Women empowerment and adoption of climate-smart agricultural practices in Nigeria

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Abstract

Purpose – This study assessed the extent of women empowerment and empirically investigated its effect on the adoption of climate-smart agricultural practices at the plot level in Nigeria.

Design/methodology/approach – Using the empowerment score and women empowerment gap for each household which were derived from the Abbreviated Women's Empowerment in Agriculture Index, a multivariate probit model which controlled for the influence of gender and women empowerment on climate-smart agricultural practices' adoption was estimated. The study made use of data from the ECOWAS-RAAF-PASANAO survey conducted in Nigeria in 2017.

Findings – The results show that men are significantly more empowered than women in four out of the five domains of empowerment and are more likely to adopt crop rotation. However, female plot managers have a higher likelihood of adopting green manure and agroforestry, while no significant gender differences in the adoption of organic manure and zero/minimum tillage were found.

Social implications – The results suggest that closing the empowerment gap between women and their spouses would positively influence the adoption of agroforestry.

Originality/value – This study represents the first attempt to examine the adoption of these practices from a gender perspective using a nationally representative plot-level dataset in Nigeria. Furthermore, this study contributes to existing literature on how gender differences influence technology adoption by modelling the effect of empowerment score for each plot manager, and the women empowerment gap for each household on the adoption of five climate-smart agricultural practices.

Keywords Women empowerment, Gender, Climate-smart agriculture, Adoption, Multivariate probit model

Paper type Research paper

Introduction

The global climate is changing and is becoming more evident through increasing temperatures, more unpredictable rainfall and more frequent extreme weather events (Eckstein *et al.*, 2019; Lobell *et al.*, 2008). However, the adverse effects of climate change will be felt more by smallholder farmers in developing countries, who have low adaptive capacity to cope with changing weather patterns due to their limited resources (Hundera *et al.*, 2019; Goh, 2012; Morton, 2007). This is especially true in sub-Saharan Africa, where about 96% of the total cropland is based on rain-fed systems which leave agricultural production, and the livelihood of the people highly exposed to changes and fluctuations in climatic conditions (Srivastava *et al.*, 2017; Calzadilla *et al.*, 2008). This necessitated the promotion of climate-smart agricultural (CSA) practices as those that sustainably increase agricultural productivity and incomes of farming households, build their resilience and capacity to adapt to climate change and reduce or remove greenhouse gases emission while enhancing national food security (Neufeldt *et al.*, 2013).

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However, the adoption of CSA practices remains generally low, particularly in sub-Saharan Africa (Abegunde *et al.*, 2019; McCarthy and Brubaker, 2014), leading to a growing body of literature on its determinants, with a view to identifying appropriate mechanisms by which wide-spread adoption of CSA practices may be promoted to ensure improved livelihood in the region (Tran *et al.*, 2019; Mujeyi *et al.*, 2019; Khatri-Chhetri *et al.*, 2017; Teklewold *et al.*, 2013). However, most of these studies traditionally address adoption at the household level, and thus assume that farm production and allocation decisions are taken centrally either by the household head or jointly with him (Meinzen-Dick *et al.*, 2019; Ndiritu *et al.*, 2014; Quisumbing and Pandolfelli, 2010), and presuppose that benefits of available household resources are shared equitably, irrespective of gender (Agarwal, 1994). This is contrary to reality in many African production systems as pointed out by Udry (1996), as productive assets are not shared equitably, and farm households produce on different plots, which are managed by different members of the household. Indeed, Asongu and Odhiambo (2019) posit that globally, the highest level of gender exclusion exists in Africa. Therefore, the assumption that the adoption decision is jointly made within a household may neglect differences which exist in intra-household farming decisions, which could lead to wrong conclusions and policy decisions (Gebre *et al.*, 2019; Ndiritu *et al.*, 2014).

This is particularly important as literature suggest that significant intra-household disparities exist between women's access to, ownership of and control over productive resources compared to men (Meinzen-Dick *et al.*, 2019; Kieran *et al.*, 2017; Quisumbing and Pandolfelli, 2010) as men are generally advantaged in owning assets due to gender norms which govern its ownership. Specifically, women are constrained in terms of access to land (Murugani and Thamaga-Chitja, 2019; Massay, 2019), access to credit and other financial assets (Brixiová *et al.*, 2020; Ali and Awade, 2019), education (Khoza *et al.*, 2019), extension services (Rola-Rubzen *et al.*, 2020; Huyer, 2016) as well as other social perceptions about their perceived lack of suitability as farmers (Rola-Rubzen *et al.*, 2020). Obayelu, Ogbe and Edewor (2020) also establish that female farmers' agricultural productivity is negatively affected (up to 25% compared to male counterparts) by this disparity in productive assets. Furthermore, they are also more vulnerable to the loss of these assets and rights due to separation, divorce or widowhood (Doss, 2018; Peterman *et al.*, 2010; Fletschner, 2008). Given that it has been estimated that if rural women have the same access to agricultural resources as men, yields could increase by 20–30% and the total number of hungry people around the world reduced by 12–17% (FAO, 2011), understanding how adoption decisions vary along gender lines within and across households is of critical importance in order to provide better information on the factors driving CSA practices' adoption at the plot level, which will enable policymakers better target policies and interventions to catalyse the diffusion of CSA practices, towards the achievement of improved and sustainable livelihoods among farm households in Nigeria.

This study addressed the knowledge gap around the extent of women empowerment, and empirically investigated its potential effect on adoption of CSA practices at the plot level in Nigeria. Specifically, this study analysed the adoption of a range of climate-smart practices (green manure, agroforestry, organic manure, crop rotation, zero/minimum tillage) using the Multivariate Probit (MVP) model, and controlled for the influence of women empowerment among other covariates.

This study contributes to existing literature on two main fronts. Firstly, although the literature show a growing number of recent studies which have attempted to investigate the determinants of CSA practices' adoption in Africa using plot level data, most of these have been conducted in Eastern and Southern Africa (Mujeyi *et al.*, 2019; Maguza-tembo *et al.*, 2017; Kassie *et al.*, 2015; Ndiritu *et al.*, 2014; Arslan *et al.*, 2013; Teklewold *et al.*, 2013), with a few carried out in the West Africa sub-region (Theriault *et al.*, 2017; Asfaw *et al.*, 2016) and none in Nigeria to the best of our knowledge. Thus, this study fills a gap in existing literature by using a nationally representative plot-level dataset to examine the adoption of CSA practices in Nigeria.

Secondly, while most of these studies controlled for gender differences in adoption by including the gender of the plot manager and/or household head in the analysis (Ndiritu *et al.*, 2014), or estimating the adoption model for male and female managed plots separately (Theriault *et al.*, 2017), this study contributes to the on-going discussion by estimating the empowerment score for each plot manager, as well as the women empowerment gap for each household using the A-WEAI methodology. These two variables are included in the analysis, in an attempt to robustly explore how gender differences influence adoption.

Methodology

Study area

Nigeria is the largest geographical country in West Africa, and the most populous in Africa. It occupies a land area of approximately 923, 768 km^2, and lies between Latitudes 4^0 to 14^0 North and Longitudes 2^02' and 14^030' East. Nigeria is bordered in the South by the Atlantic Ocean, in the West by the Republic of Benin, in the North by the Niger and in the East by the Republic of Cameroon (National Bureau of Statistics (NBS), 2010). Nigeria has diverse agro-ecological zones, ranging from the mangrove swamps and humid tropical forest zone of the South that has longer rains to the Northern Savannah part of the country which experiences lower rainfall and shorter rainy season. However, these natural agro-ecological zones have been modified over time through the interaction of climate, human activities as well as man's pattern of land use. Based on the above, Nigeria's agro-ecological zones can be classified into Savannah zones (Sahel, Sudan, Northern Guinea, Southern Guinea and Derived) and the humid rainforest (Shittu *et al.*, 2018).

The population of Nigeria was estimated by the National Population Commission to be 186,939,754 people in 2015, with an average annual growth rate of about 2.8% (NBS, 2017). In particular, Nigeria has the highest population growth among the 10 largest countries in the world and is expected to become the third largest in the world by 2050 (United Nations Department of Economic and Social Affairs (UNDESA), 2015). The natural endowment of the country includes land, water, minerals, agricultural and forest resources through which its population derive their livelihood. Nigeria is agrarian, as agriculture provides employment for over 90% of the rural dwellers, who constitute about 70% of the total population. Nigeria's expansive 853 km coastline in the South (NBS, 2017), which predisposes farmers' livelihoods to floods, and her proximity to the Sahara Desert in the North where desertification is advancing unabated, makes this study imperative, in order to mitigate the adverse effects of climate change in the country, as well as reduce agriculture's contribution to greenhouse gases (GHGs) emissions wherever and whenever possible.

Data and sampling procedure

The data used for this study were drawn from a nationwide farm household survey, collected by the Federal University of Agriculture, Abeokuta, in collaboration with the National Cereals Research Institute for implementation of the project titled "*Incentivising Adoption of Climatic Smart Practices in Cereals Production in Nigeria: Sociocultural and Economic Diagnosis*", which was sponsored by the ECOWAS – Regional Agency for Agriculture and Food (RAAF) under its Support Programme for Food and Nutrition Security in West Africa (PASANAO).

The sampling process was based on the World Bank–sponsored Agricultural Development Programme (ADP) structure across the 36 States of Nigeria, which organized farming communities into Cells (or Circles), Blocks and Zones. The cells are groups of farming communities assigned for coverage to an Agricultural Extension Officer under the Training and Visit (T&V) Extension System adopted by various States' ADPs in Nigeria. The Blocks are groups of five to eight Cells, usually made up of the Cells in a Local Government Area (LGA). A number of Blocks are brought together as a Zone, under the headship of a Zonal Manager, with each state having three or four agricultural zones under the Programme Manager (Shittu *et al.*, 2018).

The respondents for this study were drawn in a multi-stage sampling process. The first stage was a purposive selection of two States per agro-ecological zone, which are those reputed as the leading producers of rice and maize in Nigeria. At the second stage, three (3) agricultural blocks reputed for maize production were purposively chosen from each State that had been selected (This was done in consultation with the States' ADPs, given the lack of production data per block within the States). In stage three, two extension cells were randomly selected from each block, while the last stage was a random selection of 10 maize farmers from each of the selected cells. This process yielded a total of 1,747 rice and maize farmers interviewed across 141 farming communities that were spread across 12 States and six of the seven agro-ecological zones in Nigeria. However, after dropping households which do not have a primary adult female, 998 households and 1,578 plots were left.

Analytical framework

Modelling the adoption decision

In this study, a farmer is considered to be an adopter of a CSA practice if he/she has used the practice at least one planting season before the interview and was still utilizing such practice as at the time of interview (Afolami *et al.*, 2015). It is assumed that each plot manager (i.e. individual family members) compares the CSA practices with the traditional technology and adopts it if he/she perceives that the expected utility from adoption exceeds the utility of the traditional technology (Awotide *et al.*, 2016). Furthermore, it is assumed that farmers make multiple adoption decisions at the same time, and attempting to model adoption of single technologies separately using a Probit or Logit model ignores the potential correlation among the unobserved disturbances in the adoption equations, thus leading to inefficient estimates and thereby wrong inference (Theriault *et al.*, 2017). Thus, this study utilized the MVP model, as it models the influence of the set of explanatory variables on each of the different CSA practices by estimating a set of binary Probit models simultaneously, while allowing the error terms in those models to be correlated (Greene, 2008). The MVP model for multivariate choice decision problems can be represented by two systems of equations. First, a system of equations with latent (unobservable) dependent variables are described by a linear function of a set of observed household (h) and plot (p) characteristics (X_{hp}) and multivariate normally distributed stochastic terms (ε_{hp}). Each equation in the system can be written as:

$$Y^*_{hpk} = X_{hp}\beta_k + \varepsilon_{hp} \qquad (\text{where } k = G,\ A,\ O,\ C,\ Z) \tag{1}$$

where Y^*_{hpk} denotes the latent dependent variables which can be represented by the level of expected benefit and/or utility derived from adoption of green manuring (G), agroforestry (A), organic manure (O), crop rotation (C), zero/minimum tillage (Z)

ε = Error term h = Household characteristics p = Plot characteristics

The second system of equations describing the observable dichotomous choice variables of households is given as:

$$Y_{hpk} = \begin{cases} 1 & \text{if } Y^*_{hpk} > 0 \\ 0 & \text{otherwise} \end{cases} \tag{2}$$

where Y_{hpk} is the adoption of the kth CSPs by the hth household on plot p.

Abbreviated Women's Empowerment in Agriculture Index (A-WEAI)

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 six indicators and can be used to compute two important empowerment metrics, which are of interest in this study (see Table 1).

The first is the *empowerment score*, which measures a woman's achievement of empowerment based on six 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.

Results and discussion

Description of explanatory variables

The explanatory variables in the empirical model are based on a review of empirical literature on adoption of sustainable agricultural practices (Tran *et al.*, 2019; Ehiakpor *et al.*, 2019; Abegunde *et al.*, 2019; Oladele *et al.*, 2019; Theriault *et al.*, 2017; Wossen *et al.*, 2017; Ndiritu *et al.*, 2014; Kassie *et al.*, 2015). Table 2 presents the description and summary statistics of the explanatory variables used in this study. The results show that the farmers were mostly male (88.0%) and married (99.7%), with a mean household size of ten persons. The average farmer was about 45 years and had undergone eight years of formal education.

Furthermore, most (86.0%) of the farmers claimed to be natives of the community they were domiciled in. Due to the complex nature of land tenure and property rights in Nigeria, this is an important factor in the ease of accessing and maintaining these rights. Most (69.0%)

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

Source(s): Malapit *et al.* (2015)

Table 1. Domains, indicators and their respective weights in the A-WEAI

Table 2. Definition and summary statistics of independent variables – Plot level

Variable	Description	Expected sign	Empirical studies	Mean (SD)
Age	Age of the plot manager in years	+/−	Tran *et al.* (2019), Maguza-tembo *et al.* (2017)	44.88 (12.06)
Gender	If plot manager is female = 1, Male = 0	−	Theriault *et al.* (2017)	0.12 (0.33)
Marital Status	If the plot manager is married = 0; Otherwise = 1	+	Ehiakpor *et al.* (2019)	0.03 (0.17)
Years of Schooling	Years of formal education of the plot manager	+	Ghimire and Huang (2016)	7.81 (5.83)
Extension Contact	Number of visits by an agricultural extension agent to the plot manager or by the plot manager to an extension service office during last 1 year	+	Wossen *et al.* (2017), Abegunde *et al.* (2019)	13.71 (42.63)
Off farm income	Plot manager's total off farm income in the last year (in Naira)	+	Kassie (2017), Coulibaly *et al.* (2016)	98,308.15 (294,881.40)
Household size	Number of household members	+	Mujeyi *et al.* (2019), Ndiritu *et al.* (2014)	9.58 (6.04)
Native	If plot manager is a native of the community = 1; Otherwise = 0	+	Sanou *et al.* (2019)	0.86 (0.35)
Land ownership status	If plot manager owns the plot = 1; Otherwise = 0	+	Kassie *et al.* (2015)	0.69 (0.46)
Farm size (Ha)	Size of the plot being cultivated by plot manager in hectares	+	Oladele *et al.* (2019)	3.49 (6.14)
Plot Trekking distance from home	Number of minutes used in trekking to the plot	−	Ndiritu *et al.* (2014)	56.18 (58.43)
Land type	If plot is upland = 0; Lowland = 1	−	Mansaray *et al.* (2019)	0.41 (0.49)
Fertilizer use	If plot manager used inorganic fertilizer = 1; Otherwise = 0	−	Makate *et al.* (2019)	0.71 (0.45)

of the farmers owned the land which they cultivate, a reasonable percentage (41.0%) of which were lowlands. According to Farauta *et al.* (2012), this substantial cultivation of lowlands could be as a result of farmers' adaptation to climate change in Nigeria. Also, the average plot was about an hour's (56.18 min) journey from home on foot. This could have negative implications for the adoption of sustainable practices that involve transporting bulky inputs on farm plots farther away from home, relative to those closer to the homestead (Ndiritu *et al.*, 2014).

Description of dependent variables

Table 3 shows the distribution of CSA practices' adoption by the gender of the plot manager. A *t*-test was also conducted to determine if any difference observed in the adoption of the CSA practices between male and female plot managers is significant, and the results are also presented in Table 3. Interestingly, the results show that female plot managers adopted four out of the five CSA practices considered more than their male counterparts. Specifically, female plot managers adopted green manure (21.0%), agroforestry (71.0%), organic/compost use (39.0%) and zero/minimum tillage (45.0%) more. This result corroborates earlier work on CSA practices' adoption in developing countries. For instance, Aryal *et al.* (2014) reported that female-headed households in India are more likely to adopt CSA practices, while female farmers adopted all the 17 CSA practices assessed by Bernier *et al.* (2015) more than male farmers in Kenya. Conversely, male plot managers adopted crop rotation (23.0%) than their female counterparts, probably because they can afford to rotate crops among multiple plots, since they have access to more land (Massay, 2019; Goh, 2012). However, the adoption of these practices is fairly low across both genders, with the exception of agroforestry, thus corroborating the findings of previous literature (McCarthy and Brubaker, 2014).

Gendered comparison of plot managers' achievement in the domains of empowerment

As discussed earlier above, A-WEAI has two important empowerment metrics – the empowerment score, which is the weighted sum of a woman's achievement in the six weighted indicators, and the empowerment gap, which measures a woman's relative achievement of empowerment based on a comparison of her empowerment score to that of her spouse (or primary male). Table 4 presents the results of these two metrics, disaggregated by gender. A *t*-test was also conducted to determine if any difference observed in the achievement of empowerment between male and female plot managers in any of the six indicators is significant, and the results are also presented in Table 4.

The results show that male plot managers are significantly more empowered relative to their female counterparts in all the indicators, except the workload indicator. Consequently,

	Full sample		Male plot managers		Female plot managers		
Variables	Mean	S.D	Mean	S.D	Mean	S.D	*t*-test
Green manure	0.15	0.36	0.14	0.35	0.21	0.40	−2.05**
Agroforestry	0.55	0.50	0.53	0.50	0.71	0.45	−5.00***
Organic manuring	0.34	0.47	0.34	0.47	0.39	0.49	−1.41
Crop rotation	0.21	0.41	0.23	0.42	0.12	0.32	4.33***
Zero/Minimum tillage	0.42	0.49	0.41	0.49	0.45	0.50	−0.84
Sample size	1,578		1,388		190		

Note(s): **, *** represent 5% and 1% level of significance respectively

Table 3. Distribution of plot managers' adoption of CSA practices

	Male plot managers (N = 1,388)		Female plot managers (N = 190)		Full sample (N = 1,578)		
Variables	Mean	S.D	Mean	S.D	Mean	S.D	*t*-test
AchmtAsset	0.91	0.28	0.67	0.47	0.88	0.32	6.84***
AchmtGrpMem	0.90	0.30	0.71	0.46	0.88	0.33	5.76***
AchmtProDec	0.86	0.35	0.71	0.46	0.84	0.37	4.41***
AchmtIncCon	0.81	0.39	0.54	0.50	0.78	0.41	7.36***
AchmtCredit	0.38	0.49	0.26	0.44	0.37	0.48	3.43***
AchmtWork	0.61	0.49	0.62	0.49	0.61	0.49	−0.18
Empowerment score	0.78	0.18	0.62	0.25	0.76	0.20	8.41***
Empowerment status	0.56	0.49	0.35	0.48	0.53	0.49	5.43***
Empowerment gap					0.23	0.24	

Note(s): *, **, *** represent 10%, 5% and 1% level of significance respectively

Table 4. Achievement of plot managers in five domains of empowerment

female plot managers in the sample achieve adequacy in 62.0% of the weighted indicators on the average, compared to male plot managers, who achieve adequacy in 78.0% of the indicators on the average. Based on the 80% cutoff (representing adequate achievements in four of the five domains or empowerment in some combination of the weighted indicators that reflect at least 80%) defined by Alkire *et al.* (2013), only 35.0% of the female plot managers qualify as empowered, relative to 56.0% of their male counterparts. This is consistent with findings in literature that show that women are often less empowered and generally advantaged in owning assets, taking decisions and getting credit due to gender norms (Rola-Rubzen *et al.*, 2020; Quisumbing and Pandolfelli, 2010; Goh, 2012). For instance, Alkire *et al.* (2013) found that approximately 40% of women in Southwestern Bangladesh and Uganda, and less than a third of women in the Western Highlands of Guatemala could be considered empowered (SNV, 2017). Furthermore, the empowerment gap between a female and her spouse on the average in this study was 23.0%. According to this measure, only 37.3% of female plot managers have achieved gender parity within their households, which is similar to the 37.5% reported by Seymour (2017) in Bangladesh.

Influence of gender and empowerment on adoption of CSA practices: Multivariate Probit model results

The results of the MVP model are presented in Table 5. The Wald chi-square test statistics ($\chi^2(100) = 376.78$) shows that the hypothesis that all regression coefficients in each equation are jointly equal to zero is rejected at 1% (Prob > $\chi^2 = 0.00$), thus indicating the fitness of the model with the data, and the relevance of the chosen explanatory variables in explaining the model. The results further show that the likelihood ratio test ($\chi^2(10) = 32.47$), which tests the hypothesis that the correlations between the error terms of the equations are all zero is also rejected at 1% (Prob > $\chi^2 = 0.00$), implying that some interdependence exists between some of the CSA practices considered. This supports the choice of the MVP model overestimating five different Probit (or Logit) models, since the error terms are correlated.

The MVP results indicated that consistent with the results shown in Table 3, female plot managers have a higher probability of adopting green manure and agroforestry, while male plot managers were more likely to adopt crop rotation relative to their female counterparts. This may be because male plot managers have access to more land (as presented in Table 4) and can afford to rotate crops among their multiple plots, while their female counterparts must utilize the relatively limited plot available for them to produce staple food items for family consumption. Literature has also shown that women are often allocated marginal lands (Amigun *et al.*, 2011; Patel *et al.*, 2014), which are closer to the homestead, which may account for women's higher likelihood of adopting soil restoring CSA practices such as green manure and agroforestry, in a bid to replenish the fertility of the plot available for their use.

Furthermore, no evidence of a significant relationship was found between the empowerment score and the adoption of any of the five CSA practices. However, the empowerment gap (the difference in empowerment between the primary male and primary female adult within each household) negatively influenced the adoption of agroforestry. This implies that the likelihood of adopting agroforestry increased, with declining empowerment gap in the household. This is in line with the assertion of Seymour *et al.* (2016), who argue that households in which women are empowered tend to be more progressive in their beliefs, and consequently more open to adopting new technologies. This resonates with the finding of Seymour (2017), who reported that a narrowing of the empowerment gap between spouses is associated with higher levels of technical efficiency in Bangladesh and Diiro *et al.* (2018), who found that women's empowerment in agriculture significantly increases maize productivity on both female-managed and male-managed plots.

Table 5. Influence of gender and empowerment on adoption of CSPs: Results of multivariate probit regression

Variables	Green manure Coeff	Green manure Z	Agroforestry Coeff	Agroforestry Z	Organic manuring Coeff	Organic manuring z	Crop rotation Coeff	Crop rotation z	Zero/Minimum tillage Coeff	Zero/Minimum tillage z
Age	0.0059	1.49	−0.0017	−0.51	0.0053	1.51	−0.003	−0.86	0.0042	1.22
Gender	0.3399	2.13**	0.4807	3.17***	0.1709	1.21	−0.500	−2.95***	0.0249	0.18
Marital status	−0.1826	−0.84	−0.0084	−0.05	0.1191	0.72	0.072	0.37	−0.1290	−0.78
Years of schooling	0.0190	2.24**	0.0006	0.08	−0.0088	−1.21	−0.009	−1.15	0.0076	1.03
Household size	−0.0177	−1.90*	0.0081	1.09	0.0010	0.13	0.006	0.8	0.0040	0.57
Empowerment score	−0.3059	−1.18	−0.0049	−0.02	−0.0312	−0.14	0.120	0.52	−0.2136	−0.94
Empowerment gap	−0.1305	−0.59	−0.3888	−2.24**	0.2019	1.16	−0.190	−0.99	0.2129	1.18
Native	−0.0687	−0.51	0.3263	2.8***	−0.2030	−1.78*	0.328	2.41**	0.0757	0.65
Land ownership status	−0.0062	−0.06	0.4956	5.75***	−0.1708	−1.98**	−0.079	−0.85	0.4630	5.14***
Farm size (Ha)	−0.0120	−1.27	0.0007	0.11	0.0021	0.35	0.004	0.58	−0.0149	−2.03**
Land type	0.1105	1.14	−0.0360	−0.45	−0.1645	−2.02**	0.137	1.57	0.1541	1.89**
Extension contact	0.0001	0.12	0.0016	2.01**	0.0016	1.66*	0.000	0.38	−0.0005	−0.51
Off farm income	0.0000	1.05	0.0000	−0.03	0.0000	0.32	0.000	−0.99	0.0000	−0.44
Plot trekking distance from home	−0.0005	−0.57	0.0007	0.97	−0.0006	−0.84	0.001	0.74	0.0003	0.41
Fertilizer use	0.0410	0.38	0.1205	1.39	0.1856	2.08**	−0.112	−1.19	0.8123	8.59***
Derived Savannah	0.6579	1.89*	0.3269	1.58	−0.0294	−0.14	−0.095	−0.42	−0.0902	−0.42
Northern Guinea	0.6207	1.84*	0.3882	1.99**	0.1343	0.68	−0.095	−0.45	−0.0614	−0.31
Rainforest	0.8280	2.57***	0.2582	1.39	−0.0102	−0.05	0.124	0.63	−0.0728	−0.39
Southern Guinea	0.4775	1.43	0.5231	2.75***	−0.0400	−0.21	0.069	0.34	−0.0207	−0.11
Sudan Savannah	0.9436	2.9	0.0823	0.44	0.2592	1.35	−0.193	−0.95	−0.2660	−1.37
Constant	−1.8859	−4.15***	−0.7879	−2.42**	−0.2808	−0.85	−1.015	−2.82***	−1.4736	−4.35***
Wald $chi^2(100)$	376.7800									
Prob > Chi^2	0.0000									
Log pseudo likelihood	−3053.619									

Likelihood ratio test of rho21 = rho31 = rho41 = rho51 = rho32 = rho42 = rho52 = rho43 = rho53 = rho54 = 0: $chi^2(10)$ = 32.4783, Prob > chi^2 = 0.0003

Note(s): *, **, *** represent 10%, 5% and 1% level of significance respectively

In addition to these variables of interest, other household and plot characteristics influence the adoption of these practices, albeit heterogeneously. For instance, farmers who own the land which they cultivate are more likely to adopt agroforestry and zero/minimum tillage. This seems hardly surprising given that theoretically, secure land tenure is expected to increase the incentives for a rational farmer to invest in technologies that yield future benefits to him/her (Feder, 1988; Gavian and Fafchamps, 1996). However, there is no consensus empirically, as different studies yield conflicting results (Abdulai *et al.*, 2011; Zeng *et al.*, 2018). This result corroborates the theoretical standpoint, and as Kassie *et al.* (2015) argue, this could be an expression of Marshallian inefficiency, in which farmers use less inputs or make less investments on rented plots compared to owned plots. Similarly, farmers who are indigenous to the community are also likely to adopt agroforestry and crop rotation, probably as a result of access to family and communal land, as well as the relative security of their tenure, given their status as natives. Interestingly, the results show that landowners are less likely to adopt organic manure. This could probably be a reflection of the fact that those who own land, are the wealthier farmers, who can afford to use inorganic fertilizers which are more expensive, but highly desired by farmers.

Furthermore, the importance of agricultural extension in diffusion and continued use of technologies among farmers was underscored, as the results showed that frequency of contact with extension agents positively influenced agroforestry and organic manure adoption. This is consistent with earlier findings in literature (Umar *et al.*, 2014; Kassie *et al.*, 2015; Wossen *et al.*, 2017). Education also positively influences the likelihood of adopting green manure, as farmers with more years of education are characteristically expected to be more enlightened, i.e. able to process information relating to new technologies, and adopt faster relative to less educated farmers (Ghimire and Huang, 2016). However, the results show that farmers with larger household sizes are less likely to adopt green manure. This could be as a result of the unwillingness of farmers to allow an economically unproductive fallow period, which would be an inefficient use of available family labour (Yusuf and Yusuf, 2008).

Conclusion

The objective of this study was to examine how CSA practices' adoption decisions vary along gender lines at the plot-level, within and across households in Nigeria. In order to achieve this, the empowerment score for each plot manager was computed, as well as the women empowerment gap for each household using the A-WEAI methodology. These two metrics, together with the gender of the plot manager, were included as explanatory variables in the MVP model estimated to identify determinants of CSA practices' adoption in Nigeria. The results show that men are significantly more empowered than women in four out of the five domains of empowerment, while preliminary descriptive statistics indicate that female plot managers adopted the CSA practices considered more than their male counterparts. Econometric results confirm that female plot managers have a higher likelihood of adopting green manure and agroforestry, while male plot mangers are more likely to adopt crop rotation. However, no significant gender differences in the adoption of organic manure use and zero/minimum tillage were found. The results also suggest that closing the empowerment gap between women and their spouses would positively influence the adoption of agroforestry. The findings of the study underscore the importance of women empowerment in the drive for CSA practices' adoption in Nigeria, as they are more likely to adopt them relative to men, but are constrained in terms of productive resources. The study concludes that policies that recognize gender differentials in access to these resources should be made and targeted at improving women's access in order to catalyse the diffusion of CSA practices, towards the achievement of improved and sustainable livelihoods among farm households in Nigeria.

References

Abdulai, A., Owusu, V. and Goetz, R. (2011), "Land tenure differences and investment in land improvement measures: theoretical and empirical analyses", *Journal of Development Economics*, Vol. 96 No. 1, pp. 66-78.

Abegunde, V.O., Sibanda, M. and Obi, A. (2019), "The dynamics of climate change adaptation in sub-Saharan Africa: a review of climate-smart agriculture among small-scale farmers", *Climate*, Vol. 7 No. 11, p. 132, doi: 10.3390/cli7110132.

Afolami, C.A., Obayelu, A.E. and Vaughan, I.I. (2015), "Welfare impact of adoption of improved cassava varieties by rural households in South Western Nigeria", *Agricultural and Food Economics*, Vol. 3, p. 18, doi: 10.1186/s40100-015-0037-2.

Agarwal, B. (1994), "Gender and command over property: a critical gap in economic analysis and policy and South-East Asia", *World Development*, Vol. 22 No. 10, pp. 1455-1478.

Ali, E. and Awade, N.E. (2019), "Credit constraints and soybean farmers", *Welfare in Subsistence Agriculture in Togo' Heliyon*, Vol. 5 No. 4, e01550, doi: 10.1016/j.heliyon.2019.e01550.

Alkire, S., Meinzen-Dick, R., Peterman, A., Quisumbing, A.R., Seymour, G. and Vaz, A. (2013), "The women's empowerment in agriculture index", *World Development*, Vol. 52, pp. 71-91.

Amigun, B., Musango, J.K. and Stafford, W. (2011), "Biofuels and sustainability in Africa", *Renewable and Sustainable Energy Reviews*, Vol. 15 No. 2, pp. 1360-1372.

Arslan, A., McCarthy, N., Lipper, L., Asfaw, S. and Cattaneo, A. (2013), "Adoption and intensity of adoption of conservation farming practices in Zambia", *Agriculture, Ecosystems and Environment*, Vol. 187, pp. 72-86.

Aryal, J.P., Farnworth, C.R., Khurana, R., Ray, S. and Sapkota, T.B. (2014), "Gender dimensions of climate change adaptation through climate smart agricultural practices in India", *Innovation in Indian Agriculture: Ways Forward*, Institute of Economic Growth (IEG), New Delhi, and International Food Policy Research Institute (IFPRI), New Delhi, Washington DC.

Asfaw, S., Battista, F. and Lipper, L. (2016), "Agricultural technology adoption under climate change in the Sahel: micro-evidence from Niger", *Journal of African Economies*, Vol. 25 No. 5, pp. 637-669, doi: 10.1093/jae/ejw005.

Asongu, S. and Odhiambo, N. (2019), "Inequality and the economic participation of women in sub-Saharan Africa: an empirical investigation", *African Journal of Economic and Management Studies*, Vol. 11 No. 2, pp. 193-206, doi: 10.1108/AJEMS-01-2019-0016.

Awotide, B.A., Karimov, A.A. and Diagne, A. (2016), "Agricultural technology adoption, commercialization and smallholder rice farmers' welfare in rural Nigeria", *Agricultural and Food Economics*, Vol. 4, p. 3, doi: 10.1186/s40100-016-0047-8.

Bernier, Q., Meinzen-Dick, R., Kristjanson, P., Haglund, E., Kovarik, C., Bryan, E., Ringler, C. and Silvestri, S. (2015), "Gender and institutional aspects of climate-smart agricultural practices: evidence from Kenya", CCAFS Working Paper No. 79, CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS), Copenhagen, available at: www.ccafs.cgiar.org.

Brixiová, Z., Kangoye, T. and Tregenna, F. (2020), "Enterprising women in Southern Africa: when does land ownership matter?", *Journal of Family and Economic Issues*, Vol. 41 No. 1, pp. 37-51, doi: 10.1007/s10834-020-09663-2.

Calzadilla, A., Zhu, T., Rehdanz, K., Tol, S.J.R. and Ringler, C. (2008), "Economic-wide impacts of climate change on agriculture in sub-Saharan Africa", University of Hamburg Working Paper FNU-170, Hamburg, Germany.

Coulibaly, J.Y., Chiputwa, B., Nakelse, T. and Kundhlande, G. (2016), "Adoption of agroforestry and its impact on household food security among farmers in Malawi", ICRAF Working Paper No. 223, World Agroforestry Centre, Nairobi, doi: 10.5716/WP16013.pdf.

Diiro, G.M., Seymour, G., Kassie, M., Muricho, G. and Muriithi, B.W. (2018), "Women's empowerment in agriculture and agricultural productivity: evidence from rural maize farmer households in western Kenya", *PloS One*, Vol. 13 No. 5, e0197995, doi: 10.1371/journal.pone.0197995.

Doss, C.R. (2018), "Women and agricultural productivity: reframing the issues", *Development Policy Review*, Vol. 36 No. 1, pp. 35-50.

Eckstein, D., Künzel, V., Schäfer, L. and Winges, M. (2019), *Global Climate Risk Index 2020*, Germanwatch, Bonn, available at: https://www.germanwatch.org/sites/germanwatch.org/files/20-2-01e%20Global%20Climate%20Risk%20Index%202020_16.pdf.

Ehiakpor, D.S., Danso-Abbeam, G., Dagunga, G. and Ayambila, S.N. (2019), "Impact of Zai technology on farmers' welfare: evidence from northern Ghana", *Technology in Society*, Vol. 59, pp. 1-8, doi: 10.1016/j.techsoc.2019.101189.

FAO (Food and Agriculture Organization of the United Nations) (2011), *The State of Food and Agriculture*, Food and Agriculture Organization, Rome, available at: http://www.fao.org/docrep/013/i2050e/i2050e00.htm.

Farauta, B.K., Egbule, C.L., Agwu, A.E., Idrisa, Y.L. and Onyekuru, N.A. (2012), "Farmers adaptation initiatives to the impact of climate change on agriculture in northern Nigeria", *Journal of Agricultural Extension*, Vol. 16 No. 1, pp. 132-144.

Feder, G. (1988), *Land Policies and Farm Productivity in Thailand*, Johns Hopkins University Press, Baltimore, Maryland.

Fletschner, D. (2008), "Women's access to credit: does it matter for household efficiency?", *American Journal of Agricultural Economics*, Vol. 90 No. 3, pp. 669-683.

Gavian, S. and Fafchamps, M. (1996), "Land tenure and allocative efficiency in Niger", *American Journal of Agricultural Economics*, Vol. 78 No. 2, pp. 460-471.

Gebre, G.G., Isoda, H., Amekawa, Y. and Nomura, H. (2019), "Gender differences in the adoption of agricultural technology: the case of improved maize varieties in southern Ethiopia", *Women's Studies International Forum*, Vol. 76, p. 102264, doi: 10.1016/j.wsif.2019.102264.

Ghimire, R. and Huang, W.C. (2016), "Adoption pattern and welfare impact of agricultural technology: empirical evidence from rice farmers in Nepal", *Journal of South Asian Development*, Vol. 11 No. 1, pp. 113-137.

Goh, A.X.H. (2012), "A literature review of the gender-differentiated impacts of climate change on women's and men's assets and well-being in developing countries", CAPRi Working Paper No. 106.

Greene, W.H. (2008), *Econometric Analysis*, 7th ed., Prentice Hall, New Jersey.

Hundera, H., Mpandeli, S. and Bantider, A. (2019), ""Smallholder farmers' awareness and perceptions of climate change in Adama district, central rift valley of Ethiopia", *Weather and Climate Extremes*, Vol. 26, p. 100230, doi: 10.1016/j.wace.2019.100230.

Huyer, S. (2016), "Closing the gender gap in agriculture", *Gender, Technology and Development*, Vol. 20 No. 2, pp. 1-12, doi: 10.1177/0971852416643872.

Kassie, M., Teklewold, H., Jaletab, M., Marenya, P. and Erenstein, O. (2015), "Understanding the adoption of a portfolio of sustainable intensification practices in eastern and southern Africa", *Land Use Policy*, Vol. 42, pp. 400-411.

Kassie, G.W. (2017), "Agroforestry and farm income diversification: synergy or tradeoff? The case of Ethiopia", *Environmental Systems Research*, Vol. 6 No. 1, p. 8, doi: 10.1186/s40068-017-0085-6.

Khatri-Chhetri, A., Aggarwal, P.K., Joshi, P.K. and Vyas, S. (2017), "Farmers' prioritization of climate-smart agriculture (CSA) technologies", *Agricultural Systems*, Vol. 151, pp. 184-191.

Khoza, S., Van Niekerk, D. and Nemakonde, L.D. (2019), "Understanding gender dimensions of climate-smart agriculture adoption in disaster-prone smallholder farming communities in Malawi and Zambia", *Disaster Prevention and Management: An International Journal*, Vol. 28 No. 5, pp. 530-547, doi: 10.1108/DPM-10-2018-0347.

Kieran, C., Sproule, K., Quisumbing, A.R. and Doss, C.R. (2017), "Gender gaps in landownership across and within households in four Asian countries", *Land Economics*, Vol. 93 No. 2, pp. 342-370, doi: 10.3368/le.93.2.342.

Lobell, D.B., Burke, M.B., Tebaldi, C., Mastrandrea, M.D., Falcon, W.P. and Naylor, R.L. (2008), "Prioritizing climate change adaptation needs for food security in 2030", *Science*, Vol. 319 No. 5863, pp. 607-610.

Maguza-tembo, F., Mangison, J., Edris, A.K. and Kenamu, E. (2017), "Determinants of adoption of multiple climate change adaptation strategies in southern Malawi: an ordered Probit analysis", *Journal of Development and Agricultural Economics*, Vol. 9 No. 1, pp. 1-7, doi: 10.5897/JDAE2016-0753.

Makate, C., Makate, M., Mango, N. and Siziba, S. (2019), "Increasing resilience of smallholder farmers to climate change through multiple adoption of proven climate-smart agriculture innovations. Lessons from Southern Africa", *Journal of Environmental Management*, Vol. 231, pp. 858-868.

Malapit, H., Kovarik, C., Meinzen-Dick, R. and Quisumbing, A. (2015), *Instructional Guide on the Abbreviated Women's Empowerment in Agriculture Index (A-WEAI)*, available at: https://www.ifpri.org/sites/default/files/Basic%20Page/weai_instructionalguide_1.pdf.

Mansaray, B., Jin, S. and Horlu, G.S.A. (2019), "Do land ownership and agro-ecological location of farmland influence adoption of improved rice varieties? Evidence from Sierra Leone", *Agriculture*, Vol. 9 No. 12, pp. 1-20, doi: 10.3390/agriculture9120256.

Massay, G. (2019), "The struggles for land rights by rural women in sub-Saharan Africa", *African Journal of Economic and Management Studies*, Vol. 11 No. 2, doi: 10.1108/AJEMS-03-2019-0120.

McCarthy, N. and Brubaker, J. (2014), *Climate-Smart Agriculture and Resource Tenure in Sub-saharan Africa: A Conceptual Framework*, FAO, Rome.

Meinzen-Dick, R., Quisumbing, A., Doss, C. and Theis, S. (2019), "Women's land rights as a pathway to poverty reduction: framework and review of available evidence", *Agricultural Systems*, Vol. 172, pp. 72-82, doi: 10.1016/j.agsy.2017.10.009.

Morton, J.F. (2007), "Climate change and food security special feature: the impact of climate change on smallholder and subsistence agriculture", *Proceedings of the National Academy of Sciences*, Vol. 104 No. 50, pp. 19680-19685.

Mujeyi, A., Mudhara, M. and Mutenje, M.J. (2019), "Adoption determinants of multiple climate smart agricultural technologies in Zimbabwe: considerations for scaling-up and out", *African Journal of Science, Technology, Innovation and Development*, Vol. 11, pp. 1-12, doi: 10.1080/20421338.2019.1694780.

Murugani, V.G. and Thamaga-Chitja, J.M. (2019), "How does women's empowerment in agriculture affect household food security and dietary diversity? The case of rural irrigation schemes in Limpopo Province South Africa", *Agrekon*, Vol. 58 No. 3, pp. 308-323, doi: 10.1080/03031853.2019.1610976.

National Bureau of Statistics (2010), "Annual abstract of statistics", available at: http://www.nigerianstat.gov.ng/download/71.

National Bureau of Statistics (2017), "Annual abstract of statistics", available at: https://www.nigerianstat.gov.ng/pdfuploads/ANNUAL%20ABSTRACT%20STATISTICS%20VOLUME-1.pdf.

Ndiritu, S.W., Kassie, M. and Shiferaw, B. (2014), "Are there systematic gender differences in the adoption of sustainable agricultural intensification practices? Evidence from Kenya", *Food Policy*, Vol. 49, pp. 117-127.

Neufeldt, H., Jahn, M., Campbell, B., Beddington, J., DeClerck, F., De Pinto, A., Gulledge, J., Hellin, J., Herrero, M., Jarvis, A., LeZaks, D., Meinke, H., Rosenstock, T., Scholes, M., Scholes, R., Vermeulen, S., Wollenberg, E. and Zougmore, R. (2013), "Beyond climate-smart agriculture: toward safe operating spaces for global food systems", *Agricultural Food Security*, Vol. 2 No. 12, pp. 1-6.

Obayelu, A.E., Ogbe, A.O. and Edewor, S.E. (2020), "Gender gaps and female labour participation in agriculture in Nigeria", *African Journal of Economic and Management Studies*, Vol. 11 No. 2, pp. 285-300.

Oladele, O.I., Chimewah, A.N. and Olorunfemi, O.D. (2019), "Determinants of farmers' adoption of alternate wet and dry techniques in lowland rice production in Ghana, Uganda and Cameroon for climate smart agriculture", *The Journal of Developing Areas*, Vol. 53 No. 3, pp. 170-181.

Patel, P., Douglas, Z., Farley, K., Stangl, A., Brady, L., Kes, A., Jacobs, K. and Namy, S. (2014), *Securing Women's Land and Property Rights - A Critical Step to Address HIV, Violence, and Food Security*, Open Society Foundations, available at: http://globalinitiative-escr.org/wp-content/uploads/2014/03/Securing-Womens-Land-Property-Rights-20140307.pdf.

Peterman, A., Behrman, J. and Quisumbing, A. (2010), *A Review of Empirical Evidence on Gender Differences in Non-land Agricultural Inputs, Technology, and Services in Developing Countries*, FPRI, Washington, DC.

Quisumbing, A.R. and Pandolfelli, L. (2010), "Promising approaches to address the needs of poor female farmers: resources, constraints, and interventions", *World Development*, Vol. 38 No. 4, pp. 581-592.

Rola-Rubzen, M.F., Paris, T., Hawkins, J. and Sapkota, B. (2020), "Improving gender participation in agricultural technology adoption in Asia: from rhetoric to practical action", *Applied Economic Perspectives and Policy*, Vol. 42 No. 1, pp. 113-125, available at: http://doi:10.1002/aepp.13011.

Sanou, L., Savadogo, P., Ezebilo, E.E. and Thiombiano, A. (2019), "'Drivers of farmers' decisions to adopt agroforestry: evidence from the Sudanian savannah zone Burkina Faso", *Renewable Agriculture and Food Systems*, Vol. 34 No. 2, pp. 116-133.

Seymour, G., Doss, C., Marenya, P., Meinzen-Dick, R. and Passarelli, S. (2016), "Women's empowerment and the adoption of improved maize varieties: evidence from Ethiopia, Kenya, and Tanzania", Selected Paper Prepared for, *Presentation at the 2016 Agricultural and Applied Economics Association Annual Meeting,* International Food Policy Research Institute, Milwaukee, Wisconsin, July 31-August 2, 2016, available at: http://ebrary.ifpri.org/utils/getfile/collection/p15738coll5/id/5451/filename/5452.pdf.

Seymour, G. (2017), "Women's empowerment in agriculture: implications for technical efficiency in rural Bangladesh", *Agricultural Economics*, Vol. 48 No. 4, pp. 513-522.

Shittu, A.M., Kehinde, M.O., Ogunnaike, M.G. and Oyawole, F.P. (2018), "Effects of land tenure and property rights on farm households willingness to accept incentives to invest in measures to combat land degradation in Nigeria", *Agricultural and Resource Economics Review*, Vol. 47 No. 2, pp. 357-387.

SNV (2017), "Enhancing opportunities for women's enterprises (EOWE) Programme: Kenya baseline report", *Netherlands Development Organisation Knowledge series*, available at: http://www.snv.org/public/cms/sites/default/files/explore/download/kn_eowe_baseline_report.pdf.

Srivastava, A.K., Mboh, C.M., Gaiser, T. and Ewert, F. (2017), "Impact of climatic variables on the spatial and temporal variability of crop yield and biomass gap in Sub-Saharan Africa- a case study in Central Ghana", *Field Crops Research*, Vol. 203, pp. 33-46.

Teklewold, H., Kassie, M. and Shiferaw, B. (2013), "Adoption of multiple sustainable agricultural practices in rural Ethiopia", *Journal of Agricultural Economics*, Vol. 64 No. 3, pp. 597-623, doi: 10.1111/1477-9552.12011.

Theriault, V., Smale, M. and Haider, H. (2017), "How does gender affect sustainable intensification of cereal production in the West African Sahel? Evidence from Burkina Faso", *World Development*, Vol. 92, pp. 177-191.

Tran, N.L.D., Rañola, R.F., Sander, B.O., Reiner, W., Nguyen, D.T. and Nong, N.K.N. (2019), "Determinants of adoption of climate-smart agriculture technologies in rice production in Vietnam", *International Journal of Climate Change Strategies and Management*, Vol. 12 No. 2, pp. 238-256.

Udry, C. (1996), "Gender, agricultural production, and the theory of the household", *Journal of Political Economy*, Vol. 104, pp. 1010-1046.

Umar, S., Musa, M.W. and Kamsang, L. (2014), "Determinants of adoption of improved maize varieties among resource-poor households in Kano and Katsina States Nigeria", *Journal of Agricultural Extension*, Vol. 18 No. 2, pp. 196-205.

UNDESA (2015), *World Population Prospects the 2015 Revision Key Findings and Advance Tables*, ESA/P/WP.241, Department of Economic and Social Affairs Population Division, New York, available at: https://esa.un.org/unpd/wpp/publications/files/key_findings_wpp_2015.pdf.

Wossen, T., Abdoulaye, T., Alene, A., Haile, M.G., Feleke, S., Olanrewaju, A. and Manyong, V. (2017), "Impacts of extension access and cooperative membership on technology adoption and household welfare", *Journal of Rural Studies*, Vol. 54, pp. 223-233, doi: 10.1016/j.jrurstud.2017.06.022.

Yusuf, A.A. and Yusuf, H.A. (2008), "Evaluation of strategies for soil fertility improvement in northern Nigeria and the way Forward", *Journal of Agronomy*, Vol. 7, pp. 15-24.

Zeng, D., Alwang, J., Norton, G., Jaleta, M., Shiferaw, B. and Yirga, C. (2018), Land ownership and technology adoption revisited: improved maize varieties in Ethiopia", *Land Use Policy*, Vol. 72, pp. 270-279.

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