northeast; NW, Northwest.

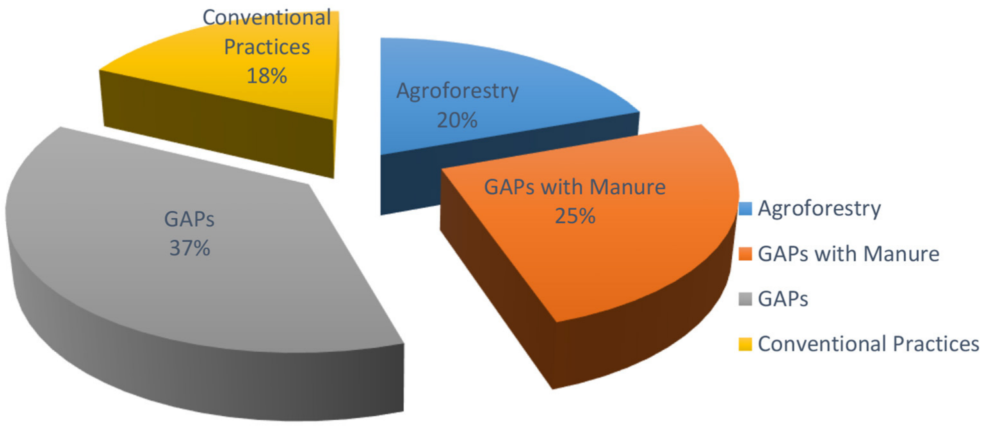


FIGURE 2
Preference for RFPs among Smallholder Farmers in Nigeria. Field survey; 2017.

49% of their parcels on a leasehold agreement. Figure 5 also shows that only 4% of the sampled farmers had their land registered with the land registry. This implies that only a few out of the sampled smallholder farmers had *de jure* tenure security while the majority had insecure tenure, which can lead to eviction from their farmland and regular harassment by the land grabbers. The result is closely in line with the findings of Birner and Okumo (2012) and Shittu et al. (2018) who found that only three percent of the land in Nigeria are formally registered.

4.4. Land tenure and willingness to embrace resilient farming practices

The multinomial logistic regression provides evidence with respect to the influence of various hypothesized determinants on the resilient farming practices in Nigeria. Results in respect of the influence of land tenure and land-use antecedents—newly deforested land, mono-cropping, mechanical clearing, bush burning, use of fertilizer and herbicide, registered freehold, land acquisition through purchase, lease, and communal are found in the first 10 rows of Table 3. Three categories (GAPs with agroforestry, GAPs, and GAPs with manure application) of resilient farming practices were used in this study with the conventional farming practice as a base outcome for the analysis. The log pseudo-likelihood (−3558.47) can be used in the comparison of nested models while the Wald chi-square of 230.75 with a p-value $<$ 0.01 suggests that the model has a strong explanatory power i.e., the model as a whole fits significantly better than a model with no predictors.

4.5. Land tenure and land-use antecedents influence on willingness to embrace RFPs

The coefficients of mechanical clearing and newly deforested land are significantly positive at 5 and 1% levels across the three RFPs except that of agroforestry under newly deforested land. These results clearly show that the farmers that engage tractor services on their farms, as well as cultivating a virgin or secondary forest, are more likely to be willing to embrace GAPs with agroforestry, GAPs, and GAPs with manure application on their respective farms. This can be because the farmers want to try the innovations and see what they stand to gain from the RFPs. The coefficient of fertilizer used is negative and statistically significant at a 5% level for both the GAPs and GAPs with manure application. This shows that the farmers

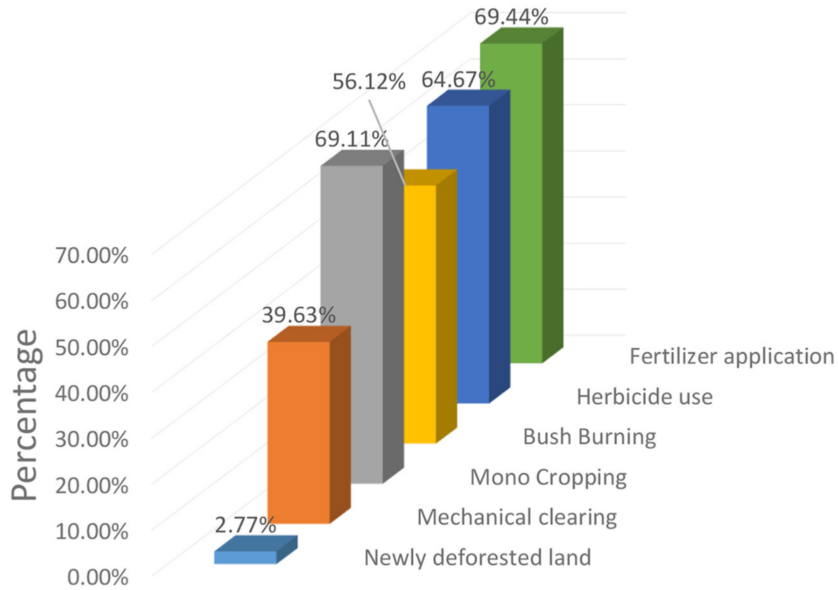
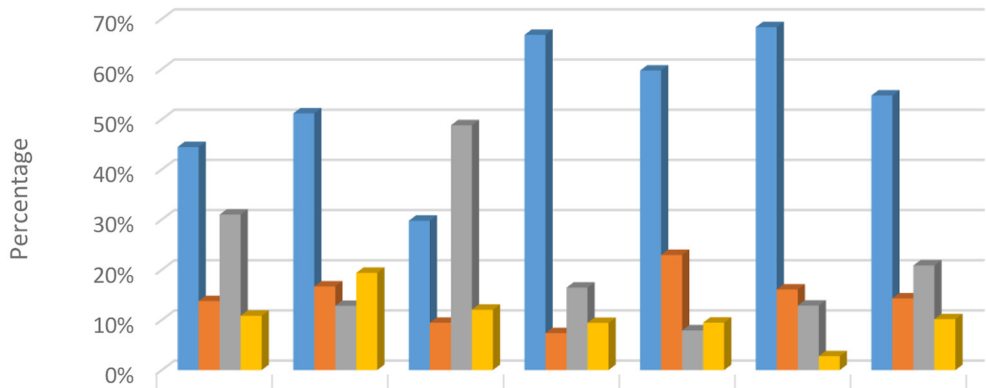


FIGURE 3
Land-use antecedents among the smallholder farmers.



	SS	SE	SW	NC	NW	NE	All GPZs
Inherited	44%	51%	30%	67%	60%	68%	55%
Purchase	14%	17%	9%	7%	23%	16%	14%
Leasehold	31%	13%	49%	16%	8%	13%	21%
Communal	11%	19%	12%	9%	9%	3%	10%

FIGURE 4
Tenure type by geopolitical zones.

that use inorganic fertilizer are less likely to embrace the two earlier-mentioned RFPs. These results are in order as manure and other GAPs such as planting of leguminous cover crops will serve the same purpose with synthetic fertilizer (Roth and McCarthy, 2013).

The coefficients of the inherited and purchased lands are positive and significant at 1, 5, and 10% levels, respectively across the three RFPs. This shows that the willingness to embrace RFPs rises with the acquisition of land through the personally inherited and/or purchased (freehold) as opposed to cultivating communal land. These results are consistent with the evidence in Shittu et al. (2018), who found that smallholder farmers embraced agricultural practices with climate-smart agriculture potentials when they were confident that their title to farmland is well-defined and *de facto* secure. It also corroborates the evidence from Besley (1995), that secure land tenure provides incentives for farmers to invest and make improvements to their land to ensure full utilization of land.

Similarly, the coefficient of the land titling (*de jure*) is positive and significant across the two RFPs, namely; GAPs with agroforestry and GAPs. These results imply that secure land tenure will increase the willingness to embrace agroforestry and

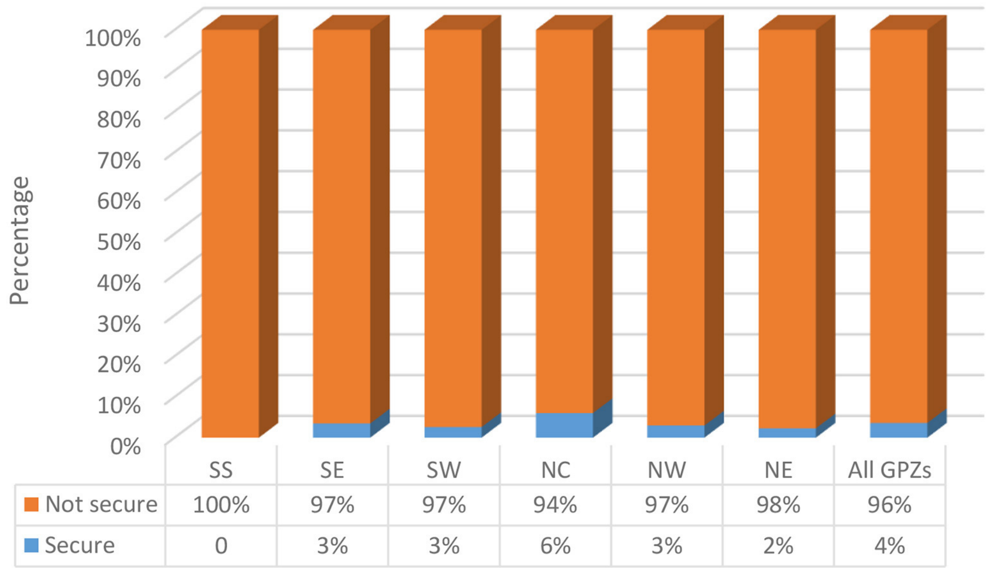


FIGURE 5
Tenure Security by GPZs.

GAPs when compared to the reference category of not having a secure tenure. This finding is in line with the finding of Nigussie et al. (2017) and Asaaga et al. (2020) who found that secure tenure enhanced agricultural investments in Ghana and Ethiopia, respectively.

4.6. Socio-economic and institutional factors influencing willingness to embrace RFPs

Results in Table 3 show that there is a significant and positive relationship between the age of the household head and the willingness to embrace GAPs with agroforestry, even though the relationship is not linear as confirmed by the negative coefficient of the age-squared variable. This further shows that an increase in age will increase the likelihood of embracing agroforestry among smallholders in Nigeria. However, as the household heads grow older in life, their willingness to embrace agroforestry reduces; hence, contradicting the popularly-placed opinion that farmers tend to invest more in land development because of their long experience in farming operations. This result, however, supports the findings of Owombo et al. (2015) and Abdulai et al. (2011) who found that the older a farmer is the less likely he would adopt new technology.

The coefficient of household head education is significantly positive at 5% across the three RFPs. This shows that an increase in the level of education of household heads will increase the likelihood of embracing RFPs. This suggests that the level of formal education has a great impact on increasing the technology adoption of RFPs. Evidence in the literature (Morton, 2007; Nurie et al., 2013; Kehinde et al., 2022) shows that households with higher education tend to invest more in land improvements. The result also agrees with Liniger et al. (2011) who assessed agroforestry practices as a land-use option for sustainable agricultural production in Osun State and found that level of education is a determinant of agroforestry adoption. On the contrary, Moronge and Nyamweya (2019) concluded that the level of education does not necessarily influence the adoption of agroforestry practices, though it appears that the adoption of new technologies requires a certain minimum level of education, but not necessarily the knowledge that is acquired through formal education.

On the contrary, the coefficient of the gender of the household head is negative across the three RFPs but statistically significant at 5 and 10%, respectively for GAPs and GAPs with manure. This shows that being a female-headed household will reduce the willingness to embrace RFPs among the smallholder farmers in Nigeria. This result can be because women usually do not have access to productive resources and agricultural services as opined by Bifarin et al. (2013). The coefficient of membership of cooperatives is significant and positive for both GAPs at 10% levels. This is in agreement with the expectation of the study that membership of the association would have a positive relationship with the willingness to embrace the GAPs. The implication is that access to credit opportunities of smallholder farmers through their cooperative society serves as an avenue to stimulate their investment propensity (Ajadi et al., 2015).

The coefficient of household size for GAPs with manure was negative and significant at a 1% level. This shows that an increase in the household size will reduce the likelihood of farmers embracing GAPs with manure, though we expect that there should be a positive relationship between the two because of the labor-intensive nature of GAPs with manure. For GAPs, the coefficient of the farm size was positive and significant at the 5% level. This shows that an increase in the farm size will increase the likelihood that farmers will embrace GAPs. The likely explanation is that the farmers with large farm sizes are usually into commercial farming and tend to

TABLE 3 Influence of land tenure and land use antecedents on RFPs.

Explanatory variables	Agroforestry		GAPs		GAPs with manure	
	Coef.	z	Coef.	z	Coef.	Z
Land-use antecedents						
Newly deforested land	1.1661	1.42	1.8471**	2.47	1.7382**	2.23
Mechanical clearing	0.6677***	3.63	0.4931***	3.20	0.5392***	3.26
Bush burning	0.4942***	2.70	0.1841	1.19	0.2145	1.29
Herbicide use	−0.0305	−0.18	−0.0911	−0.62	−0.0607	−0.39
Fertilizer application	−0.1713	−0.98	−0.3334**	−2.20	−0.4295***	−2.67
Land tenure and land-related variables						
Lowland	−0.3402**	−2.22	−0.4594***	−3.43	−0.2986**	−2.12
Land titling	0.5927***	2.66	0.4725**	2.29	0.2881	1.30
Land on inheritance	0.5062**	2.29	0.4206**	2.16	0.3834*	1.83
Land on purchase	0.8722***	3.22	0.7244***	2.98	0.9120***	3.53
Land on leasehold	0.0693	0.28	−0.0820	−0.38	0.1221	0.54
Land fragmentation (SI)	0.3065	1.33	0.1784	0.87	0.3257	1.50
Crop diversity	−0.5391	−1.34	−0.9338***	−2.65	−1.6179***	−4.21
Socio-economic characteristics						
Age (years)	0.0539*	1.69	0.0215	0.76	−0.0129	−0.43
Age squared	−0.0006	−1.63	−0.0002	−0.74	0.0002	0.59
Gender (Female = 1)	−0.0676	−0.30	−0.4604**	−2.27	−0.3926*	−1.82
Household size	0.0006	0.06	−0.0112	−1.40	−0.0288***	−3.21
Farm size (ha)	0.0002	0.01	0.0318**	2.14	0.0162	1.04
Education (years)	0.0292**	2.46	0.0269***	2.60	0.0237**	2.15
Institutional variables						
Extension service (Access = 1)	0.2133	1.44	0.1146	0.88	0.1650	1.20
Belongs to cooperative society	−0.1203	−0.85	0.2432*	1.95	0.1641	1.24
Location variables						
Location is Southwest	0.5021**	2.23	0.3630*	1.83	0.5030**	2.43
Location is South-south	1.4738***	4.12	0.9917***	2.87	1.2971***	3.74
Location is Southeast	0.4786	1.03	0.6765	1.58	0.5347	1.15
Location is Northeast	1.0256***	3.43	1.1899***	4.39	1.1344***	3.96
Location is North central	0.0778	0.45	0.0171	0.12	0.3196**	2.05
Constant	−2.3396***	−2.90	−0.2433	−0.34	0.1357	0.18
Diagnostics						
Wald chi-square (75)	230.75					
Prob > chi square	0.0000					
Log pseudo-likelihood	−3558.47					
Pseudo *R* square	0.0337					

Source: Field survey; 2017. *, **, *** significant at 10%, 5%, and 1%.

be more financially capable; therefore, more likely to embrace RFPs (Kassie et al., 2015).

The location dummy variables for South-south, northeast and southwest GPZs, which were included in the models (Table 3), were significant and positive at 1 and 5% levels, respectively. This shows that the willingness to embrace RFPs is location-specific as farm households residing in these three GPZs are more likely to embrace RFPs as against their counterparts in the northwest region.

5. Conclusion and policy implications

This study used household survey data of smallholder farmers to examine the influence of land tenure and land-use antecedents on willingness to embrace resilient farming practices in Nigeria with a particular focus on GAPs, GAPs with manure application, and GAPs with agroforestry. The results show that about 20, 25, and 37% of the respondents were willing to adopt the GAPs with agroforestry, GAPs, and GAPs with manure application, respectively while about 18% preferred to stick to their conventional farming practices. The multinomial logit result shows that resilient farming practices were significantly influenced by age of the household head, household head education, membership of the cooperative, the gender of household head and household size, land acquisition through inheritance and purchase, newly deforested land, mechanical clearing, and bush burning.

It is worthy to note that, as the household heads grow older in life, their willingness to embrace agroforestry reduces. The likelihood of embracing GAPs with agroforestry, GAPs and GAPs with manure application rose with the use of mechanical clearing, land titling, land acquisition through inheritance and purchase. On the contrary, being a female-headed household reduced the willingness to embrace RFPs among the smallholder farmers in Nigeria. The likelihood of choosing GAPs rose significantly with a membership of cooperatives while an increase in farm size increases the likelihood of choosing any of the RFPs. The analysis, therefore, suggests that land titling and some level of perceived or *de facto* tenure security that comes from land acquisition through inheritance and/or outright purchase are necessary conditions for smallholder farmers to embrace RFPs in Nigeria. In addition, cooperative societies can be leveraged for programme intervention in terms of training needs and capacity building of smallholder farmers on RFP principles.

Arising from the abovementioned empirical findings, the paper recommends that policies aiming at developing agroforestry schemes should be targeted on educated and young farmers that cultivate upland farms with a registered title on their farms or acquire the farm through inheritance or purchase. Similarly, policies aiming at developing GAPs with or without manure application should be targeted on male farmers that: cultivate virgin land/secondary forest, mechanize the farm, apply fertilizer, cultivate upland areas, and acquire the farmland through inheritance and/or purchase.

In view of the long-term benefits from RFPs, incentives in form of transition funds and payment for ecosystem services should be provided to farmers by government agencies, private institutions, and development partners to encourage them to shift from status quo (current practice) to RFPs, this would sustain them in the short run. Again, creating avenues to exchange and discuss with farmers to resolve any challenges they may have, for example providing technical assistance where necessary will make transitioning to RFPs more accessible and sustainable. Finally, it is very important that policymakers and agricultural institutions focus their attention on adjusting and implementing policies to reduce the barriers in the area of basic infrastructure, market linkage, price instability, land tenure system, and more that impede smallholder farmers' ability to successfully transit to RFPs.

The authors recognize that interaction effects of the variables used in this study as well as inclusion of other variables such as capital investments, markets, value chains, among others could play crucial roles in the adoptions of GAPs. Again, we believed that the farmers were conservative and preferred to continue with their conventional farming practices. However, further probing of the farmers to know the reasons for sticking to *status quo* was not captured in the study. These are some of the limitations of the study that could be considered for future research.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Author contributions

MK: conceptualization, data curation, formal analysis, investigation, methodology, writing (original draft), and writing (review and editing). AS: conceptualization, methodology, project administration, supervision, and writing (review and editing). OO and SE: writing (review and editing) of the manuscript. All authors contributed to the article and approved the submitted version.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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