Journal of
Earth Science & Climatic Change

Adetoye et al., J Earth Sci Clim Change 2017, 8:10
DOI: 10.4172/2157-7617.1000417

Research Article Open Access

Agroforestry Practices and Carbon Sequestration Cost Estimates among Forest Land Dependent Households in Nigeria: A Choice Modelling Approach

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Abstract

Forest land use among farming households in Nigeria contributes adverse environment effect. The study assessed adoption and the cost implication of sustainable forest land use (agroforestry practices) among farming households in Nigeria forest reserves. A total of 300 farming households were randomly sampled using a multistage sampling technique. It was revealed that household size ($p<0.01$), non-farm income ($p<0.01$) and current farm debt ($p<0.01$) are main factors that exert influence on choice of agroforestry systems and consequently cost of carbon sequestration. The cost estimate of carbon sequestration among households revealed that the lowest cost of carbon sequestration was recorded from boundary planting system of agroforestry. If a total of 55 Mg C is sequestered per hectare per year, carbon would be sold as low as N1,498.9 ≡$3.9. It was observed that planting trees haphazardly on farm plot will leave carbon sequestration cost at a range of $11.5 and $144. Likewise, hedgerow intercropping will yield a cost range of $63.5 and $38. The study therefore concludes that, boundary planting of trees around farm land provides a low cost of achieving carbon sequestration while addressing unhealthy forest land use among farming households in Nigeria.

Keywords: Forest; Households; Carbon Sequestration; Cost; Agroforestry and Nigeria

Introduction

From time immemorial, human settlements have been associated with tropical forests, and to date, in Nigeria, human settlements are found within or beside forest regions, mostly the rural dwellers, whose lives and existence are solely dependent on the forests and their resources. Greengrass [1] noted that most of the households living within the forest communities are farmers and timber workers, indicating that their livelihood depends on the forests. Forest community households have been depending on forests from several centuries back and worse still, their illiteracy and poverty level is very high [2].

The clearing of forestland for farming in Nigeria accounts for over 80% of total forest area being deforested every year [3]. Rural farmers (more than 20 million) practice shifting cultivation where by each farmer cultivates a plot of land for two to three years after which soil fertility is depleted and he moves to another plot to allow the previous plot to fallow and recuperate. During land preparation by the farmers, the trees are felled and burnt on site. As cultivated lands are depleted, farmers look to forested lands for fertile soils. The tendency is for farmers to encroach on forest reserves where soils are relatively more fertile. This means more deforestation and depletion of forest resources (NFP, 2006). This livelihoods activity generates adverse effect on the environment through a release of a major greenhouse gas (carbon dioxide – CO_2) precipitating global warming.

Over the years, there has been unending conflict on environmental sustainability, agricultural production and forest resources utilization. Following this land use conflicts, FAO, (2001) stated that "the forest estate which is only about 10 million hectares (10% of total land area of Nigeria) is declining at a rate of 3.5% annually due to encroachments, excisions and outright de-reservations." The forestry component of the National Agricultural Policy prescribes an increase from its present level of 10% of total land area to 20% but this has been elusive. The most important factor contributing to environmental degradation of the country in Nigeria is un-coordinated land use policy. It is evident that forests are being displaced and depleted by other forms of land-use such as agriculture, grazing and water management leading to formation of deserts, bare surfaces and general environmental degradation. Land under agricultural cultivation is increasing at an average rate of 554,657 ha per annum while land under high forest is diminishing at a rate of 105,865 hectares per annum (FAO, 2001). This land use pattern is exacerbated by drought, forest fires, overgrazing and flooding which lead to severe environmental degradation, loss of biodiversity, diminished forest productivity etc. If the trend of forest degradation among the community forest households were to continue as usual the potential of Nigeria remaining a low carbon emitter is bleak and most of the land remaining under forests and woodlands will likely be absorbed into arable agriculture. Thus, there is the need to provide sustainable means of forest protection to enhance its contribution to food security, sustainable environmental services and possible income generation from carbon trade market. One of the best means of achieving such a win-win scenario is through agroforestry practices.

Agroforestry, the practice of introducing trees in farming has played a significant role in enhancing land productivity and improving livelihoods in both developed and developing countries. Although carbon sequestration through afforestation and reforestation of degraded natural forests has long been considered useful in climate change mitigation, agroforestry offers some distinct advantages. According to the IPCC (2007) agroforestry systems offer important opportunities of creating synergies between both adaptation and mitigation actions with a technical mitigation potential of 1.1- 2.2 PgC in terrestrial ecosystems over the next 50 years. The planting of trees along with crops improves

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Received May 12, 2017; **Accepted** October 23, 2017; **Published** October 27, 2017

Citation: Adetoye AM, Okojie LO, Akerele D (2017) Agroforestry Practices and Carbon Sequestration Cost Estimates among Forest Land Dependent Households in Nigeria: A Choice Modelling Approach. J Earth Sci Clim Change 8: 417. doi: 10.4172/2157-7617.1000417

soil fertility, controls and prevents soil erosion, controls water logging, checks acidification and eutrophication of streams and rivers, increases local biodiversity, decreases pressure on natural forests for fuel and provides fodder for livestock [4]. It also has the ability to enhance the resilience of the system for coping with the adverse impacts of climate change. The effectiveness of agroforestry systems in storing carbon depends on both environmental and socio-economic factors; in humid tropics, agroforestry systems have the potential to sequester over 70 Mg/ha in the top 20 cm of the soil [5]. Although, the carbon storage capacity in agroforestry varies across species and geography [6]. Furthermore, the amount of carbon in any agroforestry system depends on the structure and function of different components within the systems put into practice [7]. This implies that different agroforestry systems would influence type of crop and system of farming among rural households. Hence, the need to determine choice of agroforestry practices among households. Against these backdrops, the study seeks to: assess the adoption of agroforestry practices among fam households living within the forest reserves; determine choice of agroforestry practices among farm households; and estimate cost of carbon sequestration through agroforestry practices.

Theoretical Framework

In the practice of a new farming technique, farmers are considered not only as producers but also consumers. On the production side, they combine resources such as land and agro-inputs to produce an output. They are also consuming resources, such as agrochemicals and seeds to produce the final output. This means that farmers can best fit into the theory of farm households where farmers make critical decisions as a result of the complex interrelation between production and consumption [8]. As such, farmers do not only make decisions on the adoption of new practices based solely on profit maximization but also on their being able to achieve the highest level of utility. Farmers' willingness to accept to participate in carbon trade earnings involves the sacrifice of current practices for increased production which will eventually lead to increased utility. The decision to practice agroforestry system of farming given the utility maximization problem can be analyzed using a random utility theory. According to RUT, the utility of a good is composed of: an observable or deterministic component, which is a function of a vector of attributes, and an unobservable or random error component [9].

The following equation for an individual's utility, formalises the basic relationship where (Vi) is the observable component and ε_i represents the error component of utility.

$$U_i = V_i + \varepsilon_i \quad (1)$$

The equation (2) below disaggregates the systematic component of choice further, where respondent i derives utility U_{ij} from the alternatives j in choice set (C); utility is held to be a function of the attributes of the relevant good Z_{ij} and the characteristics of the individual S_{ij} together with the error term.

$$U_i = (Z_{ij} S_{ij}) + \varepsilon_i \quad (2)$$

Due to the inherent stochastic or random error component of U_i, a researcher can never hope to fully understand and predict preferences; hence, choices made between alternatives are expressed as a function of the probability that respondent i will choose j in preference to other alternatives:

$$P_{ij} = \Pr(V_{ij} + \varepsilon_{ij} > V_{ih} + \varepsilon_{ij}) \quad (3)$$

For all h in choice set C, j ≠ h

Statistical techniques for the analysis of discrete choices have been used increasing regularity in demographic analyses. The best known are the binomial logit and probit techniques, both of which are suitable for binary choice problems. For problems involving the choice among three or more categories, the multinomial logit technique is most often employed; the corresponding probit model (Tables 1 and 2) is used relatively little because of its computational difficulty. In this general specification, i.e., equation (2) above, the vector Z_{ij} can be written to include variables S_i, which are "attributes" (i.e., personal characteristics) of the individual. The inclusion of S_i is usually considered when modelling a mixed multinomial logit. In mixed multinomial logit, choice of alternative is dependent on the characteristics of the alternative as well as the characteristics of the individual making the choice.

The choice of agroforestry (agrisilvicultural) practices among farm household obviously is expected to vary with the specific attributes of the practice (e.g. crop combination, number of trees, tree arrangement etc.), willingness to accept (WTA), as well as socio-economic characteristics of individual. such function can be analysed using various choice model.

It is observed that farmers have a level of utility they want to meet and therefore make choices based on that. For instance, given a number of utility levels M, a farmer will choose a level that conforms to the highest level of utility given his budget. Such discrete choice scenarios are modelled using the random utility theory. The utility of a farmer is given as U_{ij}, from choosing alternative j. A farm household will choose whether or not to practice agroforestry depending on the relative utility levels associated with the two choices. Therefore, the probability that alternative j will be chosen is given by

$$P(y_i = j) = P[(V_j + \varepsilon_j) \geq (V_k + \varepsilon_h)] = [(\varepsilon_k - \varepsilon_j) \leq (V_j - V_k)] \forall_k \in_k = 1,....H; j \neq k \quad (4)$$

Where y_i is the observed outcome for the ith observation i=1,……,N indexes the rural farm households, j=1 and k=i,…..k are the alternatives being considered and ε_k and ε_j are the random errors. It is assumed from this that a farm household will select the alternative choices of agroforestry option based on the highest level of utility, implying that if participation in agroforestry practice for carbon sequestration will enhances his/her highest level of utility, based on a specific type of agroforestry then the farmer will choose that option.

As stated earlier, agroforestry system depends on the structure and function of different components within the systems put into practice. The attributes of a farm household are observed but that of the agroforestry system is unobserved.

The specification of the econometric model that is about deciding how the error terms enter the conditional indirect utility function and what is assumed about the distribution of the error term. After the estimation of parameters with an econometric model, the welfare measure for a selected policy defined in terms of attribute levels the producer surplus in the case of an increase in the supply of environmental good can be derived using the standard utility difference expression:

$$\mathrm{WTA}_i = -1/\beta_{\mathrm{WTA}} [\ln\left(\sum \exp\left(V^1\right)\right) - \ln\left(\sum \exp\left(V^0\right)\right)] \quad (5)$$

β_{WTA} = parameter estimate of the attributed WTA amount

V^1 = utility evaluated in the choice of agroforestry practices

V^0= utility derived from the existing farming system

Ordered Group	Characteristics of Group Members	Agroforestry Category based on tree arrangement	Agroforestry systems
0	Respondents willing to participate, but have rejected the bid offered in the four categories	I – IV.	All agroforestry system
I	Respondents willing to practice any of the system in group I	I = Tree in hedges	Alley cropping, Shelterbelts and wind breaks
II	Respondents that are willing to practice any of the system in group II	II = Tree scattered on farm plot	Multipurpose tree on crop lands
III	Respondents that are willing to practice any of the system in group III	III = Trees on interrow or intra-row	Plantation crop combination, Homogardens, Taungya
IV	Respondents that are willing to practice any of the system in group IV	IV = Tree on the entire farm plot	Trees in soil conservation, Multilayer tree gardens

Table 1: Ordered probit model for classified agroforestry systems.

Variables	Description	Measurement
Age	Age of the household head	Years
Education	Educational level of the household head	0 = no formal education, 1= otherwise
Sex	Gender of the household head	0 = male, 1 = female
Marital status		Single parent =1 otherwise = 0
Household size	The number of dependant members in the family	Number
Farm size	The size of land of the farmer	Hectares
Farming experience	Number of years of farming	Years
Dominant crop type	Type of crop currently on farm land	0 = permanent, 1= otherwise
Awareness of importance of trees on farm land as a means of Climate change mitigation	State of awareness about the role of trees in carbon sequestration	1= aware, 0 = not aware
Awareness of climate change effect a. Not aware b. Aware correct c. Aware not correct	The degree of awareness of effect of climate change	Aware correct =1, others = 0 Aware not correct =1, others = 0
Land ownership	The right of ownership	0 = owned, 1 = others
Land tenure security	Ability to ascertain control over the desired period on the farm land	Secured =1, not secure = 0
Farm income	Amount of money derived from the farm activity per annum	Naira
Non-farm income	Amount of money derived from other livelihood activities per annum	Naira
Current farm debt	The amount of farm debt outstanding as at the time of the study	Naira
Presence of trees on farm land	Presence of natural trees on the current farm land	1 = yes, 0 = otherwise
Willingness to accept bid	Amount willing to accept to practice observed choice of agroforestry system over a 50year period.	Naira

Table 2: Variables in the ordered probit model.

Research Methodology

The study was done in three major forest reserves in southwestern Nigeria. The climate of Southwestern Nigeria is tropical in nature and it is characterized by wet and dry seasons. The temperature ranges between 21oC and 34oCwhile the annual rainfall ranges between 1500 mm and 3000 mm. The forest reserves that were considered include: the one considered as the largest forest reserve in Ogun – Omo forest reserve (134,730 ha); Osun – Shasha forest reserve (36,834 ha); and Ondo – Oluwa forest reserve (84,636 ha). The rationale for the selection follows that the Forest Reserves contain some of the last remaining forest in South-Western Nigeria. i.e., 40% of the natural forest in the reserves still remains (NCF, 2017). Likewise, the number of dependent rural communities around forest reserves is a function of size of the forest reserves and the selected forest reserves represents the largest forest reserves in each of the state (FAO, 1998). The study was based on primary data collected from a rural farm household (specifically crop farmers) through the use of personally administered questionnaire using a multi-stage sampling technique. A total 300 households were randomly selected for the study. Data was elicited from the household head.

There are about nine types of agroforestry systems that could be practiced among farm households in tropical agro-ecological region like south-western Nigeria. However, each of the system is distinguished based on their components and ecological adaptability [10]. Each of these systems also have varying volume of carbon sequestration potential as estimated by different authors [10,11]. This implies that a farm household has to choose a specific type of agroforestry systems from the set of choices (nine systems) to indicate his/her participation in carbon sequestration programme. In order to reduce the complexity of choice making among farm household, all the agroforestry systems were grouped into four categories based on the following attributes; tree arrangement; and range of volume of carbon each is able to sequester based on past studies. The approach is similar to the method adopted by Albrecht and Kandji [7] in estimating carbon storage in different agroforestry systems. The categorization is presented in Table 1.

Thus, the choice of preference was estimated using this classification. It is important to note that the classification can be ordered based on the density of tree population on farm land. The first represent the category with less or no interaction of trees with farm plot while the second represent light interaction of trees with crop on farm land. The categories increase with an increase in tree volume on farm land. This implies that, the choice preference of a farm household in carbon sequestration varies with an increase in the volume of trees on farm land. The choice estimation was therefore carried out using a maximum likelihood estimation of an ordered outcomes. The group is therefore ordered and estimated as follows: the 0 category represents those not willing to participate, having rejected all the system of agroforestry in the four categories; the group 1 includes those respondents that are willing to practice any of the system in category 1; group 2 includes respondents that are willing to practice any of the system in category 2; group 3 includes respondents willing to practice any of the system in category 4; and the group 5 contains respondents willing to participate, willing to practice any of the system in category 4.

An index model for a single latent variable y^* which is unobservable, we only know when it crossess thresholds). y_i^* is latent variable that determines the value of y_i when it takes on the value of 0, 1, 2, 3, and 4 representing if a farm household chooses any of the category as expressed in Table 1.

$$y_i^* = x_i^{'}\beta + u_i \tag{6}$$

$$y_i = j \; if \; \alpha_{j-1} < y_i^* \leq \alpha_j \tag{7}$$

where y $_i$^* is a latent variable describing the households choice preference of agroforestry systems, x_i is a vector of variables (which include the personal, socio-economic and other social factors) explaining the choice preference, and u_i represent the error term assumed to be independent and distributed as u_i~N(0,σ^2). Assuming that the error term is normally distributed, equation (6) will be estimated using the ordered probit technique that employs maximum likelihood calculations to generate the coefficient and error vector. The probability that a household i will select alternative j from the set of agroforestry systems therefore becomes:

$$p_{ij} = p(\text{yi} = \text{j}) = \text{p}(\alpha_{j-1} < y_i^* \leq \alpha_j) = F(\alpha_j - x_i^{'}\beta) - F(\alpha_{j-1} - x_i^{'}\beta)$$

The ordered probit model with j alternative has one set of coefficients with (j-1) intercepts and j sets of marginal effects. The marginal effect of an increase in a regressor x_r on the probability of selecting alternative j is expressed as:

$$\partial p_{ij} / \partial X_{ri} = \left\{ F'(\alpha_{j-1} - x_i^{'}\beta) - F'(\alpha_j - x_i^{'}\beta) \right\} \beta_r$$

It is however worthy to note that the marginal effects of each variable on the different alternatives sum up to zero.

In order to estimate the cost of achieving these practices, the minimum willingness-to-accept (WTA) bid was elicited from the individual farm household. The true social cost of conservation policies is equal to the sum of WTA of landowners agreeing to conservation contracts reviewed studies on lump sum compensation over a specific time frame following a 50-year period of land use for carbon sequestration programme through agroforestry practices is ideal for tropical rain forest region [12]. Hence, the lump sum WTA bid was based over a 50 year period. In order to estimate for cost of carbon sequestration in the classified group, the WTA bid was included in the ordered probit model. Thus, the WTA for agreeing to participate in each of the four possible practices ordered as j=1, 2, 3 and 4 was obtained by dividing the parameter value δ_j with the willingness to pay parameter (i.e., δ_z/(-δ_(price). Marginal Willingness to Accept (MWTA) is thus specified as follow:

$$MWTA_i = \frac{\delta_j}{\delta_{bid}} \tag{12}$$

Where,

δ_j = coefficient estimate for the positive ordered group;

δ_{bid} = coefficient estimate for the incentive.

Carbon Sequestration Cost Estimates

After the estimation of cost of different agroforestry practices based on their categories, the value of each practices was interacted with the range of carbon sequestration potential in each group. Carbon sequestration potential of different agroforestry systems in tropical ecological region (in different nations) of the world has been estimated by different studies [7,10]. Table 3 shows the summary of the classified agroforestry systems and their respective range of carbon sequestration (i.e., carbon in plant biomass). A range of C against the exact value was used because, the amount of C sequestered largely depends on the agroforestry system put in place, the structure and function of which are, to a great extent, determined by environmental and socio-economic factors. Other factors influencing C storage in agroforestry systems include tree species and system management [7,10]. Thus, the C range equivalent for all the classified agroforestry systems was based on the commonly practiced agroforestry systems in Nigeria (particularly southwest) and the tree species. Studies on potential C of different agroforestry systems in Nigeria was used in defining the range of carbon equivalent for each group. Where no record of certain agroforestry systems exists, studies conducted in other west Africa countries was used as a proxy and where none exist for certain systems in Africa, findings of other C sequestration volume in humid tropical region was used.

The product of the lower range of carbon in each category and the respective estimated WTA can be used to arrive at the cost of carbon sequestration for each group. However, since forest land dependent household (farmer) is assumed to be a profit oriented individual, and will choose to maximize profit at all levels, it is better to assuming that he/she will effectively managed his/her farm plot in order to maximize profit from carbon market. Thus, upper range of carbon can as well be used. On the contrary, since other natural factors also influence rate of carbon sequestration, using higher range will result in the over estimation of carbon volume which will consequently result in low price of carbon against the actual value. Moreover, since each group is made at least two different systems of agroforestry, it was considered necessary to estimate C cost using lower and upper boundary (Figure 1) and the average value. This gives a range of lower, middle and upper

Group	Classes of Agroforestry	Agroforestry systems	Range of carbon equivalent (*Mg C ha⁻¹ Yr⁻¹*)
I	Boundary Planting	Alley cropping, Shelterbelts and wind breaks	24 – 55
II	Tree scattered on farm plot	Multipurpose tree on crop lands	2 – 25
III	Hedgerow Intercropping	Plantation crop combination, Homogardens, Taungya	6 – 10
IV	Trees on entire farm plot	Trees in soil conservation, Multilayer tree gardens	29 – 52

Table 3: Classes of agroforestry systems and their equivalent carbon sequestration potential.

boundary. This approach agrees with Department of Energy (DoE, 1999) method to carbon sequestration. Specific agroforestry systems in each group has a range of C that best describes the carbon potential in the system. Cost of carbon at all level was attributed to a specific system of agroforestry that best falls will equivalent range of C. The estimate was based on $Mg\,C\,ha^{-1}Y_r^{-1}$. The cost of carbon sequestration will be specified in dollar equivalent amount using the exchange rate rate at the parallel market.

Results

Table 4 shows the result of the ordered probit regression in order to estimate the potential carbon sequestration among farming household living within the forest reserves. The result of the estimates shows that the model was significant at 1%. The log pseudolikelihood and the pseudo – R2 of the model were estimate at -332.56979 and 0.0829 respectively [13-20].

The result shows among the socio-economic factor considered in the estimation that household size ($p<0.01$), non-farm income ($p<0.01$) and current farm debt ($p<0.01$) are main factors that exerts influence on choice of agroforestry systems (which in turns determines potential volume of carbon sequestration). Although farming experience ($p<0.10$) was also significant. Others like age, education, income, farm size etc. either decrease or increase the likelihood of the choice of categories but were not significant. The estimation shows that the higher the household size among farming household the more the likelihood of selecting one of out of the categories (i.e., 1-4). This implies that a unit increase in the household size will cause 2 percent decrease in the likelihood of rejecting all the agroforestry system alternatives while a unit increase will result to a proportional increase in likelihood of selecting any of the agroforestry systems in category 2 (i.e., Alley cropping, Shelterbelts and wind breaks). The reason could be as a result physical effort required in achieving forest land use diversification from the existing use to deliberate planting of trees on farm plot.

Non-farm income and current farm debt exert similar influence on choice of categories. They both have the likelihood to reduce the selection of any of the agroforestry systems arranged in categories 1-4. This implies that as non-farm income and current farm debt increase, the less the likelihood of a farming household participating in carbon sequestration programme through any of the categories agroforestry systems. The sign of the estimated coefficient agrees with the a priori expectation. The more the non-farm income increases the more competition rises in the share of the non-farm income to the overall income of the household and thus the less will a farming household see the need for forest land diversification. Likewise, a farming household considered the immediate farm debt to be paid and think of land use system that will yield increase productivity within a short period of time in order to meet the debt payment. Thus, as the farm debt increases particularly in hundreds of thousands (or possibly in millions), the more the likelihood of increase in percentage of forest household that would reject forest land use in carbon sequestration. This condition applies to all the system of agroforestry under each category.

Apart from the identified socio-economic characteristics that exert influence on the likelihood of participation in forest land use for carbon sequestration, other factors like dominant crop type ($p<0.01$), preference for tree on farm land ($p<0.01$) and the willingness to accept amount ($p<0.01$) also exert influence on likelihood of participation in forest land use for carbon sequestration among farming household. Annual and bi-annual crop farmers are more likely to participate in forest land use for carbon sequestration (through agroforestry practices). This is because annual or bi-annual crops can easily survive under agroforestry system especially in Taungya system which is commonly being practiced in most rain tropical forest. Contrarily, perennial crop farmers are the dominant group in the study areas and thus the reason for their less likelihood to participate in forest land use for carbon sequestration. This is because trees naturally inhibit proper functioning of perennial crops especially crops like cocoa, kolanut, etc. which are the major crops being commonly grown among farming household in forest reserves. Although their establishment over a long period of time offers a significant contribution to carbon sequestration but not so much compared to forest trees. The dominant crop type (if annual or bi-annual) reduces the likelihood of farming household

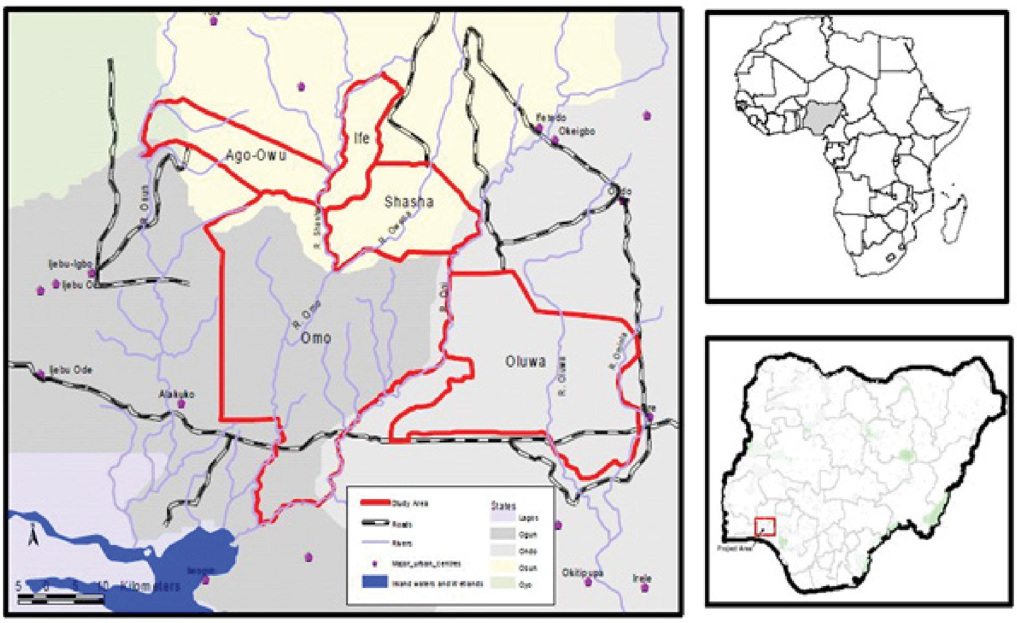

Figure 1: Carbon sequestration choice modelling.

Independent Variables	Coefficients	Robust S.E.	Z	Marginal Effects Estimates for the Categories				
				0	I	II	III	IV
Age	0.006904	0.006762	1.02	-0.00275	0.000128	0.000477	0.0013	0.000849
Gender	-0.03051	0.227712	-0.13	0.01217	-0.0006	-0.00214	-0.00573	-0.00369
Education	-0.06867	0.089064	-0.77	0.027394	-0.00127	-0.00474	-0.01293	-0.00845
Marital status	0.29463	0.245151	1.2	-0.11637	0.009487	0.023337	0.053448	0.030102
Household size	0.060497***	0.02719	2.22	-0.02413	0.001122	0.004179	0.01139	0.007444
Farm size	0.024067	0.016983	1.42	-0.0096	0.000446	0.001663	0.004531	0.002961
Farming experience	-0.0147*	0.007664	-1.92	0.005865	-0.00027	-0.00102	-0.00277	-0.00181
Income	4.08E-08	1.24E-07	0.33	-1.63E-08	7.56E-10	2.82E-09	7.68E-09	5.02E-09
Non-farm income	-4.16E-07***	1.61E-07	-2.58	1.66E-07	-7.72E-09	-2.88E-08	-7.84E-08	-5.12E-08
Current farm debt	-1.51E-06***	5.79E-07	-2.61	6.03E-07	-2.80E-08	-1.04E-07	-2.85E-07	-1.86E-07
Land ownership status	-0.12795	0.251653	-0.51	0.050971	-0.00307	-0.0094	-0.02384	-0.01466
Land security status	-0.20274	0.166297	-1.22	0.08062	-0.00255	-0.0129	-0.03827	-0.02689
Dominant crop type	0.470636***	0.194191	2.42	-0.18343	-0.00066	0.023043	0.087166	0.073883
Preference for tree on farm land	0.683902***	0.185172	3.69	-0.26363	0.025476	0.05503	0.118392	0.064728
Awareness of importance of tree	-0.01154	0.26588	-0.04	0.004604	-0.00021	-0.00079	-0.00217	-0.00143
Climate change awareness (correct)	-0.17431	0.242562	-0.72	0.06938	-0.00431	-0.01289	-0.03239	-0.01979
Climate change awareness (not correct)	-0.06402	0.182641	-0.35	0.025535	-0.00115	-0.00439	-0.01206	-0.00793
Willingness to accept bid (WTA)	7.61E-08***	2.33E-08	3.27	-3.04E-08	1.41E-09	5.26E-09	1.43E-08	9.37E-09
Constant of group (I)	0.941051	0.491215						
Constant of group (II)	1.256901	0.493941						
Constant of group (III)	1.652625	0.497901						
Constant of group (IV)	2.482134	0.505544						
Log – Likelihood	-332.56979							
Wald Chi^2 (18)	78.58							
Prob > Chi^2	0.0000							
Pseudo R^2	0.0829							

Table 4: Ordered probit regression result showing the estimation of cost of carbon sequestration among farming households.

from not participating in forest land use for carbon sequestration by 18 percent while it also increases the likelihood of participation from scattered tree on farm plot to tree on the entire farm plot by 2, 8 and 7 percent respectively. Positive preference for tree also increases the likelihood of participation. This applies to both perennial, annual and bi-annual crop farmers. Perennial crops sometimes prefer trees on farm land especially at the establishment stage of their crop. At that stage, trees offer protection for crops like cocoa and kolanut by preventing them direct heat of sunlight which may results in death of the crop. However, as the crops grow old, farmers prefer to cut down the trees to allow for proper fruiting of the crops. Positive preference for tree on farm plot has the likelihood of increasing forest land use for carbon sequestration across the categories. It contributes the likelihood of about 2, 12, and 6 percent to forest land use in carbon sequestration among farming household through tree scattered on farm plot, trees on inter or intra-row and trees on entire farm plot respectively than the no preference group.

Moreover, apart from the identified demographic and the socio-economic characteristics that exert influence on forest land use in carbon sequestration, the use of incentive (willingness to accept) among farming household also contributes significantly to increasing the likelihood of forest land use in carbon sequestration. The incentive (WTA) was significant at 1%. As willingness to pay increases in millions, there is also the likelihood of increasing forest land area for carbon sequestration among farming household. The condition holds across all the systems of agroforestry. This result agrees with the expected a priori expectation. The reason for such high level of incentive was due to the range of income among farming household in the study area. As discussed earlier, majority are cash crop farmers who earn their income mostly in millions. However, majority prefer to leave the land for carbon sequestration practices once they receive such level of incentive. Majority of the farming household expresses uncertainty in annual payment of incentive and thus they stated their pay-off value particularly if their entire farm land is to be used for carbon sequestration programme. However, some farming household expressed zero willingness to accept particularly for agroforestry systems in category 1 and these include alley cropping, shelterbelts and wind breaks. This offers positive support for their farm land against wind, erosion and other related hazards that may affects their crops. However, in order to determine the most cost effective level of forest land use in carbon sequestration among farming household in forest reserves there is the need to estimate the mean WTA for each of the category.

Proportion of Forest Land Use in Carbon Sequestration among Farming Households

Table 5 shows the proportion of household participation in forest land use in carbon sequestration through various agroforestry systems. About 50 percent of the household are not willing to participate in forest land use for carbon sequestration irrespective of the agroforestry systems. However, about 11 percent of the population are willing to practice either Alley cropping or Shelterbelts and wind breaks systems. Likewise, about 12 percent of the population are willing to engage in planting of scattered trees on farm plot – Multipurpose tree on crop land while about 17 percent are willing to engage on planting of trees in between their crops (i.e., intra or inter row planting of trees). This includes agroforestry systems like Plantation crops combination, Tuangya system and Homogardens. The agroforestry systems in this category represent the prominent group most households are willing to practice. This could be as result of familiarity with the systems

Category	Agroforestry Systems	Mean	Std. Dev.	Minimum	Maximum
0	None of the systems	0.49949	0.194813	0.004107	0.938985
I	Boundary Planting	0.10862	0.02223	0.005867	0.125484
II	Tree scattered on farm plot	0.123911	0.034691	0.01673	0.156847
III	Hedgerow Intercropping	0.176496	0.08092	0.010967	0.32107
IV	Trees on entire farm plot	0.091484	0.105003	0.00101	0.864789

Table 5: Proportion of forest land in carbon sequestration among households.

(particularly the Taungya system), as well as knowledge of its possible outcomes in terms of crop performance and the expected returns. The remaining proportion (9%) includes those willing to convert engage in forest land use diversification from farming to planting of trees on their entire farm plot. The practice includes agroforestry systems like Trees in soil conservation and Multilayer tree gardens.

Cost of Agroforestry Practices among Farming Households

Table 6 presents the mean WTA for all the categories of agroforestry systems (agrisilviculture) relevant to tropical rain forests. The results of the estimate show that the mean WTA increase down the increase in volume of trees in each of the system. The estimate was based on a 50year release of the land for carbon sequestration through agroforestry practices. This is to give room for ensuring the livelihood of the rural populace. An average farming household having about 3 ha of land will engage his/her acquired forest land for carbon sequestration programme (through alley cropping, shelterbelt and wind breaks) if he/she will earn up to about N12,365,979 throughout the period of engagement (say at least 50 years). This gives about N82,439.86 ≡ $216.95 per year. Likewise, for the category with the highest proportion (category 3) an average farming household will engage his/her land for carbon sequestration through plantation crop combination, Homogardens or Tuangya if he/she will earn about N21,716,419.5 (an equivalent of N144,776.61 ≡ $380.99 per annum) throughout the period of engagement while those willing to release their land fully for carbon sequestration through planting of trees on the entire farm plot would hope to earn about N32, 616, 714.(217,444.94 ≡ $572.22 per annum).

Cost of Carbon Sequestration among Farming Households

Table 7 shows the cost estimate of carbon sequestration among households. From the overall estimate, lowest cost of carbon sequestration was recorded from boundary planting system. If a total of 55 Mg C is sequestered per hectare per year, carbon would be sold as low as N1,498.9 ≡$3.9. However, an average price of N2,087 ≡ $5.4 is better assumed as the cost price. It was observed that planting trees haphazardly on farm plot (low = $144; average = $21.4; upper =$11.5) and hedgerow intercropping (low = $63.5; average = $47.6; upper = $38) have the highest cost across the range. Thus, boundary planting appears the most attractive class of agroforestry in the study area following its potential volume of carbon and the estimated cost.

Conclusion

The study examined cost of addressing negative forest land use among farming households in Nigeria. It was observed that forest land use could witness a better use among households following the willing expressed by about half of the population to adopt sustainable forest land use practice (i.e., agroforestry). Of all the system of agroforestry examined, boundary planting though was the least choice of agroforestry systems considered among households however, it offers the lowest cost of adoption and consequently the lowest cost of carbon sequestration. This study therefore concludes that boundary planting of agroforestry systems like Alley cropping, Shelterbelts and wind breaks should be encouraged among farming household living within the forest reserves in Nigeria. This will enhance sustainable forest land use while offering low cost of carbon sequestration for combating the effect of climate change.

Group	Classified Agroforestry Systems	Estimated WTA (₦)	Annualized WTA/ha
Boundary Planting	Alley cropping, Shelterbelts and wind breaks.	12,365,979	82,439.86 ($216.95)
Tree scattered on farm plot	Multipurpose tree on crop lands	16,516,438.9	110,109.59 ($289.76)
Hedgerow Intercropping	Plantation crop combination, Homogardens and Taungya	21,716,491.5	144,776.61 ($380.99)
Trees on entire farm plot	Trees in soil conservation, Multilayer tree gardens	32,616,741.1	217,444.94 ($572.22)

Table 6: Mean willingness-to-accept for the categorized agroforestry systems.

Class of Agroforestry	Lower Boundary	Average	Upper Boundary
Boundary Planting (I)	3,434,9 ≡ $9	2,087 ≡ $5.4	1,498.9 ≡ $3.9
Tree scattered on farm plot (II)	55,054.7 ≡ $144	8,156.3 ≡ $21.4	4,404.4 ≡ $11.5
Hedgerow Intercropping (III)	24,129.4 ≡ $63.5	18,097 ≡ $47.6	14477.7 ≡ $38
Trees on entire farm plot (IV)	7,498.1 ≡ $19	3,593.5 ≡ $9	4,181 ≡ $11

Table 7: Carbon sequestration cost estimates $Mg\ Cha^{-1}\ Yr^{-1}$.

References

1. Greengrass EJ (2006) A survey of chimpanzees in south-west Nigeria. NCF-WCS biodiversity research programme. unpublished report.
2. Borokini TI, Babalola TO, Amusa ST, Ivande ZJ, Wala P, et al. (2012) Community-based forest resources management in nigeria: case study of ngel nyaki forest reserve, Mambilla plateau, Taraba state, Nigeria. J Tropical Forestry Environ 2: 69-76.
3. http://www.fao.org/forestry/15148-0c4acebeb8e7e45af360ec63fcc4c1678.pdf
4. Makundi WR, Sathaye JA (2004) GHG Mitigation Potential and Cost in Tropical Forestry-relative Role for Agroforestry. Environ Dev Sustainability 6: 235-260.
5. Mutuo PK, Cadisch G, Albrecht Palm CA, Verchot L (2005) Potential of agroforestry for carbon sequestration and mitigation of greenhouse gas emissions from soils in the tropics. Nutrient Cycling in Agroecosystems 71: 43-54.
6. Newaj R, Dhyani SK (2008) Agroforestry for carbon sequestration: Scope and present status. Indian J Agroforestry 10: 1-9.
7. Kandji ST, Verchot LV, Mackensen J, Boye A, Van NM (2006) Opportunities for linking climate change adaptation and mitigation through agroforestry systems:

World agroforestry into the future, Garrity DP, Okono A, Grayson M, Parrott (eds) World Agroforestry Centre (ICRAF), ISBN, Nairobi, Kenya. 2: 113-121.

8. Findeis JL (2002) Subjective equilibrium theory of the farm household: theory revisited and new directions. in workshop on farm household-firm unit. retrieved from ageconsearch.umn.edu/bitstream/15723/1/cp02fi01.pdf

9. Boxall PC, Macnab B (2000) Exploring the preferences of wildlife recreationists for features of boreal forest management: A choice experiment approach. Can J For Res. 30: 1931-1941.

10. Nair PK (1993) An introduction to agroforestry. Kluwer Academic Publishers, Dordrecht, The Netherlands p: 499.

11. Kuersten E, Burschel P (1993) CO_2-mitigation by agroforestry. Water Air Soil Pollut 70: 5330-544.

12. Lubowski RN, Plantinga AJ, Stavins RN (2005) Land-use change and carbon sinks: Econometric estimation of the carbon sequestration supply function. J Environ Economics Manag 51: 135-152.

13. Dixon RK (1995) Agroforestry systems: Sources or sinks of greenhouse gases? Agroforestry Syst 31: 99-116.

14. DOE (1999) Carbon sequestration: State of the science. us department of energy (DOE), Washington, DC. USA.

15. Food and Agriculture Organization (2001) Global Forest Resources Assessment 2000. FAO Forestry Paper 140. FAO, Rome, Italy.

16. Parry ML, Canziani JP, Palutikof PJ, Van der linden CE (2007) Impacts, adaptation and vulnerability. Contribution of working group II to the Fourth Assessment Report of the Intergovernmental Panel On Climate Change. Cambridge University Press, Cambridge, United Kingdom and New York, USA.

17. Stocker TF (2013) The physical science basis. Cambridge University Press, Cambridge, UK.

18. Jarecki MK, Lal R (2003) Crop management for soil carbon sequestration. Crit Rev Plant Sci 22:471–502

19. Montagnini F, Nair PKR (2004) Carbon sequestration: An underexploited environmental benefit of agroforestry systems. Agroforestry Syst 61: 281-295.

20. Nigeria Conservation Foundation (2017) http://www.ncfnigeria.org/projects/biodiversity-action-plan-edo/item/32-omo-oluwa-shasha-forest-reserve.