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Effects of gender and women empowerment on adoption of climate – smart agricultural practices among smallholders in Northern Nigeria

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Abstract

This study assesses the roles of gender and women empowerment in Agriculture on adoption of CSA practices on male/female controlled rice and/or maize plots among smallholder farmers in Northern Nigeria. The data were collected by personal interviews of respondents, which were drawn in a multi-stage random techniques, covering 1,218 respondents sampled across eight States. Data were analysed using descriptive statistics and econometric method within the framework of Multivariate Probit (MVP) regression. Empowerment score results showed that male plot managers were empowered in three out of the five domains of empowerment when compared to their female counterpart. The MVP results shows that probability of adopting residue retention and crop rotation increased significantly with female empowerment in group membership and credit achievement in the study area. Likewise, the probability of adopting farmyard manure, green manure, residue retention and agroforestry among female plot managers rose significantly with women empowered in control over use of income, access to and decisions on credit, allocation of time to productive tasks as well as satisfaction with the time available for leisure. This study recommends that policies targeted at improving women's access to resources be made to accelerate the adoption of these CSA compliant practices in Northern Nigeria.

Keywords: Women empowerment, Climate-smart practices, smallholders, Northern Nigeria

Introduction

Agriculture is performing below expectation in many developing countries for quite a number of reasons (FAO, 2011) among which is climate change impacts, thus exacerbating agricultural systems particularly in sub Saharan Africa. Climate change is possibly the most serious environmental threat facing mankind worldwide. In developing countries like Nigeria, dependence on rain-fed agriculture and natural resources as the main livelihood strategy, is making farmers, especially women, extremely vulnerable to the impacts of climate change

(Thornton *et al*., 2014). Recently, Climate – Smart Agriculture (CSA) which is an approach to ensure food security, increase productivity and incomes, build resilience to climate change, and reduce emissions from agricultural systems where possible has proven to be the only feasible solution to combat effects of climate change (FAO, 2013). It comprises of wide range of technologies and practices such as improved weather and early warning systems, risk management approaches, improved water management techniques, conservation tillage, agroforestry, integrated crop-livestock management, among others (McCarthy & Brubaker, 2014; Wollenberg *et al*., 2012). Though these technologies exist, they are not always available, adapted and equally accessible to men and women (WOCAN, 2014).

Low performance of agriculture is also due to the fact that women lack the resources and opportunities they need to make the most productive use of their time. Despite the fact that women are farmers, workers and entrepreneurs, they still face more severe constraints than men which limit their access to land and other productive resources, information, finance, infrastructure, technologies and markets (FAO, 2011; UN Women, 2016). This "gender gap" hinders their productivity and reduces their contributions to the agriculture sector and to the achievement of broader economic and social development goals (FAO, 2011). Closing the gender gap in agriculture through informed investments that remove/address these constraints would produce significant gains for society by increasing agricultural productivity, reducing poverty and hunger and promoting economic development and societal resilience (UN Women, 2016).

The gender gap in agriculture is a pattern, documented worldwide, in which women in agriculture have less access to productive resources, financial capital and to advisory services compared to men (FAO, 2011). They often lack secure tenure and resource rights, while they rely directly on climate-affected natural resources for their livelihoods. Existing research suggest that women farmers are more vulnerable to climate impacts than men because they greatly depend on natural resources for livelihoods and food security (Perez *et al*., 2015, UN Women Watch, 2009).

Though, women's rights to access, own and control land are firmly recognized formally under international law (UN HABITAT, 2002), however in Africa, customary laws, male – dominated/controlled systems, traditions and attitude placed women at a disadvantage from enjoying their rights (Benschop, 2004; Quisumbing and Pandolfelli, 2010; Landac, 2017; Goh, 2012). Even where matrilineal system is practiced in Nigeria, women occupy the smallest landholdings. Generally, ownership of land is conferred on men and by custom, they are allowed to dispose land without seeking permission from their spouses, decide on what crops to grow, and control income from the land. Patriarchal customary systems allow women's land rights to depend on their relationship to a male relative, rendering women's right more tenuous (World Bank, 2009). In addition, land is usually transferred through inheritance, and it is almost always men who inherit the land. The gender gap in agriculture is of relevance to CSA as it potentially puts women and men in unequal positions in terms of participating in and benefitting from site-specific CSA practices, hence it is a critical dimension of CSA that cannot be overlooked.

It is against this background that this study considers the effects of gender and women empowerment vis-à-vis their achievement in asset, credit, group membership, productive and income decision and how all these influence adoptions of climate – smart agricultural practices among smallholders in Northern Nigeria. This study contributes to the growing economic literature on adoption of agricultural technology in two ways –though technology adoption remains one of the most researched areas in the field of agricultural economics, very few studies have looked at the factors that determine adoption of climate – smart practices with respect to gender and women empowerment in northern Nigeria. Secondly, methods that recognizes the interdependence between different CSPs and jointly analyze the decision to adopt multiple CSPs, including green manure, residue retention, farmyard manure, crop rotation, zero/minimum tillage and agroforestry are used. Multivariate probit (MVP) regression analysis was carried out on 2,093 plots owned and or cultivated by 1,218 households, MVP explicitly allows for correlation in the error terms of the adoption equations to control for interdependence in decisions on CSPs' adoption. Our results emphasized the importance of women empowerment in the drive for adoption of CSA compliant practices in Northern Nigeria, as their likelihood of adopting these technologies tend to be relatively higher than that of the male plot managers but are constrained in terms of productive resources.

In the next section, we outline the methods in which we have the study area, data collection and sampling, Abbreviated Women's Empowerment in Agriculture Index as well as land tenure and property rights measurement. In section three we describe the theoretical framework underpinning adoption of CSPs and the econometric approach of multivariate probit. In section four we describe and discuss our results. We conclude with the implications of our findings in a final section.

Methodology

The Study Area

The study was carried out in selected farming communities across four agro-ecological zones in Northern, Nigeria. The study area is located between longitudes 3° and 15° East and latitudes 9° and 14° North. Northern Nigeria shares land borders with the Republic of Benin in the West, Chad and Cameroon in the East, Niger Republic in the North, and Southern Nigeria in the South. It is made up of 19 out of 36 states of Nigeria as well as the FCT, grouped into three geopolitical zones: Northeast, Northwest and Northcentral. The region also has six out of the seven agro-ecological zones (AEZ) in Nigeria, ranging from the Derived to the Sahel Savannahs, and 11 out of the 12 leading rice producing States in Nigeria.

Data and Sampling

The study was based on primary data collected through cross-sectional survey by interviewing - 1,218 rice and/or maize farmers across 128 farming communities, spread across 8 of the 19 northern Nigeria States, and the three geopolitical zones as well as four (4) of the seven AEZs in Nigeria. The respondents were drawn in a multi-stage sampling process, as follows:

The respondents were drawn in a multi-stage sampling process, as follows:

Stage I: Purposive selection of eight States that have been the leading rice and/or maize producers in Northern Nigeria (excluding conflict prone areas), based on production statistics from NBS (2012).

Stage II: Purposive selection of four (4) Agricultural Blocks per crop/State from the main rice producing areas of the State, and two (2) Extension Cells per block - that is, 12 Cells per State, and 128 Cells in all.

Stage III: Proportionate stratified random selection of 10 Rice/Maize farmers' groups in each of the selected cells. This process yielded a total of 1,218 rice and/or maize farmers that were interviewed in the study.

LTPRs' Measurement

Three indicators were employed in assessing Land Tenure and Property Rights (LTPRs) of farmers in this study. They include:

i. **Tenure Type**: This refers to mode of land acquisition which was measured on a nominal scale, using three dummy variables – Freehold, Leasehold and Communal. Each of these takes the value of one (1) if the right to use the parcel of land was acquired through direct inheritance and/or purchase for freehold, leased or rented for leasehold, and joint ownership with extended family or other community members for communal land use. Otherwise, the dummy variables were assigned a value zero (0).

ii. **Tenure duration:** This refers to how long a farmer may be able to enjoy outcomes of investment in land development. Plot managers were categorized into three based on the type of rights they enjoy on their farmland, and the implications on how long they can continue to enjoy their investment on the land. This include *"short term"* if the use right is restricted to arable cropping for 1-2 years; *medium term* if the farmer's rights would extend to being able to cultivate tree crops, develop irrigation and/or other structure on the parcel. The tenure duration was categorized as *long-term* if rights include being able to lease out, sell or bequeath the land to other people. These were measured by two dummy variables short, medium and long term

iii. **Tenure security (legal):** A tenure was classified as *de jure* secure, if the parcel has been surveyed and duly registered with the Land registry; otherwise it was classified as unsecure (de jure). This variable was meant to assess the importance of title registration.

Abbreviated Women's Empowerment in Agriculture Index

The Abbreviated Women's Empowerment in Agriculture Index (A-WEAI) is an abbreviated version of the full WEAI, which was developed to improve it in response to feedback such as its time consuming nature, sensitivity and comprehension difficulty of some of its sections (Malapit *et al*., 2015). A-WEAI has five Domains of Empowerment (5DE) and 6 indicators, and can be used to compute two important empowerment metrics, which are of interest in this study.

The first is the *empowerment score*, which measures a woman's achievement of empowerment based on 6 weighted indicators. It is computed by assigning a value of one if a woman (or man) achieved adequacy according to cutoffs defined by Alkire *et al*. (2013) or zero otherwise. An empowerment score is then generated for her (or him), in which the weights of those indicators in which she (or he) enjoys adequacy are summed to create a score that lies between 0% and 100% (Seymour, 2017). According to Alkire *et al*., (2013), a woman or man is defined as empowered in 5DE if she or he has adequate achievements in four of the five domains or is empowered in some combination of the weighted indicators that reflect 80% total adequacy or more.

The second metric is the *empowerment gap* which measures the differences in empowerment between the primary male and primary female adult within each household i.e. measures a woman's relative achievement of empowerment to that of her spouse. The empowerment gap takes a value of zero if a woman's empowerment score is greater than or equal to that of her spouse, but equals the difference between her empowerment score and that of her spouse if otherwise (Seymour, 2017). Thus, higher values reflect greater gender inequality within the household. According to Alkire *et al*., (2013), in most but not all cases, the primary and secondary male and female are husband and wife. However, men and women in the same household can be classified as the primary male and female decision makers regardless of their relationship to each other.

Table 1: Domains, Indicators and their respective weights in the A-WEAI

Domain	Indicator	Weight
Production	Input in productive decisions	1/5
Resources	Ownership of assets	2/15
	Access to and decisions on credit	1/15
Income	Control over use of income	1/5
Leadership	Group membership	1/5
Time	Workload	1/5

Source: Malapit *et al*., 2015

Theories and Modelling Underpinnings Adoption of Climate – Smart Practices

The adoption of Climate – Smart Practices (CSPs) in agriculture has attracted considerable attention in the field of economics and development because a large percentage of the population of developing countries derive their livelihood from agricultural production, and thus, the adoption of new technologies (CSPs) provides an opportunity to increase their production and income, and consequently improve their livelihood (Feder *et al.,* 1985). This has made understanding and modelling the processes and consequences of decision-making (adoption process) among farmers important because of its far reaching implication on development efforts (Borges *et al.,* 2016). The economic theory which underlies this process is the theory of utility maximization.

Theory of Utility Maximization

Utility is a measure of the relative satisfaction derived from the consumption of various goods and services, and a rational consumer is expected to maximize his/her utility subject to economic constraints. Farmers are assumed to be rational, and adopt a given technology if and only if the technology is available and affordable, and at the same time, is expected to be beneficial in terms of yield and profit (de Janvry *et al*., 2010).

This implies that a farmer compares the innovation with the conventional practices and adopts it if the expected utility from adopting exceeds the expected utility of the conventional practices. Although the utility function is unobserved, the relation between the expected utility corresponding to each alternative is postulated to be a function of the vector of observed variables and an error term (Awotide *et al.,* 2016; Adesina and Zinnah, 1993).

Suppose:

U_{i0} is the utility derived from the use of a conventional practices;

U_{i1} is the expected utility from the adoption of CSPs;

Then; $U_{ij} = X\beta + \varepsilon \quad j = 0,1; i = 1, \ldots \ldots .., n$

Where;

β = parameters to be estimated

X = vector of independent variables

U_{ij} =The adoption variable which is a dummy, with 1 = adoption and 0 otherwise i.e.

a farmer adopts the innovation if $U_{i1} > U_{i0}$ $(j = 1)$

Extending the argument further, since farmers are faced with a multitude of production and climate change induced constraints, farmers consider a set of possible technologies and choose the particular technology bundle that maximizes expected utility, instead of adopting a single practice (Asfaw and Lipper, 2015).

Multivariate Probit Regression Model

Multivariate probit regression framework was used to analyze the factors that facilitate or impede adoption of CSPs, following Timu *et al*. (2013), Teklewold *et al*. (2013), and Otieno *et al*. (2011). The model is an extension of probit model used for estimation of several correlated binary choices jointly (Greene, 2003).

Considering several technologies in CSPs, there are the possibilities that some level of interdependence may exists among the technologies with farmers adopting some of these technologies as substitutes, complements or supplements. A farming household would be adopting one or more of the components of CSPs if and only if the utility expected is higher than otherwise. A positive correlation of the errors terms means the technologies are compliments while negative correlations of the errors terms imply the technologies are substitutes (Teklewood *et al*., 2013; Belderbos *et al*., 2004).

If correlation exists, simply estimating the technology adoption equations independently will generate biased and inefficient estimates of the standard errors of the model parameters for each technology (Greene 2008), inducing incorrect inference as to the determinants of technology adoption. Dorfamn (1996) observed that the estimates of separate probit equations (univariate probit) excludes useful economic information contained in interdependence and simultaneous adoption decisions. Hence, when farmers adopt a combination of technologies to deal with land degradation rather than adopting just a single practice or technology so the adoption decision is inherently multivariate. Hence, the MVP estimator corrects for these problems by allowing for non-zero covariance in adoption across technologies (Marenya & Barrett 2007).

Thus, the observed outcome of CSPs adoption can be modelled following a random utility formulation. Consider the ith farm household $i = (1, \cdots, N)$ facing a decision on whether to adopt the available CSPs on plot $p(p = 1 \cdots, P)$.

Let U_0 represent the benefits to the farmer from traditional management practices, and let U_k represent the benefit of adopting the kth CSPs: vis-a-vis, green manuring (GM), residue retention (RR), FYM/compost (OM), crop rotation (CR), Zero tillage (ZT). The farmer decides to adopt the kth CSPs on plot p if $Y_{ipk}^* = U_k^* - U_0 > 0$.

The net benefit (Y_{ipk}^*) that the farmer derives from the adoption of kth CSPs is a latent variable determined by observed household, plot and socio-economic characteristics X_{ip} and the error term ε_{ip}: $Y_{ipk}^* = X_{ip}'\beta_k + \varepsilon_{ip} \quad (k = GM, RR, FM, CR, ZT)$ (1)

Using the indicator function, the unobserved preferences in equation (1) translate into the observed binary outcome equation for each choice as follows:

$$Y_{ipk} = \begin{cases} 1 \; if \; Y_{ipk}^* > 0 \\ 0 \; otherwise \end{cases} \qquad (k = GM, RR, FM, CR, ZT) \qquad (2)$$

Equation (1) is a system of k equations as shown in equation 3 below;

$$Y_{1pk}^* = \beta_1' X_{1i} + \varepsilon_{1i} \;\; Y_{1pk} = 1 \; if \; Y_{1pk}^* > 0, Y_{1pk} = 0 \; otherwise$$

$$Y_{2pk}^* = \beta_2' X_{2i} + \varepsilon_{2i} \; Y_{2pk} = 1 \; if \; Y_{2pk}^* > 0, Y_{2pk} = 0 \; otherwise \qquad (3)$$

$$\vdots$$

$$Y_{Npk}^* = \beta_k' X_{ki} + \varepsilon_{ki} \;\; Y_{Npk} = 1 \; if \; Y_{Npk}^* > 0, Y_{Npk} = 0 \; otherwise$$

In the multivariate model, where the adoption of several CSPs is possible, the error terms jointly follow a multivariate normal distribution (MVN) with zero conditional mean and variance normalized to unity (for identification of the parameters) where $(\mu_{GM}, \mu_{RR}, \mu_{OM}, \mu_{CR}, \mu_{ZT})$, MVN $(0, \Omega)$ and the symmetric covariance matrix Ω is given by:

$$\Omega = \begin{bmatrix} 1 & \rho_{12} & \rho_{13} & \cdots & \rho_{1k} \\ \rho_{12} & 1 & \rho_{23} & \cdots & \rho_{2k} \\ \rho_{13} & \rho_{23} & 1 & \cdots & \rho_{3k} \\ \vdots & \vdots & \vdots & 1 & \rho_{4k} \\ \rho_{1k} & \rho_{2k} & \rho_{3k} & \cdots & 1 \end{bmatrix} \tag{4}$$

The off-diagonal elements in the covariance matrix represent the unobserved correlation between the stochastic components of the different types of CSPs. This assumption means that equation (2) generates a MVP model that jointly represents decisions to adopt farming practices. This specification with non-zero off-diagonal elements allows for correlation across the error terms of several latent equations, which represent unobserved characteristics that affect the choice of alternative CSPs.

The computation of the maximum likelihood function based on a multivariate normal distribution requires multidimensional integration. Different simulation methods were proposed to approximate such a function (Train, 2002). The Geweke–Hajivassiliou–Keane (GHK) simulator is a particularly popular choice in empirical research (Geweke *et al*., 1997). The GHK simulator exploits the fact that a multivariate normal distribution function can be expressed as the product of sequentially conditioned univariate normal distribution functions, which can be accurately evaluated (Cappellari and Jenkins, 2003). The GHK simulator relies on a Cholesky factorization, and to do this, the estimate of the correlation matrix at each iteration must be positive definite.

Results and Discussion

Descriptive Statistics

Table 1 shows descriptive statistics for the variables that we use to explain adoption of climate – smart practices in Nigeria. MVP regression analysis was carried out on 2,093 plots owned and or cultivated by 1,218 households. The upper part of the table shows adoption rates for the CSPs considered in this study. Zero tillage, farmyard manure, residue retention and agroforestry were adopted on 48%, 32%, 34% and 54% of the plots respectively whereas green manure and crop rotation were practiced on 15% and 7% of the plots.

Table 1: Definitions and Summary Statistics of the Variables Used in the Analysis

Variable	Description	Mean (Std. Dev)
Technology adoption dummies		
Green Manure	1 = adopt Green manuring	0.15 (0.36)
Residue Retention	1 = adopt residue retention	0.34 (0.48)
Farmyard manure	1 = adopt Farmyard manure	0.32 (0.47)
Crop Rotation	1 = if single parent, otherwise 0	0.07 (0.26)
Zero/Minimum Tillage	1 = adopt Zero/Minimum tillage	0.48 (0.50)
Agroforestry	1 = adopt agroforestry, otherwise 0	0.54 (0.50)
Socio-economic characteristics		
Single	1 = if the farmer is single	0.06 (0.24)
Household size	Number of household member	11 (7)
Education	Years of formal education	7 (6)
Native	1 = Native, otherwise 0	0.88 (0.32)
Age	Age of the farmers in years	44 (12)
Age Squared	Age of the farmers squared	2109 (1112)
Gender	1 = if Gender of the farmer is female	0.06 (0.23)
Five DEs interacted with gender		
Asset Achievement*Gender	1 = female has asset achievement	0.04 (0.20)
Group Achievement*Gender	1 = female has group achievement	0.05 (0.21)
Achievement in Production Decision*Gender	1 = if female has achievement in production decision	0.05 (0.21)
Achievement in Income Decision*Gender	1 = if female has achievement in income decision	0.04 (0.19)
Credit Achievement*Gender	1 = if female has credit achievement	0.02 (0.13)
Work Achievement*Gender	1 = if female has work achievement	0.04 (0.21)
Plot level characteristics		
Land ownership	1 = Land ownership	0.71 (0.46)
Farm size (Ha)	Total landholdings in Ha	2.42 (8.01)
Lowland	1 = Lowland	0.39 (0.49)
Land titling	1 = Land titling	0.04 (0.20)
Long term rights	1 = Long term use, otherwise 0	0.59 (0.49)
Communal	1 =Land acquisition by communal means	0.12 (0.33)
Simpson Index	Extent of land fragmentation	0.31 (0.31)
Institutional characteristics		
Extension contact	1 = Extension contact, otherwise 0	0.70 (0.46)
Empowerment gap	1 =Empowered, otherwise 0	0.53 (0.50)
Off-farm income	1 = Off-farm income	93,304.81 (369,704.20)

Source: Field survey; 2017

Empowerment Scores and Adoption of Climate – smart Practices of Plot Managers

Adoption result of CSA compliant practices (Table 2) disaggregated by male and female controlled plots revealed the percentage of zero tillage (48%, 51%), farmyard manure (33%, 23%), residue retention (35%, 29%), green manure (15%, 13%) and crop rotation (7%, 5%) that were practiced by plot owners in the study area. Similarly, empowerment scores results showed the percentage of adequate achievement of both male and female plot managers in ownership of asset (83%, 67%), group membership (85%, 75%), input in productive decision (80%, 72%), control over the use of income (75%, 61%) and access to and decisions on credit (38%, 26%) respectively. This shows that male plot managers were more empowered in three out of the five domains of empowerment when compared to their female counterpart.

Table 2: Distribution of Plot Managers by their Empowerment Score and Adoption of Climate-smart Practices

Variables	*Male-controlled Plot*	*Female-controlled Plot*	*Total*
	Mean (SEM)	*Mean (SEM)*	*Mean (SEM)*
Empowerment scores			
Achievement in asset	0.83 (0.009)	0.67 (0.033)	0.82 (0.009)
Achievement in Group membership	0.85 (0.008)	0.75 (0.031)	0.84 (0.008)
Achievement in productive decision	0.8 (0.009)	0.72 (0.032)	0.8 (0.009)
Achievement in income	0.75 (0.01)	0.61 (0.034)	0.74 (0.01)
Achievement in credit	0.38 (0.011)	0.26 (0.031)	0.37 (0.011)
Achievement in work	0.66 (0.011)	0.78 (0.029)	0.67 (0.01)
Adoption of CSPs			
Green Manure	0.15 (0.008)	0.13 (0.024)	0.15 (0.008)
Agroforestry	0.54 (0.012)	0.57 (0.035)	0.54 (0.011)
Farmyard manure	0.26 (0.01)	0.21 (0.029)	0.26 (0.01)
Crop Rotation	0.07(0.006)	0.05 (0.016)	0.07 (0.006)
Zero/Min. Tillage	0.48 (0.012)	0.51 (0.035)	0.48 (0.011)
Residue retention	0.35 (0.011)	0.29 (0.032)	0.35 (0.011)

Source: Field Survey; 2017.
Standard Error of Mean (SEM) in parenthesis

Adoption decisions of Climate – Smart Agricultural Practices

The MVP model is estimated using maximum likelihood method on plot-level observations. The model fits the data reasonably well – the Wald test of the hypothesis that all regression coefficients in each equation are jointly equal to zero is rejected. Table 3 shows the likelihood ratio test [chi^2(15) = 156.523, p=0.000)] of the null hypothesis that the covariance of the error terms across equations are not correlated is also rejected. This is supported by the correlation between error terms of the adoption equations reported in Table 3. The estimated correlation coefficients are statistically significant in eleven of the fifteen pair cases, where four coefficients have negative signs and the remaining seven have positive signs. The result shows that farmyard manure is complementary with green manure, residue retention and crop rotation while zero tillage complements residue retention and agroforestry. The correlation between adoption of farmyard manure and green manure is the highest (23.54%) while that of farmyard manure and zero/min. tillage is the least (8.42%). However, residue retention exhibits a substitute relationship with green manure and farmyard. These findings suggest that using ordinary probit or logit regression to assess the determinants of CSPs adoption among smallholder farmers in Nigeria will yield inefficient estimates.

Table 3: Results of the Wald Test Simultaneity of the Decision to Adopt CSPs

	Coef.	p-value
rho21 (Residue retention &Green Manure)	-0.1018	0.0100
rho31 (Farmyard manure & Green Manure)	0.2354	0.0000
rho41 (Crop rotation & Green Manure)	0.1113	0.0450
rho51 (Zero/Minimum tillage & Green Manure)	-0.0285	0.4590
rho61 (Agroforestry & Green Manure)	-0.0252	0.5120
rho32 (Farmyard manure & residue retention)	-0.0897	0.0130
rho42 (Crop Rotation & residue retention)	0.0848	0.0990
rho52 (Zero/Minimum Tillage & residue retention)	0.1429	0.0000
rho62 (Agroforestry & residue retention)	0.2271	0.0000
rho43 (Crop Rotation & Farmyard manure)	0.1684	0.0000
rho53 (Zero/Minimum Tillage & Farmyard manure)	-0.0842	0.0150
rho63 (Agroforestry & Farmyard manure)	-0.1034	0.0020
rho54 (Zero/Minimum Tillage & Crop Rotation)	0.0283	0.5210
rho64 (Agroforestry & Crop Rotation)	0.0096	0.8300
rho65 (Agroforestry & Zero/Minimum Tillage)	0.1697	0.0000

Likelihood ratio test of rho21 = rho31 =rho41 = rho51 =rho61= rho32 =rho42 =rho52 = rho62=rho43=rho53 =rho63= rho54 =rho64=rho65=0.00

Factors Determining Adoption of Climate –smart Agricultural Practices

Table 4 shows that the likelihood to adopt residue retention ($p < 0.05$) decreased in the early years and increased in the latter years while for crop rotation ($p < 0.01$), reverse was the case as the likelihood of adoption increased in the early years and declined later on. The result clearly shows that the likelihood of female farmers ($p < 0.05$) adopting residue retention and crop rotation was significantly lower than that of male in the study area. Adoption of residue retention and crop rotation increased significantly with female empowerment in group membership and credit achievement in the study area. Likewise, the probability of adopting farmyard manure ($p < 0.05$), green manure ($p < 0.05$), residue retention ($p < 0.01$) and agroforestry ($p < 0.01$) among female plot managers rose significantly ($p<0.05$) with women empowerment vis-a-vis control over use of income, access to and decisions on credit and allocation of time to productive and domestic tasks and satisfaction with the time available for leisure. However, the result clearly shows that the probability of female plot owners ($p < 0.05$) adopting residue retention and crop rotation was significantly lower than that of their male counterparts while the tendency to adopt crop rotation increased with having contact with the extension agents ($p < 0.1$) in the study area.

In line with earlier work on technology adoption (Kassie *et al*., 2010), Table 4 shows that having longer term rights ($p <0.05$) on the cultivated plot(s) and land acquisition by communal means ($p < 0.05$) positively influenced the probability of adopting green manure, farmyard manure and agroforestry, it however reduced significantly the probability of adopting zero tillage ($p < 0.05$) in the study area. All these may be attributed to tenure (in)security, given the fact that the benefits from long-term investments (adoption of CSA compliant practices) accrue over time, this inter-temporal aspect suggests that secure land access or tenure impacted positively on adoption decisions of CSA compliant practices.

Table 4: Determinants of Adoption of Climate-Smart Agricultural Practices: Results of Multivariate Probit Regression

Variables	*Green Manure*		*Residue Retention*		*Farmyard Manure*		*Crop Rotation*		*Zero/Min. Tillage*		*Agroforestry*	
	Coef.	*z*	*Coef.*	*z*	*Coef.*	*z*	*Coef.*	*Z*	*Coef.*	*z*	*Coef.*	*z*
Age (years)	-0.0204	-1.45	-0.0329	-2.55**	0.0156	1.23	0.0651	3.74***	0.0129	1.04	0.0087	0.71
Age Squared	0.0002	1.24	0.0003	2.09**	-0.0002	-1.08	-0.0006	-3.34***	-0.0002	-1.23	-0.0001	-0.76
Gender (Female = 1)	-0.8406	-1.46	-1.1023	-2.27**	-0.5901	-1.06	-3.7251	-6.21***	0.5748	1.3	-0.3814	-0.88
Asset Achievement * gender	-0.3146	-0.75	-0.4183	-1.17	0.5208	1.41	0.0844	0.22	0.1213	0.36	0.0283	0.09
Group Achievement *gender	0.6972	1.01	0.7557	1.93*	0.0109	0.03	3.7818	9.01***	-0.4102	-1.15	0.3359	0.99
Achievement ProDec*gender	-0.0331	-0.09	-0.0259	-0.07	-0.4981	-1.19	0.0976	0.25	0.1052	0.29	-0.3750	-1.05
Achievement IncDec*gender	0.3158	0.82	-0.6708	-2.16**	0.7804	2.16**	0.0352	0.09	-0.3659	-1.28	0.1317	0.46
Credit Achievement *gender	0.7714	2.41**	0.6066	2.1**	-0.1342	-0.45	0.6759	1.81*	-0.0229	-0.08	0.1150	0.43
Work Achievement *gender	-0.0784	-0.23	1.0736	3.31***	-0.3358	-1.03	-0.2778	-0.7	0.0006	0	0.5493	1.88*
Single	0.2082	1.5	-0.1100	-0.85	0.0452	0.34	0.5936	3.69***	0.0137	0.11	0.1563	1.24
Household size	-0.0082	-1.71*	0.0030	0.75	0.0002	0.04	-0.0092	-1.42	0.0005	0.13	-0.0009	-0.23
Schooling Year	-0.0035	-0.6	-0.0051	-1.05	-0.0060	-1.24	0.0108	1.53	0.0023	0.49	-0.0187	-3.99***
Native	0.0719	0.64	-0.1581	-1.76*	0.1382	1.47	0.0858	0.64	-0.0397	-0.45	-0.0801	-0.9
Land ownership	-0.0151	-0.2	-0.1339	-2.12**	0.0298	0.46	-0.0526	-0.57	-0.0350	-0.57	-0.0230	-0.37
Farm size (ha)	0.0004	0.1	-0.0039	-1.01	-0.0032	-0.7	-0.0005	-0.1	0.0050	1.28	0.0022	0.61
Lowland	0.0849	1.17	0.0623	1.02	-0.0011	-0.02	0.0525	0.58	-0.0322	-0.54	-0.0703	-1.18
Land titling	-0.0924	-0.78	0.0223	0.22	-0.0719	-0.74	-0.0830	-0.55	0.1047	1.09	-0.0590	-0.61
Long term Use Rights	0.1649	2.03**	-0.1060	-1.58	0.2762	4.01***	0.1414	1.38	-0.3230	-4.92***	0.1220	1.87*
Communal	0.2377	2.12**	0.0083	0.09	0.2041	2.07**	0.1218	0.83	-0.3211	-3.36***	0.1640	1.73*
Extent of Fragmentation	0.0669	0.56	-0.0708	-0.69	-0.0408	-0.38	0.1129	0.75	0.0111	0.11	0.0075	0.07
Extension contact	0.0358	0.47	0.0820	1.29	0.0290	0.45	0.1788	1.82*	-0.0349	-0.57	0.0960	1.56
Empowerment gap	0.0453	0.65	-0.0227	-0.38	-0.0113	-0.19	0.0118	0.13	0.1113	1.95*	-0.0311	-0.54
Off farm income	1.69E-09	0.02	-1.68E-07	-1.88*	-1.96E-09	-0.02	-1.16E-07	-0.82	-4.46E-08	-0.56	6.55E-08	0.88
Constant	-0.7139	-1.89*	0.7498	2.25**	-1.1087	-3.32***	-3.3892	-7.05***	-0.0685	-0.21	0.0146	0.05
Wald chi2(138)	2498.66		2498.66		2498.66		2498.66		2498.66		2498.66	
Prob > Chi2	0.0000		0.0000		0.0000		0.0000		0.0000		0.0000	
Log pseudo-likelihood	-6590.79		-6590.79		-6590.79		-6590.79		-6590.79		-6590.79	
Number of observation	2040		2040		2040		2040		2040		2040	

Source: Field Survey, 2017

Note: ***, **, * represent statistical significance at 1%, 5% & 10%

Conclusion and Policy Implication

This study assesses the roles of gender, LTPRs and women empowerment in Agriculture, among other factors, on adoption of CSA compliant practices on male/female controlled rice and/or maize plots among smallholder farmers in Northern Nigeria. Data were analysed using descriptive statistics and econometric method within the framework of Multivariate Probit (MVP) regression. Adoption result of CSA compliant practices disaggregated by male and female controlled plots revealed the percentage of zero tillage (48%, 51%), farmyard manure (33%, 23%), residue retention (35%, 29%), green manure (15%, 13%) and crop rotation (7%, 5%) that were practiced by plot owners in the study area. Similarly, empowerment score results showed percentage of the adequate achievement of both male and female plot managers in ownership of asset (83%, 67%), group membership (85%, 75%), input in productive decision (80%, 72%), control over the use of income (75%, 61%) and access to and decisions on credit (38%, 26%) respectively, suggesting that male plot managers were more empowered in three out of the five domains of empowerment when compared to their female counterpart.

The Wald test of simultaneity of the decision to adopt CSA compliant practices revealed that farmyard manure is complementary with green manure, residue retention and crop rotation while zero tillage complements residue retention and agroforestry. The correlation between adoption of farmyard manure and green manure is the highest (23.54%) while that of farmyard manure and zero/minimum tillage is the least (8.42%). These findings suggest that using ordinary probit or logit regression to assess the determinants of CSA compliant practices adoption among smallholder farmers in the study area will yield inefficient estimates.

The MVP results clearly shows that the probability of female plot owners adopting residue retention and crop rotation was significantly lower than that of their male counterparts in the study area. Adoption of residue retention and crop rotation increased significantly with female empowerment in group membership and credit achievement in the study area. Likewise, the probability of adopting farmyard manure, green manure, residue retention and agroforestry among female plot managers rose significantly with women empowerment in control over use of income, access to and decisions on credit and allocation of time to productive and domestic tasks and satisfaction with the time available for leisure.

However, the probability of adopting residue retention was less likely among the female plot managers that were not empowered in the control over use of income. Also, having longer term rights on the cultivated plot(s) and land acquisition by communal means positively influenced the probability of adopting green manure, farmyard manure and agroforestry, it however reduced significantly the probability of adopting zero tillage in the study area. All these may be attributed to tenure (in)security, given the fact that the benefits from long-term investments (adoption of CSA compliant practices) accrue over time, this inter-temporal aspect suggests that secure land access or tenure impacted positively on adoption decisions of CSA compliant practices.

The findings of the study emphasized the importance of women empowerment in the drive for adoption of CSA compliant practices in Northern Nigeria, as their likelihood of adopting these technologies tend to be relatively higher than that of the male plot managers but are constrained in terms of productive resources. It is therefore recommended that policies targeted at improving women's access to resources be made to accelerate the adoption of these CSA compliant practices in Northern Nigeria.

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