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Analysis of Agroforestry Farm Profitability and Potential Economic Value of Carbon Sequestered by Agroforest Lands in Oyo State, Nigeria

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ABSTRACT

The potentials of agroforestry farming are yet to be fully exploited for carbon sequestration, increased crop and farmers' income. This study estimates the agroforestry farm profitability and potential economic value of carbon sequestered by agroforest land in Oyo State, Nigeria. Three-stage sampling procedures were adopted to select 346 agroforestry farmers involved in one agroforestry practice or the other. A structured electronic questionnaire (*Kobotool* app) and field observation were used in collecting primary data for the 2022 cropping season. Descriptive statistics and the Net Present Value (NPV) statistics were used for the data analysis. The potential net economic value of carbon sequestered in the study area was ₦7,246.37 ($9.18) per ha. The results indicated that agroforestry practices in the study area have a huge capacity to sequester carbon and in the long run, generate additional income for smallholder farmers. Although carbon revenues drop at 0.2-0.3% of NPV, carbon payments can still generate substantial revenue for farmers especially when carbon payments are combined with other payments for environmental services provided by agroforestry. Agroforestry practice was adjudged to be profitable with the net farm income of agroforestry farmers as ₦237,966.68 ($311.12) in the last production season. Furthermore, the returns on investment were said to be at 0.63. Despite significant results recorded from agroforestry practices, there is a greater need to create better awareness among farmers on the carbon sequestration and carbon credit generating potential of agroforestry by relevant government agencies such as the Ministry of Environment.

1. Introduction

The craving for increased agricultural production has been under tremendous strain due to rapid population expansion, forest degradation, and indiscriminate usage of agricultural land (Jag Mohan *et al.,* 2021). By 2050, the demand for food will go up by 60% around the world and 100% in developing countries including Nigeria (Jag Mohan *et al.,* 2021). Therefore, adopting agroforestry, a climate-smart farming strategy, is necessary to maximize output and productivity (Aba *et al.,* 2017). There is also little knowledge of the tremendous advantages offered by agroforestry practices, which can help millions of homes stuck in poverty.

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2. Literature review

According to, Food and Agriculture Organization of the United Nations (FAO 2015), Agroforestry is generally referred to as land-use systems and technologies where woody perennials (trees, shrubs, palms, bamboo, etc.) are intentionally used on the same land areas or units with crops and animals, in some form of spatial arrangement or temporal sequence. agroforestry systems in Nigeria include home gardens or traditional agroforestry system (TAS), Taungya farming, integrated Taungya, improved fallow in shifting cultivation, Alley-cropping (hedge row intercropping), and alley farming; others include Shelterbelts, windbreaks, multipurpose trees on cropland, and trees in social conservation.

Carbon sequestration is the process of taking carbon out of the atmosphere and storing it in different parts of the ecosystem. Trees on farms can sequester and store a lot of carbon (Callesen *et al.,* 2023). The amount of carbon sequestration can be estimated based on different tree species and their growth patterns. It's estimated that carbon capture and storage could reduce global Greenhouse Gas (GHG) emissions by 14% by 2050, with a total of 120 billion tons of carbon dioxide captured and stored between 2015 and 2050 (International Energy Agency, 2019).

The greatest role of agroforestry in climate change is perhaps in mitigating the emissions of CO_2 by productively sequestering carbon from the atmosphere. Carbon can sequester in two parts through agroforestry systems: aboveground and belowground. Carbon sequestration in agroforestry systems occurs in above-ground biomass, i.e., stem, branch, and foliage, and belowground biomass, i.e., roots, and in soil.

However, there is little knowledge of the tremendous advantages offered by agroforestry practices, which can help millions of rural homes stuck in poverty. Therefore, there is a need for a global agroforestry transformation to mobilize science and resources to remove the socio-economic, ecological, and political barriers to the widespread adoption of agroforestry innovations and thereby aid in achieving sustainable development goals (SDGs) (Bernard *et al.,* 2019).

Most smallholder agroforestry farmers in rural areas are unaware of the Kyoto Protocol, which might allow them to participate in the international carbon markets and increase the profitability of agroforestry. To allow developing countries to trade in GHG emission reductions, United Nations Framework Convention on Climate Change UNFCCC (2017), and enhance their income, this has been presented as two market-based approaches. Despite the above-elicited literature attempting to address some of these gaps in Nigeria, there is not so much literature covering the value of carbon sequestrated and potential carbon credits of agroforestry farmlands in Southwest Nigeria. Therefore, the study aims to estimate the potential economic value of carbon sequestered by agroforest land and analyze the profitability of selected agroforestry practices among farming households in Oyo State, Nigeria.

3. Research Methodology

The study was carried out in Oyo State in the Southwestern part of Nigeria. The State covers approximately an area of 28,454 square kilometers and is ranked 14^{th} by size in Nigeria (Olajide *et al.,* 2021). Agriculture is the main occupation of the rural people of Oyo State (OSG, 2023). The climate in the state favors the cultivation of crops like maize, yam, cassava, millet, rice, plantains, cocoa, palm produce, and cashews (Atser, 2019). Most farmlands are cropped with fruit trees making the potential of agroforestry in the study area a huge one with a great impact on climate change mitigation and carbon sequestration.

Multi-stage sampling procedure was used to select the respondents from the study area. The first stage involved sampling of the total population of all four agro-ecological zones in Oyo state since due to a dominance of farmers mostly involved in agroforestry. The second stage involved the random selection of Local Government Areas (LGAs) also known as blocks from the selected zones. Three LGAs each were selected from Ibadan/Ibarapa and Saki zones while two LGAs each were selected from both Oyo and Ogbomoso zones.

The selection was made based on the proportion of the number of LGAs in each of the selected zones. The third stage was the random selection of two communities in each LGA, making a total of twenty (20) communities in all. In the fourth and final stage, farming households who are into one form of agroforestry or the other were randomly selected using the Yamane scientific formula for calculating sample size. A sample size determination using ≥10% is highly recommended when the sample size is relatively large (Sani and Oladimeji, 2017). However, 9% was used.

The scientific formula which was given by Yamane (1967), was used to select the sample size at a 95% confidence level.

$$n = \frac{N}{1+N(\propto^2)} \quad \text{.......................................} (1)$$

Where: n = sample size,

N = Sample frame (A sample frame of lists of farmers was obtained from ADP, Oyo State),

and $\propto^2$= precision level (0.05).

Primary data were collected and used for this study. Required information for the 2022 farm production season on socio-economic and institutional characteristics of agroforestry farmers, agroforestry farming operations and practices were collected using a structured questionnaire on the Kobo toolbox application. The use of the *Kobotool* app was preferred because it ensures accuracy of collection and capturing of data. The questionnaire was administered to agroforestry farming households in the selected communities in Oyo State. The amount of carbon sequestered was calculated using the formula obtained from Agriculture, Forestry, and other Land Use (AFOLU) calculator, (2014).

Data collected were analyzed using the net present value and budgetary techniques. Net present value was used to estimate the potential economic value of carbon sequestered by agroforest land in the study area. Budgetary analytical tools like Gross Margin (GM) and Returns on Rate of Investment (RORI) was used to determine the profit of agroforestry production to farmers in the study area (Kareem *et al.,* 2016).

$$GM = TR - TVC \quad \text{.......................................} (2)$$

Where: GM = Gross margin (₦), TR = Total Revenue (₦) given as Py.Y.

Where: Py = price/ unit of product from any agroforestry system practiced and Y = output (kg).

TVC = Total Variable Cost in (₦).

Net farm income (NFI) = GM – TFC; ……………………………………………………(3)

Where, TFC = Total Fixed Cost.

4. Results and Discussion

4.1 Socioeconomic and institutional characteristics of agroforestry farmers

Results from Table 1 revealed that males headed the majority (82.4%) of agroforestry farms, 33.8% had primary education, over half (60%) of the farmers have formal education with mean age of 52 years and standard deviation of 9.9 years. Furthermore, majority of the respondents were married (91.3%), have a relatively sizable household size of an average of 7 members and more than 10 years of experience in agroforestry practice and 47.1 %, have been in cooperative for about 10 years.

The results are comparable with the studies of Alabi and Safugba (2023), and Kareem *et al.* (2016), on socioeconomic profile of agroforestry farmers in Kaduna and Ogun States, respectively.

Table 1. Socioeconomic characteristics of agroforestry farmers

Variables	Dominant indicators	F	%	Mean	Stadev
Gender	Household head that were male	285	82.4	Na	na
Age	Respondent between 21-60 years	286	96.6	52.6	9.9
Education	Minimum of primary education	117	33.8	Na	na
Per household size	Respondent with 1-10 persons	313	90.5	6.8	3.0
Agroforestry practice	Respondent with 1-20 years	267	77.2	16.7	10.9
Marital status	Married respondent	316	91.3	Na	na
Extension visit	Minimum of one contact	296	85.6	3.5	0.8
Cooperative	Minimum of 10 years	163	26.6	7.4	0.4
Credit access	Access	225	65.0	Na	na
Occupation	Farming and others	259	74.9	Na	na
Agroforestry type	Agrisilviculture	219	63.3	Na	na
Land acquisition	Inherited	230	66.5	Na	na
Agroforestry farm size	Farm size between 0.2-2.1	205	59.3	2.7	2.8

Source: Computation from field survey (2023)

4.2 Potential economic value of carbon sequestered by agroforest land

The result in Table 2 shows the Net Present Value (NPV) of carbon sequestrated in the study area using the current interest rate of 18% obtained from the Central Bank of Nigeria, (2023). Findings reveal that the total carbon sequestration potential was 31.25tons of carbon. However, the NPV of carbon sequestrated in the study area is greater than zero with the value ₦ 6,772537.60 ($8514.31). With a total hectare of 945 ha under this research, the NPV of carbon per ha stood at ₦7,246.37 ($9.18/ha). The results are comparable with findings of Callesen *et al.* (2023), on carbon sequestration, allocation, and ecosystem storage in a grassed vineyard.

Table 2. Net Present economic value of Carbon sequestrated in the study area

*Cseq veg (kg)	*Cseq soil(kg)	Total *Ceq (Kg)	Total CO_2eq (Kg)	Conversion (ton)	NPV ($)	NPV per ha ($/ha)
6757.16	1756.91	8514.07	31,246.64	31.25	8680.56	9.18

*Note that *Cseq veg (kg) –Carbon sequestered in trees, Cseq soil(kg)- C sequestered in soil, Ceq-(Carbon equivalent), CO_2 eq–(Carbon dioxide equivalent*

Source: Computation from field survey, (2023)

4.3 Cost-return analysis of agroforestry practices in the study area

Results of the net farm income (profit), profitability index, and rate of investment returns were all calculated and reported in Table 3.The findings indicate that the agroforestry farmers spent a total of ₦129,880.92 on variable costs comprised of cost on labor, seeds, and seedlings, compost made from forest drops, and manure, and very often inorganic fertilizer. The result also shows that the net farm income of agroforestry farmers was ₦237,966.70 in the last production season which indicated that agroforestry is profitable and a successful business in the study area. This agrees with the work of Kareem *et al.* (2016), who also posited that agroforestry was highly profitable in his research on economic evaluation of agroforestry practices in Ogun state, Nigeria. The resulting gross margin ratio of 0.658 means that for every Naira invested in agroforestry production per hectare, 658 kobo were used to cover interest, profits, taxes, depreciation, and other costs. A lower operating ratio is considerably preferred, and the smallholder agroforestry farmers' 0.342 operating ratio shows that they were efficient in their use of resources. This suggested that the cost of output sold and other running costs were covered by 34.2% of the profits from agroforestry production. This is consistent with Alabi and Safugha, (2023).

Table 3. Costs and returns analysis of agroforestry practices in the study area

Description (per household)	Amount (₦)
Total variable costs (TVC)	129,880.92
Total fixed cost (TFC)	12,286.76
Total cost	142,167.70
Total revenue from tree produces	131,447.10
Total revenue from crop component	247,911.70
Total revenue	379,358.80

Description (per household)	Amount (₦)
Annual net farm income(profit)	237,966.70
Gross margin ratio	0.658
Operating ratio (TVC/TR)	0.342
Profitability index (NFI/TR)	0.63
RORI = PI*100	63

Source: Computation from field survey, 2023

5. Conclusions and Recommendations

Based on the findings from the study it can be concluded that agroforestry practices have huge potential for carbon sequestration, generate carbon credits for farmers and improve food security through increased profitability. With the significant effect carbon sequestered on agroforestry farms which is connected to carbon sequestration and improved profitability, it becomes imperative to continue educating farmers on the importance of practicing agroforestry. Agroforestry programs dedicated to creating better awareness among farmers on carbon sequestration and carbon credit generating potential of agroforestry should be mounted by relevant government agencies such as the Ministry of Environment.

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