What Drives the Adoption of Climate Smart Agricultural Practices? Evidence from Maize Farmers in Northern Nigeria

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Abstract

The adoption of Climate Smart Agriculture (CSA) remains low in sub-Saharan Africa, despite its promotion as a sustainable production system for mitigating agriculture's contribution to climate change, as well as for helping farmers adapt to the adverse effects of climate change. This necessitates continuing research on its determinants, in order to identify appropriate mechanisms to encourage adoption. This paper investigates the factors that drive CSA practices' adoption using recent plot-level survey data from Northern Nigeria. A Multivariate Probit Model was used to analyse the adoption of six CSA practices and control for the influence of socioeconomic, plot and institutional factors. Our study finds that the likelihood of CSA practices' adoption is influenced by land ownership, social capital, gender, off-farm work participation and plot distance from homestead. However, these factors do not unanimously influence the six CSA practices considered and vary significantly among them. It was concluded that these factors have to be considered when designing policies to promote CSA towards the achievement of sustainable livelihoods among farm households in Nigeria. We recommend that farmers be encouraged to join groups (farmer groups, cooperatives), in order to build their social capital, which could expose them to better practices, obtain informal training from those who have adopted them, and obtain help for implementation.

Keywords: Climate Smart Agriculture, Multivariate Probit, Sustainable Agriculture

Résumé

L'adoption de l'agriculture intelligente climatique (ASC) reste faible en Afrique subsaharienne, malgré sa promotion en tant que système de production durable pour atténuer la contribution de l'agriculture au changement climatique, ainsi que pour aider les agriculteurs à s'adapter aux effets changement climatique. Cela nécessite la poursuite des recherches sur ses déterminants, afin d'identifier les mécanismes appropriés pour encourager l'adoption. Cet article examine les facteurs qui ont conduit l'adoption des pratiques de l'ASC à l'aide de données récentes sur les enquêtes au niveau de l'intrigue dans le nord du Nigéria. Un modèle Multivariate Probit a été utilisé pour analyser l'adoption de six pratiques de l'ASC et le contrôle de l'influence de facteurs socio-économiques, de complot et institutionnels. Notre étude révèle que la probabilité de l'adoption des pratiques de l'ASC est influencée par la propriété foncière, le capital social, le sexe, la participation au travail à l'extérieur de la ferme et la distance de parcelle de terrain de la ferme. Toutefois, ces facteurs n'influencent pas unanimement les six pratiques de l'ASC examinées et varient considérablement d'entre elles. Il a été conclu que ces facteurs doivent être pris en considération lors de l'conception de politiques visant à promouvoir l'ASC en vue de la réalisation de moyens de subsistance durables parmi les ménages agricoles au Nigéria. Nous recommandons que les agriculteurs soient encouragés à se joindre à des groupes (groupes d'agriculteurs, coopératives), afin de construire leur capital social, ce qui pourrait les exposer à de meilleures pratiques, obtenir une formation informelle de ceux qui les ont adoptés et obtenir de l'aide pour la mise en œuvre.

Mots-clés : Climate Smart Agriculture, Probit multivariable, Agriculture durable

1. Introduction

Climate change is a major global challenge as it affects the availability of critical resources like water, energy and land (Beddington *et al.*, 2012). As such, the issue of climate change mitigation forms a major focus of the Sustainable Development Goals (1, 2 and 13) (UNDP, 2016). The most direct impact of climate change is on agriculture and food systems, and its adverse effects (such as erratic and unpredictable rainfall, marginal soil fertility, increasing loss of land to aridity and desertification, shorter growing seasons among others) are felt more by smallholder farmers in developing countries (Brown and Funk, 2008). This is especially true in Africa, where about 85% of the population depend on rain-fed agriculture and agriculture-based activities for their livelihood (Moyo, 2016). Furthermore, about 96% of the total crop production in SSA 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). This has important implications for Nigeria's poverty alleviation efforts, as it is estimated that 69% of the poor in the country derive their livelihood from agriculture (NBS, 2012).

Already, Lobell *et al*. (2011) estimated that climate change has reduced global yields of maize and wheat by 3.8% and 5.5% between 1980 and 2008 respectively, while estimated impacts of future climate change on cereal crop yields in different regions indicate that the yield loss can be up to 60% for maize, 35% for rice, 20% for wheat and 50% for sorghum depending on the location (Khatri-Chhetri *et al*., 2017).

However, agricultural production is one of the major drivers of climate change, implying that farmers are both victims and drivers of climate change. It is estimated that agriculture is responsible for about 60% of tropical deforestation and accounts for as much as 13.5% of Greenhouse Gases (GHGs) emissions per year (IPCC, 2007; Chakravarty *et al*., 2012). Smallholder farmers in developing countries (including Nigeria) employ unsustainable practices such as excessive reliance on slash and burn agriculture, cropping on marginal lands, and over-exploitation of forest, grassland and wetland ecosystem services, which emit GHGs, predispose the soil to erosion, land degradation and desertification, with an attendant decline in soil productivity and crop yield, increased poverty and food insecurity (Garibaldi *et al*., 2017). Yet, an additional 2.4 billion people are expected to be living in developing countries by 2050, with 1.3 billion more people in Africa. In particular, Nigeria has the highest population growth among the ten largest countries in the world, and is expected to become the third largest in the world by 2050 (UNDESA, 2015). Thus, agricultural production systems require adaptation to climate change in order to ensure the achievement of national sustainable development goals (SDGs) of reduction in poverty and food insecurity, as the livelihood of majority of the poor hinge on it (Khatri-Chhetri *et al.,* 2017).

In response to these challenges, Climate Smart Agriculture (CSA) was introduced, and is promoted by the Food and Agriculture Organization (FAO) as an alternative sustainable approach to agricultural production (FAO, 2010). CSA practices are defined as those that sustainably increase agricultural productivity and incomes build resilience and capacity of agricultural and food systems to adapt to climate change, and reduce or remove greenhouse gases while enhancing national food security (Neufeldt *et al*., 2013). Although several farm level studies suggest that adoption of CSA technologies can improve crop yields, increase input use efficiency, increase net income and reduce GHG emissions (Gathala *et al*., 2011; Sapkota *et al*., 2014; Khatri-Chhetri *et al*., 2016), the adoption of such practices remains generally low, particularly in sub-Saharan Africa (Arslan *et al*., 2013; McCarthy and Brubaker, 2014). This has led 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.

This study contributes to the on-going discussion about what drives CSA practices' adoption at the plot level. Understanding the drivers of CSA adoption will enable policy-makers and development practitioners to better target policies and interventions to aid the diffusion of these practices, towards the achievement of improved and sustainable livelihoods. Specifically, we analyse the adoption of a range of CSA practices (green manure, agroforestry, organic manure, crop rotation, refuse retention and zero/minimum tillage) among maize farmers using the Multivariate Probit model to determine the influence of socioeconomic, plot and institutional factors. This study focuses on maize, as it is one of the most important staple food crops in Nigeria, with far reaching implications on the food security and livelihood of smallholder farmers. In particular, maize cultivation occupies the largest arable land area in Nigeria, as over fifty million farmers grow maize every year, while over ninety million people are employed in its processing and usage daily (Onyibe *et al*., 2014). In addition, it is cheaper than the other cereals (such as rice and wheat) and is thus more accessible to the poor, and the average person in Nigeria consumes 60g of it daily in both fresh and processed forms (Ranum, Peña-Rosas and Garcia-Casal, 2014). This is in addition to the fact that many agro-allied industries depend on it as raw material, and it contributes about 80 percent of poultry and other livestock feed in the country, thus having a great implication on protein intake. Also, with a national supply deficit of about 5.7 million tonnes in 2013 (Onyibe *et al*., 2014), there is the need for maize production to increase, in the face of constraints imposed by climate change, in order to ensure food security for the growing population. Although the literature shows a growing number of recent studies which have attempted to investigate the determinants of CSA practices adoption in Africa using plot-level data (Asfaw *et al*., 2016; Theriault *et al.*, 2017), literature on this in Nigeria is still observed to be very scanty. Thus, this study fills a gap in existing literature by using a plot-level dataset to examine the adoption of CSA practices in Nigeria.

2. Methodology

2.1 Study Area

The study was conducted in northern Nigeria. Northern Nigeria consists of three geopolitical zones; the Northwest (which consists of 7 states), North-central (which consists of 6 states and the Federal Capital Territory) and Northeast (which consists of 6 states) geopolitical zones. Northern Nigeria lies between latitude 9^0 – 14^0N and longitude 3^0 – 15^0E, and is bounded in the North by Niger republic, Chad and Cameroon in the East, and in the West by Republic of Benin (AbdulKadir *et al*., 2013). Northern Nigeria is dominated by the Guinea, Sudan and Sahel savannahs, and the vegetation density decreases northwards in response to climatic conditions. Although the region is geographically prone to drought, desertification, wind and water erosion, agriculture remains the most dominant economic activity in the region. Dominant crops grown in the region include maize, rice, sorghum, millet, cotton and groundnut, among others (Ugwu and Kanu, 2012).

2.2 Data and Sampling Procedure

This data used in this study was collected by FUNAAB-RAAF-PASANAO project, titled "*Incentivizing Adoption of Climate Smart Practices in Cereals Production in Nigeria: Sociocultural and Economic Diagnosis*" which was funded by ECOWAS - Regional Agency for Agriculture and Food (RAAF) under its Support Programme for Food and Nutrition Security in West Africa (PASANAO). The respondents for this study were drawn in a multi-stage sampling process. The first stage entailed the purposive selection of two states reputed for maize production from each of the three (3) geopolitical zones of northern Nigeria. Kaduna and Kebbi States were selected from the Northwest, while Niger and Nasarawa were selected from the North-central. However, only Taraba State was selected from the Northeast because of the religious unrest in the zone. At the second stage, three (3) blocks reputed for maize production were purposively chosen from each of the five (5) states that had been selected. In stage three, two (2) 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. After dropping households with incomplete information, this process yielded a total of 238 maize farming households and 410 plots that were used for the study. Data collected include farmers' social, economic and institutional variables, their perception of climate change, adoption of CSA practices as well as their livelihood characteristics.

2.3 Analytical Framework

Modelling the adoption decision: Utility Maximization Theory

Following Afolami *et al.* (2015), a farmer was 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 is still utilizing such practice at the time of interview. In this study, we assume that each plot manager compares the CSA practice 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, we assume 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 Multivariate

Probit model (MVP), which simultaneously 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). Consider the *i*th farmer (*i*=1,…N) facing a decision on whether or not to adopt a CSA practice on plot *p*. Let U_0 represent the benefits to the farmer from traditional management practices, and let U_k represent the benefit of adopting the *k*th CSA practice, where *k* denotes choice of CSA practice. The farmer decides to adopt the *k*th CSA practice on plot *p* if:

$$Y^*_{ipk} = U^*_k - U_0 > 0 \qquad (1)$$

However, the net benefit (Y^*_{ipk}) that the farmer derives from the adoption of the *k*th CSA practice (G = Green manure, A = Agroforestry, M = Organic manure, C = Crop rotation, R = Refuse retention, T = Zero/Minimum tillage) is a latent variable determined by observed personal, household, plot and location characteristics (X_i) and the error term (ε_i):

$$Y^*_{ipk} = X_i\beta_k + \varepsilon_i \qquad (k = G, A, M, C, R, T) \qquad (2)$$

The unobserved preferences in equation (2) above translate into the observed binary outcome equation for each choice as follows:

$$Y_{ipk} = \begin{cases} 1 & if\, Y^*_{ipk} > 0 \\ 0 & otherwise \end{cases} \qquad (k = 1, 2, \ldots k) \qquad (3)$$

Where Y_{ipk} is the adoption of the *k*th CSA practice by the *i*th farmer on plot *p*.

3. Results and Discussion

3.1 Description of Dependent Variables

The adoption of the climate smart practices was generally low; Green manure, agroforestry, crop rotation, organic manure, zero tillage and refuse retention were adopted on 18%, 40%, 27%, 45%, 38% and 44% of the sample plots used in this study, which corroborates other findings in SSA (Arslan *et al*., 2013; McCarthy and Brubaker, 2014).

3.2 Description of Explanatory Variables

The explanatory variables in the empirical model are based on a review of theoretical work and empirical literature on adoption of sustainable agricultural practices (Teklewold, Kassie and Shiferaw, 2013). Table 1 presents the description and summary statistics of these variables. The results show that most (90.0%) of the maize plots are managed by male farmers. The average age of a maize farmer was 44 years, having a mean household size of nine (9) persons. Over half (56.3%) of the respondents had at least primary education, although the average years of formal education obtained was about 7 years. Most (74.0%) of them had access to extension services in the previous season, indicating a robust presence of agricultural extension services in the study area, while only 40% received credit in the same period. The mean farm size of the maize farmers was 3.17 hectares, which indicates that the average farmer is a smallholder according to Nigeria's official definition of smallholders (<5 hectares) (Anderson *et al*., 2017). With respect to plot-specific characteristics included in the model, we found that on the average, plot managers had to trek for almost an hour (51.4 minutes) to get to their plots. According to Menale *et al*. (2012), adoption of sustainable practices that involve transporting bulky inputs is likely to be low for the farthest plots, compared to those closer to the homestead. We also found that about 67.0% of the maize plots were owned by the farmers. This is quite important in the adoption process as farmers are more likely to invest in and improve lands which they own (Oladele *et al*., 2011).

3.3 Adoption of Climate Smart Agricultural Practices: Multivariate Probit Results

Table 2 shows the results of the Multivariate Probit regression which was used to analyse the factors influencing farmers' adoption of CSA practices on the plots which they manage. The Wald chi-square test statistics [$\chi^2(120) = 486.53$] 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. Furthermore, the likelihood ratio test [$\chi^2(15) = 75.25$], which tests the hypothesis that the correlations between the error terms of the equations are all zero is also rejected at 1% (Prob > $\chi^2 = 0.00$), thus confirming the appropriateness of the MVP model over six (6) distinct univariate Probit models which ignore the potential correlation between the adoption decision of the different CSA practices by a plot manager. The correlation between error terms of the adoption equations are reported (see appendix). The estimated correlation coefficients are statistically significant in ten of the fifteen pair cases indicating that the decision to adopt CSA practices are often jointly determined.

The results reveal that farmers are more likely to adopt agroforestry and zero/minimum tillage on plots which they own. In line with earlier work on technology adoption (Kassie, 2017), this could be because they are reasonably assured of future access to return of their investment, unlike tenants who have access to the land for the duration of their tenure, and can only plan for the short term. However, plot owners are less likely to adopt green manure against *a priori* expectation. This could be a reflection of the very low acceptance of the practice in Northern Nigeria, due to two major reasons; the tedium of incorporating the green manure with native hoes, and the unwillingness of farmers to allow an economically unproductive fallow period (Yusuf and Yusuf, 2008).

Table 1: Definition and summary statistics of variables used in the analysis

Variable	Description	Mean (SD)
Climate Smart Agricultural Practices' Adoption		
Green Manure	If plot manager adopts green manure = 1, otherwise 0	0.18 (0.39)
Agroforestry	If plot manager adopts agroforestry = 1, otherwise 0	0.40 (0.49)
Organic Manure	If plot manager adopts organic manure = 1, otherwise 0	0.45 (0.50)
Refuse retention	If plot manager adopts refuse retention = 1, otherwise 0	0.44 (0.50)
Crop rotation	If plot manager adopts crop rotation = 1, otherwise 0	0.27 (0.44)
Zero/Minimum tillage	If plot manager adopts zero/minimum tillage = 1, otherwise 0	0.38 (0.49)
Socioeconomic characteristics		
Age	Age of the plot manager	43.89 (12.67)
Female plot manager	If plot manager is female = 1, otherwise = 0	0.10 (0.31)
Marital Status	If the plot manager is married = 0; Otherwise = 1	0.07 (0.25)
Years of Schooling	Years of formal education of the plot manager	6.74 (6.29)
Household size	Number of household members	9.48 (6.67)
Off farm Income	Plot manager's total off farm income in the last year (in Naira)	45,608.79 (143,214.40)
Asset ownership	1 if plot manager owns a major asset – (such as land, buildings, machinery) - 0 otherwise	0.86 (0.35)
Farmers' Group membership	1 if plot manager is a member, 0 otherwise	0.86 (0.35)
Institutional characteristics		
Extension Contact	1 if plot manager was visited by an agricultural extension agent or if plot manager visited extension service office during last 1 year, 0 otherwise	0.74 (0.44)
Access to credit	1 if plot manager received credit, 0 otherwise	0.40 (0.49)
Plot characteristics		
Farm Size (Ha)	Size of the plot being cultivated by plot manager in hectares	3.17 (4.00)
Lowland	If plot is lowland = 1; Otherwise = 0	0.35 (0.48)
Land Ownership Status	If plot manager owns the plot = 1; Otherwise = 0	0.67 (0.47)
Plot Trekking distance from home	Number of minutes used in trekking to the plot	51.36 (53.41)
Land dispute	1 if plot manager ever experienced dispute, 0 otherwise	0.04 (0.19)
Fertilizer Use	If plot manager used inorganic fertilizer on the plot = 1; Otherwise = 0	0.69 (0.46)
Plot Observations		410

Source: Field survey, 2017

The results also show that social capital positively influences the likelihood of adopting some CSA practices; particularly green manure and organic manure. This could be particularly helpful in the selection of appropriate green manure species, as well as sourcing of organic manure, which may not be readily available in required quantity (Ukoje and Yusuf, 2013). Farmers' group membership is an important component of their social capital, as it enables them to interact with other farmers, share their experiences, learn new techniques, obtain informal training from others who have already adopted better practices, and even obtain help implementing them (Akinbode and Bamire, 2015).

We also found that female farmers are less likely to adopt crop rotation and refuse retention, relative to their male counterparts. This may be because male farmers have access to more land due to gender norms which govern its ownership in the study area, and can afford to rotate crops among their multiple plots, compared to female farmers who have limited land access (Quisumbing and Pandolfelli, 2010). Furthermore, female farmers may consider bush burning over refuse retention, since it is a faster method of land clearing, given that they have to allocate their time between home management and farming (SOFA and Doss, 2011). Also, farmers who engage in off-farm activities have a greater likelihood of adopting agroforestry and green manure. This is expected, since both agroforestry and green manuring require considerable financial commitment from adopters. For example, agroforestry necessitates a reduction in effective crop area available for cultivation which may lead to a decrease in crop output initially, while adopters of green manuring have to be willing to allow an economically unproductive fallow period. Thus, farmers engaged in other income generating activities are more likely to adopt these practices, given that they have other income sources to augment household consumption (Kassie, 2017).

With respect to other plot characteristics, the likelihood of adopting organic and green manure reduced with walking distance. According to Ndiritu *et al*. (2014) who reported a similar result in Kenya, distance can be a significant cost for the adoption of certain labour-intensive technologies, especially those involving heavy and bulky inputs. Also, farmers who cultivate lowland plots are more likely to adopt crop rotation.

Farmers use lowlands as an adaptation strategy, and plant different crops on them in line with the soil water content, which is dependent on the season they are in (rainy or dry). As expected, crop rotation and refuse retention are substitutes for inorganic fertilizer. Since their main benefit is to avoid draining the soil of the same nutrients continuously (Muhammad-Lawal *et al*., 2014), farmers who use fertilizer may feel that such practices are not necessary, given that they augment soil nutrient with fertilizers. The results further show that maize farmers in the Sudan savannah are more likely to adopt green manure, agroforestry and organic compost relative to other agro-ecological zones as expected, since they are affected more by the adverse effects of climate change, particularly desertification.

Table 2: Results of Multivariate Probit Regression showing the factors influencing CSA Practices Adoption

Variables	Green Manure		Agroforestry		Organic Compost		Retain Refuse		Crop Rotation		Zero/Minimum Tillage	
	Coefficient	Z	Coefficient	Z	Coefficient	Z	Coefficient	Z	Coefficient	Z	Coefficient	Z
Socioeconomic characteristics												
Age in years	-0.066*	-1.67	-0.041	-1.23	-0.014	-0.43	-0.005	-0.14	0.024	0.68	-0.036	-1.01
Age squared	0.001*	1.86	0.000	1.04	0.000	0.74	0.000	0.15	0.000	-0.77	0.000	1.24
Female plot manager	0.154	0.53	0.245	1.00	0.257	1.14	-0.624**	-2.42	-0.694**	-2.37	-0.209	-0.77
Marital status	-0.853**	-2.10	0.227	0.73	-0.099	-0.33	0.067	0.21	-0.725	-1.76	-0.615*	-1.85
Years of schooling	0.008	0.60	-0.014	-1.23	0.008	0.75	-0.018	-1.62	-0.006	-0.59	0.006	0.51
Household size	-0.005	-0.49	0.012	1.59	0.007	0.83	-0.008	-0.92	0.002	0.27	-0.019**	-2.01
Off farm participation	0.341*	1.91	0.264*	1.77	0.058	0.40	0.231	1.54	0.037	0.23	-0.096	-0.61
Asset Ownership	-0.241	-1.02	-0.152	-0.77	-0.373*	-1.85	0.165	0.79	0.003	0.01	-0.186	-0.88
Group membership	0.453*	1.76	0.011	0.06	0.420**	2.18	-0.279	-1.33	-0.235	-1.09	-0.077	-0.37
Institutional Characteristics												
Extension contact	0.056	0.31	-0.083	-0.54	0.156	1.03	0.007	0.05	0.104	0.61	-0.273*	-1.73
Access to credit	-0.505***	-2.73	-0.149	-1.06	0.150	1.08	-0.032	-0.22	-0.091	-0.59	-0.066	-0.44
Plot characteristics												
Farm size	0.007	0.73	0.002	0.32	0.004	0.52	-0.006	-0.69	0.007	0.74	-0.015	-1.36
Lowland	0.117	0.70	-0.253*	-1.76	0.155	1.10	-0.895***	-5.88	0.441***	2.95	-0.005	-0.03
Land Ownership	-0.358**	-2.08	0.574***	3.98	0.046	0.33	0.093	0.64	0.188	1.22	0.651***	4.26
Walking distance	-0.003*	-1.77	0.000	0.39	-0.002*	-1.73	0.000	0.06	0.001	0.40	0.000	0.09
Dispute	-0.425	-0.99	-0.271	-0.84	0.368	0.99	0.013	0.04	-0.915*	-1.87	0.154	0.44
Fertilizer use	0.242	1.36	-0.076	-0.53	0.149	1.07	-0.302**	-2.06	-0.274*	-1.80	0.836***	5.34
Agro-ecological dummy (Reference category = Sudan savannah)												
Northern guinea	-2.203***	-5.22	0.240	1.15	-0.350*	-1.67	0.440**	2.02	0.832***	3.42	0.124	0.56
Derived savannah	-1.027***	-3.97	-0.415*	-1.81	-0.408*	-1.91	0.131	0.57	0.350	1.36	-0.196	-0.80
Southern guinea	-1.149***	-5.49	-0.012	-0.07	-0.620***	-3.62	0.522***	2.88	0.922***	4.44	0.295	1.59
Constant	1.161	1.19	0.605	0.74	-0.177	-0.23	0.389	0.48	-1.586*	-1.83	-0.149	-0.17
Wald chi2(120)	486.5300											
Prob > Chi2	0.0000											
Log pseudo likelihood	-1317.1499											
Likelihood ratio test of rho21 = rho31 = rho41 = rho51 = rho32 = rho42 = rho52 = rho43 = rho53 = rho54 = 0: chi2(15) = 75.25 Prob > chi2 = 0.000												

Source: Field survey, 2017. *, **, *** represent 10%, 5% and 1% level of significance respectively

Conclusion

A shift to sustainable agriculture, which mitigates agriculture's contribution to climate change and helps farmers adapt to the conditions imposed by climate change is necessary in order to achieve the SDGs in Nigeria. In this study, we analysed the probability of adoption of six CSA practices by maize farmers in northern Nigeria, using plot-level data. We found that the adoption of these practices was generally low among the respondents. The econometric results showed that factors that influence adoption of CSA practices are not unanimous and vary significantly with the practices. In summary, plot owners are more likely to adopt agroforestry and zero/minimum tillage, while farmers engaged in off-farm income generating activities have a greater likelihood of adopting green manure and agroforestry. Social capital seems to positively influence organic manure and green manuring, and female farmers are less likely to adopt practices that require more time and more land (crop rotation and refuse retention). Practices that involve heavy and bulky inputs (organic manure and green manure) are less likely to be adopted by farmers whose plots are far from home, while farmers in the Sudan savannah are more likely to adopt practices that combat desertification. Based on these results, it is recommended that farmers be encouraged to join groups (farmer groups, cooperatives) as it provides an avenue for awareness, informal education and technical assistance in applying a new agricultural practice. Furthermore, local institutions (local government areas, village councils etc.) should be strengthened to improve rural roads, as this will considerably ease the transportation of farm inputs, especially organic manure, and thus encourage its adoption. It is recommended that government provides a policy strategy to promote the off-farm sector through investment in farmers' human capital. The income stream off-farm activities generate helps to ease the liquidity constraint often faced by smallholder farmers, which causes them to be risk averse to new technology, especially those that have significant financial implications. We conclude that these factors have to be accounted for when designing policies to promote CSA towards the achievement of sustainable livelihoods among farm households in Nigeria.

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