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

Adetoye AM*, Okojie LO, and Akerele D
Department of Agricultural Economics and Farm Management, Federal University of Agriculture Abeokuta, Nigeria

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 – CO2) 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...
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 farm 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, the amount of carbon in any agroforestry system depends on the characteristics of the individual. The inclusion of Si 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 Uij 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

$$P(y_i = j) = P(V_j + \varepsilon_j > (V_i + \varepsilon_i))$$

Where y is the observed outcome for the ith observation i=1,2,…,N indexes the rural farm households, j=1 and k=i,…,k are the alternatives being considered and εj and εi 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 enhance 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:

$$WTA = \frac{1}{\beta_{WTA}} \left[ \ln \left( \sum \exp(V^i) \right) - \ln \left( \sum \exp(V^o) \right) \right] \tag{5}$$

Where VY = utility evaluated in the choice of agroforestry practices

V0 = utility derived from the existing farming system

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 can be written to include variables Si, which are “attributes” (i.e., personal characteristics) of the individual. The inclusion of Si 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 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 34oC while 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. However, each of the system is distinguished by Albrecht and Kandji [7] in estimating carbon storage in different agroforestry systems. The categorization is presented in Table 1.

It is important to note that the classification can be ordered based on past studies. The approach is similar to the method adopted 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 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 based on the following attributes; tree arrangement; 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 Andji [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 highest density of tree population on farm land. The second represent light interaction of trees with farm plot while the density of tree population on farm land. The first represent the highest density of tree population on farm land. The second represent light interaction of trees with farm plot while the third and the fourth 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 1= aware, 0 = not aware.

### 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 34oC while 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. However, each of the system is distinguished by Albrecht and Kandji [7] in estimating carbon storage in different agroforestry systems. The categorization is presented in Table 1.

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.

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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 1= aware, 0 = not aware.

### Variables in the ordered probit model.

| 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 |
| Primary 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 | | |
| 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.
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 assume 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, Multi-layer 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 \( M g C ha^{-1} Y^{-1} \). 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
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. 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) also contributes significantly to increasing carbon sequestration across the categories. It contributes 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) 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 the likelihood of forest land use in carbon sequestration. The incentive (WTA) was significant at 1%. As willingness to pay increases, the use of incentive (willingness to accept) also contributes significantly to increasing 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.

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

| Independent Variables | Coefficients | Robust S.E. | Z | Marginal Effects Estimates for the Categories |
|-----------------------|--------------|------------|---|---------------------------------------------|
| Age                   | 0.009604     | 0.006762   | 1.02 | -0.02275 | 0.0000128 | 0.000477 | 0.00013 | 0.000849 |
| Gender                | -0.03051     | 0.227712   | -0.13 | 0.01217 | -0.00006 | -0.00224 | -0.00573 | -0.00369 |
| Education             | -0.06867     | 0.089064   | -0.77 | 0.027934 | -0.001027 | -0.00474 | -0.01293 | -0.00845 |
| Marital status        | 0.28463      | 0.245151   | 1.2 | -0.11637 | 0.009467 | 0.023337 | 0.035448 | 0.030102 |
| Household size        | 0.060477***  | 0.027119   | 2.22 | -0.02413 | 0.001122 | 0.004179 | 0.01139 | 0.007444 |
| Farm size             | 0.024867     | 0.016898   | 1.42 | -0.0096 | 0.000446 | 0.001863 | 0.006541 | 0.002961 |
| Farming experience    | -0.0147*     | 0.007654   | -1.92 | 0.005985 | -0.000027 | -0.00104 | 0.002277 | 0.00181 |
| Income                | 4.08E-08     | 1.24E-07   | 0.33 | -1.63E-08 | 7.96E-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 | -0.00949 | -0.02384 | -0.01466 |
| Land security status  | -0.20274     | 0.162971   | -1.22 | 0.08062 | -0.00255 | 0.00152 | 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 | 0.26383 | 0.025476 | 0.05503 | 0.18392 | 0.064728 |
| Awareness of importance of tree | -0.01154 | 0.25588 | -0.04 | 0.004604 | -0.000021 | -0.00079 | -0.00217 | -0.00143 |
| Climate change awareness (correct) | -0.17431 | 0.242562 | -0.72 | 0.06893 | -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-09 | 9.37E-09 |
| Constant of group (I) | 0.941051     | 0.491215   | 1.92 | -0.0147 | 0.005865 | -0.00010 | -0.00277 | -0.00181 |
| Constant of group (II) | 1.256901     | 0.493941   | 2.58 | 1.66E-07 | -7.72E-09 | -2.88E-08 | -7.84E-08 | -5.12E-08 |
| Constant of group (III) | 1.652625 | 0.497901 | 3.69 | 0.26363 | 0.025476 | 0.05503 | 0.18392 | 0.064728 |
| Constant of group (IV) | 2.482134     | 0.505544   | 3.69 | 0.26363 | 0.025476 | 0.05503 | 0.18392 | 0.064728 |
| Log – Likelihood      | -332.56979   |           |     |     |     | 0.0000128 | 0.000477 | 0.00013 | 0.000849 |
| Wald Chi2 (‘18)       | 78.58        |           |     |     |     | 0.0000128 | 0.000477 | 0.00013 | 0.000849 |
| Prob > Chi2           | 0.0000       |           |     |     |     | 0.0000128 | 0.000477 | 0.00013 | 0.000849 |
| Pseudo R2             | 0.0829       |           |     |     |     | 0.0000128 | 0.000477 | 0.00013 | 0.000849 |

The 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 – Multiplupurpose 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.
(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 50-year 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 N123,657,975 throughout the period of engagement (say at least 50 years). This gives about N82,434.86 = $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 and Taungya if he/she will earn about N21,716,419.5 (an equivalent of N144,776.61 = $216.95 per year) 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 N32,616,741.1 (N572.22 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 = $47.6. However, an average price of N2,087 = $63.5 and N3,593.5 = $110.1 will be sold up to about N123,657,975 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 N32,616,741.1 (N572.22 per annum).

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.

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) Borokini WR, Sathaye JA (2004) GHG Mitigation Potential and Cost in Tropical Forestry and Agriculture. Environ Dev Sustainability 6: 235-260.
3. http://www.fao.org/forestry/15148-0c4acebeb8e7e45af360ec63fcc4c1678.pdf
4. Makundi WR, Sathaye JA (2004) GHG Mitigation Potential and Cost in Tropical Forestry Environ 2: 69-76.
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, Dhyanli 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) CO₂-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 J, Palutikof P, 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.nccnigeria.org/projects/biodiversity-action-plan-edo/item/32-omo-oluwa-shasha-forest-reserve.