Agroforest Syst (2017) 91:919–926
DOI 10.1007/s10457-016-9967-2

Determinants of agroforestry technology adoption among arable crop farmers in Ondo state, Nigeria: an empirical investigation

P. T. Owombo · F. O. Idumah

Received: 10 March 2015 / Accepted: 21 May 2016 / Published online: 16 June 2016

Abstract In addressing the problem of land degradation as well as enhancing sustainable food production, agroforestry was advocated among the arable crop farmers in the area. The study was thus conducted to investigate the determinants as well as the constraints of agroforestry technology adoption in Ondo State, Nigeria. Data collected from a multi-stage sampling procedure were analysed with the aid of descriptive statistics and double hurdle model. Findings revealed that the mean age, farming experience, level of education, and plot age were 58.6 ± 13.3, 31.9 ± 13.8, 7 ± 6.3, and 30.3 ± 10.5, respectively. While the number of adult male and extension contact increased the intensity of agroforestry adoption, value of livestock reduced the technology adoption. This implies that varying factors affect farmers' decision to adopt and intensity of use. The major constraint of agroforestry practice in the area is insecure land tenure. Policy thrust that would enhance farmers' access to extension service and redistribute land should be put in place.

Keywords Agroforestry technology · Arable crop farmers · Double hurdle model · Ondo · Nigeria

P. T. Owombo (✉) · F. O. Idumah
Moist Forest Research Station, Forestry Research Institute of Nigeria, Benin City, Nigeria
e-mail: owombopaul@gmail.com

Introduction

Soil degradation constitutes a great deal of problem to agriculture in Nigeria. This is in addition to other challenges such as low productivity, high dependence on rain-fed agriculture, insecurity of the traditional land tenure system and environmental degradation due to unsustainable agricultural practices (Kabwe et al. 2009). The magnitude of land degradation (and deforestation) far exceeds the conservation activities being carried out in developing countries of the world (Bekele and Mekonnen 2010; Ajayi 2006).

Nigeria Conservation Foundation (NCF 2000) reported that more than 80 % of the country's population depends on forest and their products. The need for sustainable agricultural productivity necessitates the concern of government of every country to make and/or encourage rural dwellers which account for over 70 % of the country's population in Nigeria to practice environmentally friendly practices. These practices involve the application of land conservation technologies. Land conservation technology involves the systematic application of scientific or other organized body of knowledge to practical purposes of reducing or minimizing damages done to agricultural soil.

Land conservation technologies adopted by rural dwellers vary with individuals and purpose. A quick and easy method for replenishing nitrogen and other trace elements would be the use of inorganic fertilizers, however, a good number of rural dwellers cannot afford it because of resource constraint (Kabwe et al.

2009). Therefore, agroforestry technologies offer an alternative solution to resource-constrained smallholder farmers, who in the absence of inorganic fertilizers would otherwise grow crops without destroying the nutrients and structure of the soil. Agroforestry is now an important and popular conservation technology as it addresses many of the global challenges such as deforestation, unsustainable cropping practices, hunger, poverty and malnutrition (Amonum et al. 2009; Alao and Shuaibu 2013). According to Lambert and Ozioma (2011), agroforestry is an agricultural approach of using the interactive benefits from combining trees and shrubs with crops and/or livestock. They added that the technology combines agriculture and forestry technology to create more integrated, diverse, productive, profitable, healthy and sustainable land use system. The importance of the technology lies not only on the soil fertility maintaining advantage but also its ability to integrate woody perennials (which are of economic benefits) with agricultural crops and/or animals under the same management unit, which enhance increasing farmers' income through efficient utilization of inputs (Lambert and Ozioma 2011).

There is a great awareness and advocation for the rural dwellers adoption of agroforestry owing to the associated benefits of enriching the soil as well as increasing farmers' income. Despite farmers' awareness of this technology as well as the associated benefits, a good number of rural framers do not adopt the practice (Adesina and Chianu 2002). For the likelihood importance and environmental benefits of agroforestry to be realized both at micro and macro level, a wide adoption of the technology becomes necessary in time and place. The low rate of agroforestry technology adoption has been traced to several factors in literature. Studies on the factors influencing agroforestry technology adoption showed that agroforestry technology determinants vary. Lambert and Ozioma (2011) reported that farmers' age, educational level, farm size, income, access to credit and extension contact influence farmers adoption of agroforestry technology while Keil et al. (2005) revealed that wealth influence technology adoption.

However, while previous studies investigated determinants of adoption of agroforestry technology, no known study investigated the determinants of adoption and intensity of adoption of the technology which this study does.

Theoretical framework

The double hurdle model (DHM) proposed by Cragg (1971) is a two-stage regression model. DHM is a parametric generalization of the Tobit model. The model is equivalent to a combination of a probit and truncated regression model. In principle, DHM is applicable where two decisions (adoption and intensity of adoption) are to be made with the assumption that the decisions are made separately and factors affecting both decisions may be different (Bekele and Mekonnen 2010). However, Moffat (2003) and Bekele and Mekonnen (2010) posited that neither straightforward binary nor censored data models may help in case where factors affecting each decision are different.

A further generalization of the model allows for the parameter to vary according to respondent's characteristics (Bekele and Mekonnen 2010). DHM results is based on the assumption that two decisions are made; the decision to adopt and how much (intensity) to adopt which the study addresses. The Tobit model assumes independent of error. An alternative to the assumption of independence of errors would be to assume that the decision to adopt agroforestry technology dominates the decision on level or intensity of adoption. This implies that once the first hurdle is passed by individuals, Standard Tobit censoring is no longer relevant, since no technology adopter would have a zero as level or intensity of adoption (Kabubo-Mariara et al. 2010; Jensen and Yen 1996; Yen and Huang 1996; Angulo et al. 2001). Jones (1989) in his study also revealed that once the first hurdle is passed, Tobit censoring is bias because the second decision would have none zero intensity. All zeros would be generated by the adoption decision (the first hurdle).

According to Cragg (1971), the generalization of the individual decision model is stated as follows: Probit regression is used to model the adoption decision (Gebremedhin and Swinton 2003; Bekele and Mekonnen 2010) as:

$$f(y = 1/X_1, X_2) = C(X_1, \beta)$$

where C is the normal cumulative distribution function, X_1 and X_2 are vectors of independent variables.

The decision on the intensity of use can be modelled as a regression truncated at non-zero as:

$$f(y/X_{1i}X_2) = (2\pi)^{-1/2}\sigma - 1\exp\left\{\frac{-\left(y - X_2^1 Y\right)^2}{2\sigma^2}\right\} \times \frac{C(X_i\beta)}{C\left(X_2^1 Y/\sigma\right)}$$

Research methodology

Area of study

The study was conducted in Ondo State, which is located in the Southwestern, Nigeria. The State is purposively selected for the study owing to predominance of arable crop enterprise. It lies between Longitude $4^0 30^1$ and $6^0 00$ ast of the Greenwich Meridian and Latitude $4^0 45^1$ and $8^0 15^1$ North of Equator. The State is a tropical coastal wetland with mean annual rainfall approaching 2800 mm, and mean number of rainy days of between 160 and 180. Mean relative humidity is between 70 and 80 %, mean annual temperature is about 27.8 °C, mean daily temperature is 26 °C, mean daily minimum temperature is 22 °C, and mean daily maximum temperature is 26.7 °C.The land area is about 13,595 square kilometres with varying physical features like hills, lowland, rivers, creeks and lagoons. The people are predominantly smallholder farmers who adopt both permanent and temporary conservation technology as well cultivating both cash and food crops (such as yam, cassava, maize and cocoyam etc.) crops for family consumption, market and cash. Farming activities are usually carried out using simple farm tools. The map of the study area is shown in Fig. 1.

Sampling procedure and data

Multi-stage sampling technique was used in selecting respondents for the study. In the first stage, Ondo State was stratified into two agro-ecological zones based on the state's Agricultural Development Programme (ADP) classification. These are Ondo and Owo zones. The second stage involved the purposive selection of three local government areas (LGAs) from each of the zones based on the predominance of yam production enterprise. These are Irele, Odigbo and Okitipupa in the Ondo zone and Akoko South West, Ose and Owo in Owo zone. The third stage involved a random selection of two villages from each of the LGAs. In the fourth and final stage, 20 respondents per village were randomly selected making a total of 240 respondents. Primary data were used for the study. The data were collected using a well structured questionnaire. Data collected include socio-economic, institutional and farm characteristics as well as agroforestry practiced by the respondents.

Empirical strategy

While investigating the determinants of adoption and intensity of agroforestry technology, the censored nature of the outcome variable has to be taken into account. In particular, it seems likely that a substantial number of the arable farmers do not adopt agroforestry. An approach to tackle this scenario is to employ a Tobit model (Tobin 1958) for analysis which has been applied in previous studies of agricultural technologies (Adesina and Zinnah 1993; Bamire et al. 2002). The major shortcoming of the Tobit model, however, is that it considers zero values as corner solution outcomes although the stochastic process that describes the individual decision to adopt may be different substantially from the intensity of adoption or use (Yen and Huang 1996; Kabubo-Mariara et al. 2010).

An appropriate model for the decision to adopt and intensity of use are determined by different stochastic processes called the double- hurdle model. The DHM is a parametric generalization of the Tobit model which involves the stochastic process of the adoption decision by a binomial probability model (probit) and the conditional distribution of the intensity of adoption by a truncated-at-zero regression model. In the DHM, both hurdles have equations associated with them, incorporating the effects of farmers' characteristics and circumstances. An explanatory variable may appear in both equations or in either of them, and a variable appearing in both equations may have opposite effects in the two equations (Bekele and Mekonnen 2010). In this study, the same set of variables was

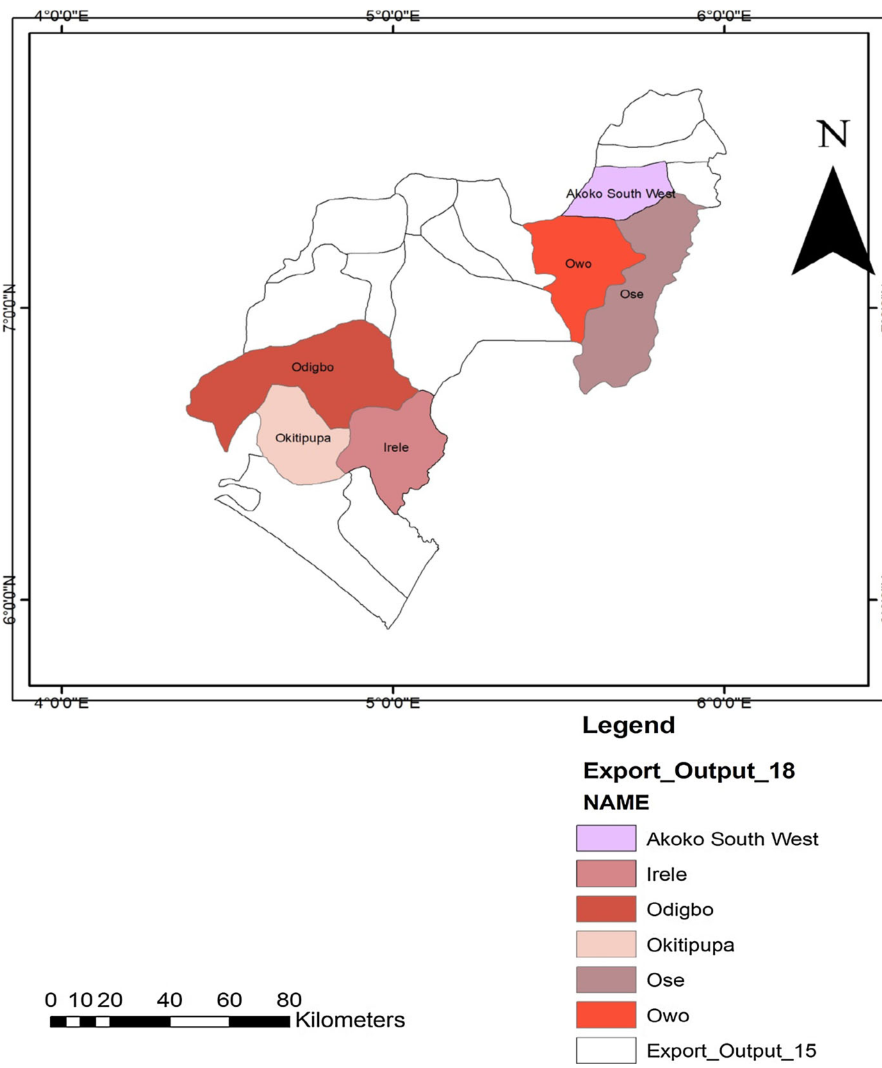

Fig. 1 Map of the study area

used. The double- hurdle model contains two equations (adoption equation and equation on level of adoption (Moffatt 2003).

$$d_i^* = z_i \beta_1^{\alpha + \in_i}$$
$$y_i^{**} = x_i \beta_2 + \mu_i \; : i = 1, 2 \ldots n$$

where d* is a latent adoption variable that takes the value 1 if adopted agroforestry, and 0 otherwise; z_i is a vector of explanatory variables; and β_1 is a vector of parameters to be estimated. y** represents intensity of adoption and x_i is a vector of explanatory variables, and β_2 is the parameter of vectors to be estimated. The ε_i and π_i are normally distributed random errors with zero mean and variance–covariance matrix

$$\sum = \begin{pmatrix} 1 & \partial_{12} \\ \partial_{12} & \partial^2 \end{pmatrix}$$

The likelihood function of this model is

$$\text{Log } L = \sum_u \text{In}\left[1 - \Phi(z_i^1 \alpha)\Phi\left(\frac{x_i\beta}{\sigma}\right)\right] + \sum_+ \text{In}\left[\Phi(z_i^1 \alpha)\frac{1}{\sigma}\phi\left(\frac{yi - x_i\beta}{\sigma}\right)\right]$$

Despite the advantage of DHM, it is not without a problem which Yen and Jones (1996) identified as the decomposition of the effects of the first hurdle on the second hurdle, when interpreting the results (Bekele and Mekonnen 2010).

The specific model for adoption and intensity of agroforestry is shown below:

$$\begin{aligned} I_a/I_i = {} & \beta_0 + \beta_1 AGEHHHED + \beta_2 ADULTMAL \\ & + \beta_3 FARMEXPR + \beta_4 FARMSIZE \\ & + \beta_5 EDUCATN + \beta_6 EXTENSN \\ & + \beta_7 LNDOWSIP + \beta_8 PLOTAGEE \\ & + \beta_9 LNDCNFLT + \beta_{10} VALTOK \\ & + \beta_{11} CROPINCM + \beta_{12} EMPLINCM \\ & + \beta_{13} CREDACCS + \varepsilon_i \end{aligned}$$

where, I_a = agroforestry adoption (1 if adopted; 0 otherwise), I_i = Intensity of adoption (proportion of plot owned that receive agroforestry treatment), B_0 = constant, B_1–β_{16} = coefficients of parameter estimate.

The definitions of the independent variables are: *AGEHHHED* = age of household head (in years), *ADULTMAL* = number of adult male, *FARMEXPR* = farming experience of respondent in years, *FARMSIZE* = farm size in hectare (ha), *EDUCATN* = level of education in years, *EXTENSN* = number of extension contact, *LNDOWSIP* = land ownership (1 if owned; 0 if otherwise), *PLOTAGEE* = number of years since land was held, *LNDCNFLT* = conflicts on land measured as dummy (1 = conflict on land, 0 = otherwise), *VALTOK* = value of livestock measured in N/year, *CROPINCM* = crop income in N/year, *EMPLINCM* = employment income in N/year, *CREDACCS* = access to credit (1 if yes; 0 if otherwise), ε_i = error term.

The expected signs of the independent variables are contained in Table 1.

Results and discussion

Agroforestry technology adoption typology

Figure 2 reveals the agroforestry technology adoption typology in the study area. The figure reveals that while 32 % of the respondents did not adopt any agroforestry technology in the area, 26.1, 23.9, 12.7 and 5.3 % of the respondents adopted scattered trees, alley/hedge row, boundary tree/trees on farm and wind breakers, respectively. The high proportion of the non-adopters might be due to insecure tenure, farm size or land conflicts which prevent permanent conservation investment in land (Kabubo-Mariara et al. 2010).

Table 1 Expected sign of independents variables

Variable	Expected sign
AGEHHHED	±
ADULTMAL	+
FARMEXPR	+
FARMSIZE	+
EDUCATN	+
EXTENSN	+
LNDOWSIP	+
PLOTAGEE	+
LNDCNFLT	–
VALTOK	+
CROPINCM	+
EMPLINCM	+
CREDACCS	+

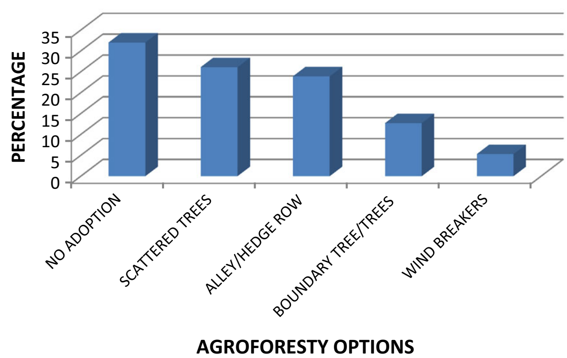

Fig. 2 Adoption typology

Socio-economic characteristics of respondents

Table 2 reveals the socio-economic and other characteristics of the respondents in the study area. The results in the table revealed that the means of the respondents' age, farming experience, level of education in years, number of adult male, farm size, plot age, crop income, employment income, value of livestock and number of extension contact were 58.6 ± 13.3, 31.9 ± 13.8, 7 ± 6.3, 4 ± 1.7, 12.7 ± 9.3, 30.3 ± 10.5, 459,163.3 ± 526,952.7, 34,502.7 ± 74,444.6, 15,502.7 ± 22,081.1 and 4 ± 1.6, respectively. The results further revealed that while 64.3 % of the respondents were male, 33.7 % were female. About 43.2 % of the respondents owned the plots on which they operate. Also, 59.7 % operate on steep plot while 40.3 % operate on non-

Table 2 Socio-economic characteristics of respondents *Source* Field survey, 2013

	Mean
Age (year)	58.6 (13.3)
Education level (year)	7 (6.3)
Farming experience	31.9 (13.8)
Number of adult male	4 (1.7)
Farm size	12.7 (9.3)
Plot age	30.3 (10.5)
Crop income	459,163.3 (526,952.7)
Employment income	34,992.2 (74,444.6)
Value of livestock	15,502.7 (22,085.1)
Number of extension contact	4 (1.6)
	%
Sex	
Male	64.3
Female	35.7
Total	100
Land ownership	
Owned	43.2
Otherwise	56.8
Total	100
Plot shape	
Steep	59.7
Otherwise	40.3
Total	
Conflict on land	
Yes	32.2
No	67.8
Total	100
Credit access	
Yes	13.2
No	86.8
Total	100
Major source of information	
Extension	12
Friends/family	48
Radio	3.2
News paper/flyers	1.1
Others	35.7
Total	100

Figure in parenthesis is standard deviations

steep plots. Some respondents in the area operate on conflicted lands. The results revealed that 32.2 % of them operate on land with conflicts while majority of them (67.8 %) operate on lands without conflict. Respondents access to credit in the area was low as just 13.2 % of them had access to formal credit while majority (86.8 %) of them do not have access to formal credit. The major source of information in the area was through friends/family which accounted for 48 % of the respondents. The least source was news paper/flyers where just 1.1 % of them indicated it as the major source. The low proportion of the respondents who indicated newspaper/flyers might be due to the low level of education in the area.

Determinants and intensity of agroforestry technology adoption

Results of the determinants and intensity of agroforestry technology adoption are presented in Table 3. The first hurdle reveals that the Log Likelihood Function, Restricted Log Likelihood Function and Chi Square values were −67.9945, 64.7881 and 39.92, respectively, while the Log Likelihood Function for the second hurdle was −200.5710. The entire models were significant at 1 % levels of probability. The results showed that the coefficients of age, adult male, farm size, extension visit, plot age and employment income were positive and significant. The results in the table further revealed that while age of household head reduced the adoption and intensity, farm size, land ownership, plot age and employment income increased the intensity of adoption. An increase in age of household head by 1 year would reduce the probability of adoption by 20 % and intensity by 0.0044 ha per hectare. An increase in the farm size by 1 ha would increase adoption by 4.2 % and intensity by 0.1017 ha per hectare. This supports Lambert and Ozioma (2011) that age and farm size influenced agroforestry adoption. Similarly, an increase in the land owned by 1 ha would increase adoption probability by 1 % and intensity by 0.0228 ha per hectare. An increase in the plot age by 1 year would increase probability and intensity of adoption by 3.2 % and 0.0439 ha per hectare, respectively. However, while value of livestock only reduce agroforestry technology adoption, number of adult male and number of extension contact increased the technology adoption. An increase in the value of livestock by N1 would reduce adoption by 2.4 %. This implies that income earned from livestock is converted to activities other than farming. This does not conform to the expected

Table 3 Average partial effects of the determinants and intensity of adoption *Source* Data analysis, 2013

Variable	First hurdle (probability)	Second hurdle (effects)
AGEHHHED	−0.0205** (0.0176)	−0.0044* (0.0033)
ADULTMAL	0.0009 (0.0002)	0.0002** (0.0004)
FARMEXPR	0.0144 (0.0021)	0.0025 (0.0058)
FARMSIZE	0.0416*(0.0380)	0.1017** (0.6257)
EDUCATN	0.0463 (0.0396)	0.0054 (0.0031)
EXTENSN	0.0094 (0.0048)	0.0603* (0.0574)
LNDOWSIP	0.0092*** (0050)	0.0228* (0.0607)
PLOTAGEE	0.0321** (0.0042)	0.0439** (0.0203)
LNDCNFLT	−0.0067 (0.231)	−0.1793 (0.2195)
VALTOK	−0.0241* (0.0089)	0.1503 (0.2603)
CROPINCM	0.0046 (0.326)	0.2254 (0.3530)
EMPLINCM	0.7941** (0.3971)	0.5186*** (0.1684)
CREDACCS	0.0136 (0.0011)	0.1503 (0.2603
	Log Likelihood −67.9945	Sigma 0.1547*** (0.7313)
	Restricted log likelihood −64.7881	Log Likelihood −200.5710
	Chi-squared 39.92	
	Significance level 0.0321	

Figure in parenthesis is standard error

* Significant at 10 %, ** significant 5 %, *** significant at 1 %

sign of the study but agrees with Bekele and Mekonnen (2010) conservation technology adoption study. Meanwhile, an increase in the number of adult male and extension contact by a unit would increase intensity by 0.0002 ha per hectare and 0.0603 ha per hectare, respectively. This finding agrees with the expectation of the study and conforms with Bekele and Mekonnen (2010).

Constraints of agroforestry technology adoption

The major constraint of agroforestry technology adoption in the area was insecure land tenure with mean 2.3. This might be due to the permanent investment nature of agroforestry which requires long term investment. The second, third and fourth major constraints were lack of capital, lack of planting materials and inadequate labour with means 2.1, 1.4 and 1.1, respectively. These were also identified by Bifarin et al. (2013) as problems militating against agroforestry technology adoption in Nigeria (Table 4).

Table 4 Constraints of agroforestry technology adoption *Source* Field survey, 2013

Constraints	Mean	Rank
Insecure tenure	2.3	1st
Lack of capital	2.1	2nd
Lack of planting material	1.4	3rd
Inadequate labour	1.1	4th

Summary and conclusion

The study was conducted to investigate the determinants and constraints of agroforestry practices in the study area. A multi-stage sampling procedure was used to select respondents for the study. Data collected were analysed with the aid of descriptive and DHM. The farmers in the area are well experienced. While the age of the household head reduced the adoption and intensity of agroforestry, farm size, land ownership, plot age and employment income increased both the decision and intensity of adoption. However, while value of livestock reduced only the adoption, number of adult male and extension contact increased only the intensity thus showing that different factors affect the decision and intensity. DHM is thus the appropriate model for the study. The major constraints of agroforestry technology adoption were insecure tenure, lack of capital, lack of planting area and inadequate labour. Therefore, it is recommended that government, should put in place policies that would redistribute land, review tenure arrangement, improve extension contact as well as encourage farmers to engage in activities other than farming.

Acknowledgments We are grateful to smallholder farmers in Ondo State, for giving us useful information for the success of the research. We are also thankful to O. E. Olofinniyi for his wonderful efforts during the data collection exercise.

Compliance with ethical standards

Conflict of interest The authors declared that we do not have conflict of interest.

References

Adesina AA, Chianu J (2002) Farmer's use and adaptation of alley farming in Nigeria. In: Barret CB, Place F, Aboud AA (eds) Natural resources management in African agriculture—understanding and improving current practices. CABI Publishing, Wallingford, pp 51–64

Adesina A, Zinnah M (1993) Technology characteristics, farmers perceptions and adoption decisions: A tobit model application in Sierra Leone. J Agric Econ 9(3):297–311

Ajayi OC (2006) Acceptability of sustainable soil fertility management technologies: Lesson from farmers' knowledge, attitude and practices in Southern Africa. J Sustain Agric 13:18–21

Alao JS, Shuaibu RB (2013) Agroforestry practices and concepts in sustainable land use systems in Nigeria. J Hortic For 5(10):156–159

Amonum JI, Babalola FD, Agera SIN (2009) Agroforestry systems in Nigeria: review of concepts and practices. J Res For Wildl Environ 1(1):18–30

Angulo AM, Gil JM, Gracia A (2001) The demand for alcoholic beverages in Spain. Agric Econ 26(1):71–83

Bamire AS, Fabiyi YL, Manyong VM (2002) Adoption pattern of fertilizer technology among farmers in the ecological zones of south-western Nigeria: a tobit analysis. Aust J Agric Res 53:901–910

Bekele G, Mekonnen A (2010) Investment in land conservation in Ethiopia highlands: a household plot-level analysis of the roles of poverty, tenure security, and market incentives. Environment for Development Discussion paper series, 10–09

Bifarin JO, Folayan AJ, Omoniyi LO (2013) Assessment of agroforestry practices as a land use option for sustainable agricultural production in Osun State. Res J Agric Environ Manag 2(3):069–074

Cragg JC (1971) Some statistical models for limited dependent variables with application to the demand for durable goods. Econometrica 39:829–844

Gebremedhin B, Swinton SM (2003) Investment in soil conservation in northern Ethiopia: the role of land tenure security and public programs. Agric Econ 29:69–84

Jesen H, Yen S (1996) Food expenditures away from home by type of meal. Can J Econ 44:67–80

Jones A (1989) A double-hurdle model of cigarette consumption. J Appl Econ 4(1):145–258

Kabubo-Mariaura J, Linderhof V, Kruseman G, Atieno R, Mwabu G (2010) Household welfare, investment in soil and water conservation and tenure security: evidence from Kenya. Environ Dev Econ 15(2):1–83

Kabwe G, Bigsby H, Cullen R (2009) Factors influencing adoption of agroforestry among smallholder farmers in Zambia. Paper presented at the 2009 NZARES conference Tahuna conference centre—Nelson, New Zealand. August 27–28

Keil A, Zeller M, Franzel S (2005) Improved tree Fakkiws in smallholder maize production in Zambia, do initial testers adopt the technology? Agrofor Syst 64:145–168

Lambert O, Ozioma AF (2011) Adoption of improved agroforestry technologies among contact farmers in Imo state, Nigeria. Asian J Agric Rural Dev 2(1):1–9

Moffatt PGA (2003) Hurdle models of lean default. School of Economics and Social Studies. University of East Anglia, Norwich, pp 63–69

Nigeria Conservation Foundation (NCF) (2000) Documentation of environmental degradation in fifteen communities in Akwa Ibom state. UNDP, Lagos, pp 185–189

Yen S, Huang C (1996) House demand for finfish: a generalized double-hurdle model. J Agric Res Econ 21(2):202–234