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ASSESSMENT OF THE SOCIO-ECONOMIC EFFECTS OF CHARCOAL PRODUCTION ON DEFORESTATION AND ENVIRONMENTAL DEGRADATION IN YEWA DIVISION, OGUN STATE, NIGERIA

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ABSTRACT

Continuous production of charcoal has been exacerbating deforestation and forest degradation in the tropical forests of the developing countries, where alternative fuel sources are scarce. This study assessed the effects of the socio-economic characteristics associated with charcoal production, with a view to examine their effects on deforestation and the environmental degradation in Yewa division of Ogun State, Nigeria. Information were extracted using questionnaire administration. Landsat imagery of 2000 and 2020 that covered the study area were analyzed using descriptive statistics and chi-square at $P < 0.05$. There was 17.59% reduction of forest cover and 18.50% increase of non-forest between 2000 and 2020. About 57% of respondents were male; about 45% were between 31 and 40 years. Most respondents (71.2%) were married and about 48% had primary education. About 42% of charcoal producers used traditional kiln techniques, while about 46% sourced their raw materials from free areas. Seventeen indigenous tree species from 14 families were utilized for charcoal production, with the Combretaceae family having the highest occurrence. About 60% of respondents preferred tree species from natural forests, while 40.2% favoured those from plantations. There was a significant relationship between educational status, occupation, experience, wood source, and type of wood utilized for charcoal production and deforestation and environmental degradation at $P < 0.05$. Most preferred tree species was *Vitellaria paradoxa.* Major significant challenges for charcoal production were tree scarcity, government interference, wildfires, and competition from saw millers. Environmental effects of earth kiln method of charcoal production were harsh weather due to increase in environment temperature and smoke from burning causing eye problems and air pollution. The study concluded that balancing the economic and livelihood needs of local people with the environmental sustainability of forest ecosystems is essential, as environmental degradation will directly affect their livelihoods.

Keywords: Satellite image; Ecosystem services; Biomass production; natural forest; remote sensing.

INTRODUCTION

Ecosystem services, such as woody biomass production and biodiversity, are critically affected by significant forest landscape loss

(Carrasco *et al.,* 2017; Curtis *et al.,* 2018). Tropical forests are particularly vulnerable to deforestation and degradation, facing greater risks compared to temperate forests (Sloan and Sayer, 2015). The increasing demand for forest products has placed immense pressure on these resources, leading to environmental degradation, deforestation, and desertification. Charcoal, a locally available and relatively clean fuel source, serves as a vital energy source for millions in urban and peri-urban areas of sub-Saharan Africa (FAO, 2014). In many rural communities, wood fuels, primarily charcoal and firewood account for over 80% of the primary fuel energy supply and provide essential household income (Mwampamba *et al.,* 2013; Jones *et al.,* 2016). However, reliance on the wood and charcoal energy source contributes significantly to deforestation, which is a leading cause of global carbon emissions (Achard *et al.,* 2017; van der Werf *et al.,* 2019). In Nigeria, charcoal production is a prominent source of livelihood, especially in rural areas with dry woodlands, where economic trees are increasingly felled for charcoal, compromising both agricultural lands and forest ecosystems. As reported by the Food and Agricultural Organization (FAO, 2014), there is a steady increase in annual production of charcoal in Nigeria from 2,131,778 in 1990 to 4,193,352 metrics tons in 2013. In Nigeria, charcoal is available in all the geopolitical zones of the country as many local communities have perfected the technology of charcoal production. In Nigeria, charcoal depots were found in places like Oyo, Isheyin, Saki, Igbo-Ora, Ogbomoso, Jebba, Omu Aran, Egbe, Kabba, Minna, Jos and Kaduna (Rotowa *et al.,* 2019). Despite its economic importance, the sector suffers from poor governance and a lack of reliable data, leading to unsustainable practices that exacerbate deforestation (Sedano *et al.,* 2016). Indiscriminate exploitation of forest resources due to open access has led to increase in deforestation which eventually contributed to global warming and food insecurity. Animals have also been deprived of their shelter, leading to extinction. Unemployment and lack of education in the rural areas have made sustainable use of forest resources a dilemma (Ado and Darazo, 2016). The lower the education status, the more likely someone is to engage in charcoal production and thus directly contribute to deforestation. Charcoal production practices in the rural areas contribute to the loss of indigenous trees due to their quality wood fuels. However, indigenous trees are known for slow regeneration when cut down. Recently, Nigeria is among the second largest producers of charcoal and also one the largest consumers of charcoal worldwide (Rotowa *et al.,* 2019). This is an indication of epileptic power supply and hike in price of alternative source of cooking fuel energy which has led many households to use charcoal for domestic cooking (Nwofe, 2013). Wood fuel for domestic cooking by low-income households is aggravating deforestation in a country where striking balance between energy consumption and population growths is a daily challenge (Luwaya, 2015). Traditionally, all tree species can be carbonized to yield charcoal but as a matter of preference, some tree species are preferred over others because of the high quality and quantity of charcoal produced. Consequently, tree species such as *Prosopis africana*, *Vitellaria paradoxa, Diospyros mespiliformis, and Vitex doniana* among others, have become threatened in the study area. Charcoal is arguably among the least examined forest products, despite being an important energy and income source for millions of people in the tropics (FAO, 2017). Charcoal production is an important cause of forest degradation (Sedano *et al.,* 2016) and is responsible for up to 7% of annual deforestation globally, especially under ineffective governance scenarios without investment in post-harvesting management (Chidumayo and Gumbo, 2013). In a real sense, charcoal production results in deforestation because of the nature of the production system. According to Specht *et al.* (2015) environmental damage from fuel wood harvesting can be significant if too many people depend on too few forested areas and the ecosystem services they deliver. Charcoal production is projected to increase by 5% by 2100, likely causing further deforestation and forest degradation (Santos *et al.,* 2017). Effective forest governance that incorporates energy substitution options to reduce pressure on fuel wood energy demand is required to mitigate these negative effects, besides routine monitoring and enforcement to control access to forest use (Schure *et al.,* 2013; van'T Veen *et al.,* 2021). As demand for charcoal continues to rise, driven by factors such as high electricity costs and a lack of affordable alternatives, sustainable management of forest resources becomes imperative to mitigate further environmental degradation and preserve biodiversity.

The research focused on the assessment of the socio-economic effects of charcoal producers and their production method on deforestation and environmental degradation. Thus, this study specifically assessed land cover changes and deforestation trends in the study area. It examined the socio-economic characteristics of charcoal producers to evaluate the ecological effects of charcoal production on forest biodiversity and regeneration rates, as well as proposing future policy measures for efficient and sustainable forest management.

METHODOLOGY

Study Area

The study was conducted in Ogun State, Nigeria, specifically in the Yewa division, which comprises Yewa North and Imeko-Afon Local Government Areas (Figure 1). Ogun State is bordered by Lagos State to the south, Oyo State to the north, the Republic of Benin to the west, and Osun State to the east. Yewa North is located on latitude 7°14'00"N and Longitude 3°02'00"E, covering an area of 2,087 km². Imeko-Afon Local Government Area is situated on Latitude 7°29'10"N and longitude 2°53'10"E. This area is predominantly rural and agrarian within the deciduous derived savanna zone, with a total land area of 1,711.43 km² (NBS, 2022). The major occupation of people in these settlements is farming. The notable Yewa River extends its tributaries across different villages. The state has two main types of vegetation namely, tropical rainforest in the south and derived savanna in the northern part where the study area was located. The forest and game reserves in the study area are Imeko-afon game reserve located in Imeko-afon, while Aworo, Egua and Ohumbe forest reserves are located in Yewa North Local Government Area. Notable tree species in the reserves were: Teak and Gmelina. Valuable indigenous trees found in the study area were: *Ceiba pentadra*, *Triplochiton scleronxylon*, *Albizia zygia*, *Afzelia africana*, *Antiaris arfricana*, *Alstonia boonie*, *Teminalia superba*, *Viterllaria paradoxa*, *Daniella oliveri* etc. Ogun State features a lowland topography with altitudes ranging from 0 to 200 meters above sea level. It experiences two distinct seasons: a dry season from November to March and a wet season from April to October. Mean annual rainfall ranges between 2,000 and 2,002 mm, with a maximum temperature of 32.5°C and relative humidity averaging 79.9% (OSG, 2016). The study area is largely characterized by wide distribution of natural grasses/ pasture and other herbaceous plants and shrubs (derived savanna), and is considered as attractive to pastoralists for grazing or for settlement. Economic activities are largely farming with maize, cassava, vegetables and spices as dominant crop production. Cattle production in the area is by sedentary Fulani pastoralists and trans-human pastoralists.

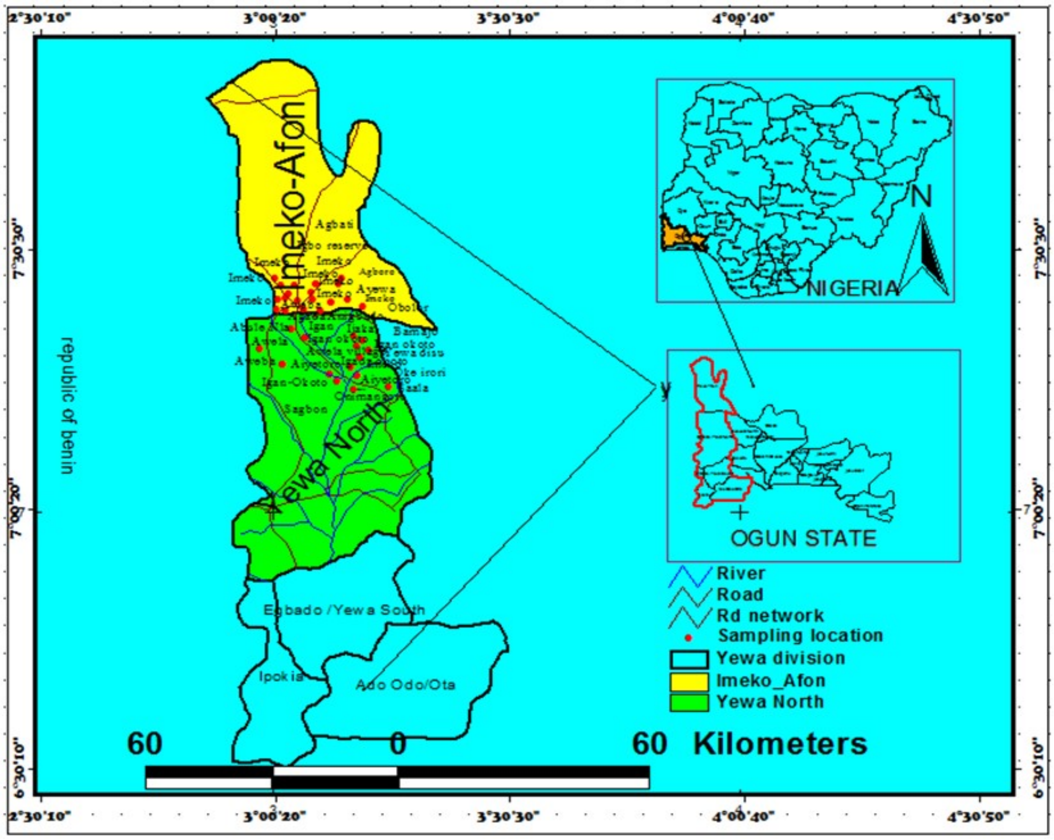

Figure 1: Map of Yewa division showing the study area

Sampling Procedure and sample sizes

For this study, a multistage sampling technique was used. Two Local Government Areas in a derived savanna in Ogun State (Yewa North and Imeko-Afon) were purposively selected because of noticeable production of charcoal. Fifty percent of the political wards (smallest administrative subunits) were selected proportionally from each of the LGA's (that is, Yewa north = 6 political wards and Imeko-Afon = 5 political wards). Twelve charcoal producers were finally selected from each of the political wards making a total of one hundred and thirty-two (132) respondents.

Data Collection and Analysis

Primary and secondary data were collected for this study. Primary data were collected using Global Positioning System (GPS). Geographic coordinates of charcoal producers' location as well as charcoal production sites were picked and recorded. Questionnaire was also administered among charcoal producers using semi-structure questionnaires. A well-structured questionnaire comprising open and closed ended questions with oral interviews were used to elicit information from charcoal producers in the study area. Field trips were carried out to gather and assess data on preferred tree species, cutting and harvesting practices, methods of charcoal production, environmental degradation, and forest degradation associated with charcoal production, and the socio-economic benefits of charcoal in the sample sites (Figures 2 and 3). Secondary data were sourced from Topographic map, on the scale of 1: 50,000 which showed the forest and game reserves located within the study area, complimented with satellite imageries (Landsat ETM+ and OLI) for the period of 2000 and 2020 to extract information on the previous and current land use and vegetation cover of the study area. The use of multiple data collection technique and sources strengthened the credibility of outcomes and enabled different interpretations and meanings to be included in the data analysis (Trift, 2009).

Data Analysis

Data collected were analyzed using descriptive and inferential statistics. Descriptive statistics such as frequency count, percentages were used to analyze the data on socio-economic characteristics, choice of trees used, charcoal producers' effects on deforestation and environment. Inferential statistics such as chi square was used to test the hypothesis following equation 1. Also spatio-temporal data analysis of land use/land cover was carried out using post classification comparison methods. The Chi-square was expressed as follows:

$$\text{Chi Square}(X^2) = \Sigma \left(\frac{O-E}{E}\right)^2 \quad \ldots\ldots\ldots\ldots\ldots 1$$

Where O = Observed frequency
E = Expected frequency
Σ = Summation sign

***Hypothesis*:**

H_0: There is no significant relationship between charcoal producers demographic and occupational characteristics and associated deforestation and environmental degradation.

H_0: There is no significant relationship between kiln type and quantity of wood load.

Significant difference was determined at 5% level ($P < 0.05$).

RESULTS AND DISCUSSION

Seven major land use/land cover (LULC) types (TF, LF, WS, CL, BO and WL) were classified for the years of 2000 and 2020 (Table 1). The LULC classification for the enhanced thematic mapper plus (ETM+) 2000 image shows that the majority of the study area was under forest cover in total covering about 183722.20 ha (52%). Thick forest (TF) and light forest (LF) covered an area of 68014.80 ha (19.25%) and 63450.70 ha (17.96%) respectively, whereas the aerial coverage of non-forest in total covered 169643.90 ha (48%) from the total study area (Table 2). Similarly in 2020, the greatest share of LULC in total was non-forest land cover which covers an area of 201028.86 ha (57%). TF and LF covered an area of 72759.30 ha (20.65%) and 48214.70 ha (13.68%) respectively. The aerial coverage of forest in total was 151396.40 ha which account for only 43% respectively (Table 2). It is evidence from the result that forest land cover has reduced over the period. This is due to agricultural expansion and charcoal production activities in the study area as evidence has been seen form the result of questionnaire survey that 43.2% of the respondents engage in farming activities (Table 3).

Table 1: Land use/Land cover Areas in 2000 and 2020

Land/Forest cover classes	2000 Area (ha)	%	2020 Area (ha)	%
Thick forest (TF)	68014.80	19.25	72759.30	20.65
Light forest (LF)	63450.70	17.96	48214.70	13.68
Wooded/Shrub land (WS)	52256.70	14.79	30422.40	8.63
Forest in total (TF, LF & WS)	**183722.20**	**51.99**	**151396.40**	**42.96**
Cultivated land (CL)	23580.50	6.67	31532.80	8.95
Built-up/open land (BO)	30198.20	8.55	59343.80	16.84
Grass/Bush land (GB)	85950.90	24.32	100709.00	28.58
Wet/bare land (WB)	29914.30	8.47	9443.26	2.68
Non-Forest (CL, BO, GB &WB)	**169643.90**	**48.01**	**201028.86**	**57.04**
Grand Total (Forest + Non-Forest)	**353366.10**	**100.00**	**352425.26**	**100.00**

Source: Image Analysis of Landsat ETM+ 2000 and OLI/TIR 2020

Land use/land cover changes and rate of change between 2000 and 2020

From 2000 to 2020, forest in total decreased by 17.59%, while non-forest land cover increased by 18.50% during the same period (Table 2). However, thick forest (TF) cover slightly increased by 7% while light forest (LF) cover reduced by 24.01% during the same period, respectively. To a greater extent, land covered by forest had transformed to other land use/land cover (LULC) areas and declined gradually. This may be linked to heavy dependency on natural forest as source of raw materials for charcoal making. The results have shown several LULC changes in the last 20 years (2000 – 2020) in the study area. Forest area in total (TF, LF and WS) was the main land cover in 2000 with 52% of the total land area in the study area followed by non-forest land area (48%). The area covered by TF increased from 68014.80 ha (19.25%) in 2000 to 72759.30 ha (20.65%) in 2020. On the other hand, LF decreased from 63450.70 ha (17.90%) to 48214.70 (13.68%) in the same period. The loss of forest cover during the period of change can be attributed to anthropogenic activities by charcoal producers in the study area. According to the results obtained from questionnaire survey, about 46% of the respondents source the materials for charcoal making from forest around the community (free area) while about 14.4% of the respondents source from the abandoned farm land. However, these materials are preference of natural forest as stated by the majority (59.8%) of the respondents during field survey. This suggests that charcoal activities have been encroaching upon the area at the expense of forest types. This is line with the finding of Kissinger *et al.* (2012) which stated that the process of degradation is conventionally associated with the direct causes of factors such as farming, forest products consumption, and export. The overall annual rate of change in the declining phase of forest cover was observed at about 0.88% while other land cover classes experience an expansion at the same period of change. The overall trend shows that forest area had decreased and non-forest area had increased in the study area. The overall loss of forest was 32325.8 ha from 2000 to 2020. This indicates that local community depends highly on agricultural activities, fuelwood harvesting, logging extraction and non-forest resources consumption which would be further expected with a decline in forest cover. Continuous exploitation of tree species without conservation strategies may be dangerous if allowed to continue and in the near future, the forest types may be totally lost to other land use/ land cover types which may have serous implication for species biodiversity in the study area. Thick forest slightly increased in total area covered between the period by 6.98% with annual increased rate of 0.35% (Table 2). This may be attributed to graduation of light forest to thick forest. However, sometimes when there is reduced pressure of over exploitation of forest cover type, light forest transits to thick forest between 10 and 16 periodic intervals if the area is left untouched (Salami, 2019). The study area has been known as agrarian community which was located in transition zone between forest and guinea savanna ecological zone. As opined by Orimoogunje, (2014), there is a strong tendency for losing more of the area under forest type to other land cover types if the trend remains unabated. Consequently, this poses a serious threat to the state of forest cover types and aggravates forest cover types depletion and tree species degradation in the area. Although natural drivers could also play a role in land cover change, the scope of this study mainly focus on anthropogenic activities associated with charcoal production. However, loss of forest cover is particularly serious in the study area where the landscape has a complex and fragile environment with vulnerability to numerous types of natural hazards. Therefore, increase in non-forest is likely to have a negative impact on the continuing and quantity of forest land area (Zomar, et al., 2016). The heavy dependency on natural forest together with land cover changes has serious impact on biodiversity loss, habitat destruction and ecosystem services in this region.

Table 2: Land use/Land covers Change and rate of Change between 2000 and 2020

LULC Types	2000	2020	Change between 2000-2020	% change	Annual Rate of change	% Annual rate of change
	Area (ha)	Area (ha)	Area (ha)	%	(ha/yr)	%
Thick Forest	68014.80	72759.30	4744.50	6.98	237.23	0.35
Light Forest	63450.70	48214.70	-15236.00	-24.01	-761.80	-1.20
Wooded/Shrub land	52256.70	30422.40	-21834.30	-41.78	-1091.72	-2.09
Forest in total	**183722.20**	**151396.40**	**-32325.80**	**-17.59**	**-1616.29**	**-0.88**
Cultivated land	23580.50	31532.80	7952.30	33.72	397.62	1.69
Built-up/open land	30198.20	59343.80	29145.60	96.51	1457.28	4.83
Grass/Bush land	85950.90	100709.00	14758.10	17.17	737.91	0.86
Wet/bare land	29914.30	9443.26	-20471.04	-68.43	-1023.55	-3.42
Non-Forest	**169643.90**	**201028.86**	**31384.96**	**18.50**	**1569.25**	**0.93**

Source: Image Analysis of Landsat ETM+ 2000 and OLI/TIR 2020

Socio-economic Analysis

About 60% of charcoal producers were male (Table 3), reflecting the physically demanding nature of the work, which often limits female participation. This supports Ali et al. (2018), who noted male dominance in similar labor-intensive sectors, though it contrasts with Cooperazione (2011), which found that over 80% of commercial charcoal producers in Ghana were women. The chi-square test of independence showed that there was no significant association between gender and deforestation and environmental degradation (32.602 - Table 3. The age distribution showed that 44.7% of respondents were aged 31 to 40 years, with an average of 38 years, indicating that most were in their productive years, which boosts household income and aligns with the findings by Jibowo (1998) and Oladimeji *et al.,* (2018), who linked labor productivity to age. The chi-square test of independence showed that there was no significant association between age and deforestation and environmental degradation (15.856) - Table 3. The study also revealed that about 48% of the charcoal producers had primary education, followed by no formal education (25%), and only 7.6% had tertiary education. The chi-square test of independence showed that there was a significant association between education status and deforestation and environmental degradation (60.599). This indicates that charcoal production serves as an income source for those with limited educational opportunities. However, an increase in the educational status of charcoal producers is more likely to improve their perception of the effect of charcoal production on deforestation. The lower the education status, the more likely someone is to engage in charcoal production and thus directly contribute to deforestation. This finding is supported by Tassie et al. (2021) who argue that charcoal producers' low level of education hurts forest sustainability. About 43% of charcoal producers are farmers, followed by trading (35.6%) and civil servants (5.3%) - Table 3. This result is in line with the report given by Tassie et al. (2021) in Mecha District (Ethiopia), that most charcoal producers also partook in farming activity. This described the significant contribution of charcoal to household cash income and supports as declared by Angelsen et al. (2014) that forest revenue contributes more to regular household income. The chi-square test of independence showed that there was a significant association between occupation and deforestation and environmental degradation (21.232) (Table 3). This implies that charcoal production compliments farming as a livelihood. Household size data showed that 47% of respondents had fewer than five members with an average of 5 members, indicating that many producers have significant familial responsibilities. Experience in charcoal production varied, with 57.6% having fewer than 10 years of experience with an average of 11.42 years, indicating that many are relatively new to the trade. The chi-square test of independence showed that there was a significant association between years of experience and deforestation and environmental degradation (43 years) at a 5% (Table 3). Income distribution showed that over 52.3% earned between ₦18,001 and ₦55,000 monthly with a mean value of ₦41174.65 monthly, a figure higher than the international poverty line and above Nigeria's national minimum wage. The chi-square test of independence showed that there was no significant association between monthly income and deforestation and environmental degradation (4.521). This confirms that charcoal production is a vital livelihood strategy in the study area. It can be inferred from these results that charcoal production plays a crucial role in sustaining the livelihoods of rural communities in the study area, serving as a significant income source, particularly for farmers and individuals with limited educational backgrounds. However, it remains a physically demanding, male-dominated enterprise, which presents challenges to broader participation.

Table 3: Socio-economic characteristics of the sampled charcoal producers and their association with deforestation and environmental degradation in the study area (n=132).

Demographic Characteristic	Category	F	%	mean	SD	X^2	p-value
Sex	Male	75	56.8			32.602[a]	0.051[NS]
	Female	57	43.2				
Age (years)	0 – 30	17	12.9				
	31–40	59	44.7	38.39	11.3	15.856[a]	0.198[NS]
	41–50	39	29.5				
	51–60	17	12.9				
Educational Status	No formal education	33	25				
	Primary education	63	47.7			60.599[a]	0.000*
	Secondary education	26	19.7				
	Higher education	10	7.6				
Marital Status	Married	94	71.2			NA	NA
	Single	21	15.9				
	Widower/Widow	14	10.6				
	Divorced	3	2.3				
Occupation	Unemployed	16	12.1				
	Trading	47	35.6				
	Farming	57	43.2			21.232[a]	0.007*
	Civil Servants	7	5.3				
	Cross border trader	5	3.8				
Household Size	0- 4	62	47				
	5 – 8	60	45.5	4.69	2.7	NA	NA
	9 – 12	10	7.6				
Experience (years)	0 – 10	76	57.6				
	11- 20	40	30.3	11.42	9.4	43.819[a]	0.000*
	21-30	10	7.6				
	31-40	2	1.5				
	41-50	4	3				
Monthly income (₦)	0 – 18000	25	18.9				
	18001 – 55000	69	52.3	41174.65	22056.9	4.521[a]	0.210[NS]
	55001 – 74000	25	18.9				
	74001 – 92000	13	9.8				

Note. (*) significant level; NS: Non-significance levels both at 5%.
F= Frequency; %= Percentage; SD= Standard deviation; X^2= chi-square values; NA=Not applicable.
Source: Survey result (2021/2022).

Charcoal Production

The findings show that about 46% of charcoal producers source tree species for charcoal from community forests (free land), 37.9% purchase from wood sellers, 14.4% from farmland, and only 1.2% from woodlots (Table 4). Most respondents (59.8%) preferred tree species from natural forests, while 40.2% opted for plantations. This contrasts with Izekor & Amiandamhen (2017), who found that 51% sourced from fuel wood sellers. The preference for natural forests may be due to the variety of tree species available, as noted by Izekor & Osayimwen (2010). The chi-square test of independence showed that there was a significant association between wood source for charcoal production, preferred forest exploitation and deforestation (57.525), and environmental degradation (41.606) at a 5% level of significance. Also, studies by World Resources Institutes (WRI) indicated that two thirds of wood fuel (charcoal) worldwide comes from non-forest sources that include alternative sources for collecting fuel wood from logging, home garden and from agro-industry plantations (WRI, 2000). A significant portion (72%) of respondents confirmed they use firewood from natural forests for charcoal production, while 28% used sawmill residues from plantations. The chi-square test of independence showed that there was a significant association between type of wood utilized for charcoal production, and deforestation and environmental degradation (21.244), Also, the respondents sourced wood from various natural forests, with Ijaka being the most popular (46.25%) forest exploited (Table 4). This aligns with Agyeman *et al.,* (2012), who reported that 88% of charcoal producers in Ghana use live trees from natural forests. The chi-square test of independence showed that there was a significant association between name of forest exploitation and deforestation and environmental degradation (64.234). Regarding production per kiln methods, 41.7% of respondents used earth mounds or pits kiln, while 16.7% used drums. The earth mound kiln method is widespread, consistent with the findings of Bada *et al.,* (2009) in Nigeria. Labor usage varied, with 41.7% employing 3 to 4 workers with an average of 4 workers, which influenced the quantity of wood processed. The chi-square test of independence showed that there was a significant association between number of labour usage for charcoal production and deforestation and environmental degradation (31.169) at a 5% ($P < 0.05$) level of significance. About 40% of the charcoal producers used between 1,000 and 2,000 kg of wood with an average value of 1598.98kg and production typically take 7 to 15 days, depending on the kiln method and wood dryness. The quantity of charcoal produced per kiln method varied, with about 30% of respondents producing between 500 and 1,500 kg with a mean value of 3017.55 kg. Most respondents (55.5%) produce charcoal twice a month and 62.9% of the respondents sell to foreign customers. However, the chi-square test of independence showed that there was no significant association between consumer preference and deforestation and environmental degradation (1.364). The study draws attention to how much charcoal is produced in natural forests, which raises questions about deforestation and the long-term viability of this method. Despite being easily accessible, the widespread use of traditional methods is ineffective and worsens the environment (Figure 2). In order to protect forest resources, better sustainable methods are desperately needed.

Table 4: Forest Exploitation and Charcoal Production in the study areas (n=132)

Variables	Category	F	%	mean	SD	X^2	p-value
Wood source	Purchased from wood seller	50	37.9				
	Community land (free area)	61	46.2			57.525[a]	0.000*
	Farm land	19	14.4				
	Wood lot (Plantation)	2	1.5				
Preferred forest exploitation	Natural.	79	59.8			41.606[a]	0.005*
	Plantation	53	40.2				
Number of labour used in	1 – 2	39	29.5				
charcoal production process	3 – 4	55	41.7	3.61	1.8	31.169[a]	0.000*
	5 – 6	30	22.7				
	7 – 8	8	6.1				
Number of days used in	7–8	59	44.7				
making charcoal	9–15	53	40.2	10.9	3.7	NA	NA
	15–21	20	16.1				
Quantity of wood used / stacked	1 – 1000	53	40.2				
per kiln method (Kg)	1001 – 2000	40	30.3	1598.98	1184.2	NA	NA
	2001 – 3000	18	13.6				
	3001 – 4000	15	11.4				
	4001 - 5000	6	4.5				
Charcoal production method	Earth mound kiln	55	41.7			NA	NA
(Type of kiln used)	Earth pit kiln	55	41.7				
	Use of metal drum	22	16.7				
Quantity of charcoal produced	1 – 1000	34	25.8				
per kiln method	1001 – 2000	39	29.5				
	2001 – 3000	27	20.5	3017.55	5738.4	NA	NA
	3001 – 4000	24	18.2				
	4001 - 5000	8	6.1				
Type of wood utilize for	Fire wood	95	72			21.244[a]	0.000*
charcoal production	Residue from the sawmill	37	28				
Name of forest source for	Ijaka	61	46.2			64.234[a]	0.002*
exploitation	Imeko	22	16.7				
	Ayetoro	22	16.7				
	Igan okoto	16	12.1				
	Erinpa	9	6.8				
	Yewa Disu	2	1.5				
Production time per month	Once	34	25.8			NA	NA
	Twice	72	54.5				
	Three times	26	19.7				
Consumer preference	Local traders	49	37.1				
	Exporters Consumers	83	62.9			1.364[a]	0.506 NS

Note. (*) significant level; NS: indicate non-significance levels both at 5%. F= Frequency; %= Percentage; SD= Standard deviation; X^2= chi-square values; NA=not applicable

Source: Author's field work.

Figure 2: Traditional earth mound kiln method of charcoal production process in the study area

(a). Stacked tree species for charcoal production (b). Soil heap loaded inside with trees; (c). Soils heaped unfold to pack the charcoal; (d). Charcoal packed in sack ready to transport; (e). Evidence of deforestation and environmental degradation from charcoal production process.
Source: Field survey, (2021).

Respondent preference on tree species use for charcoal production and the likely implications for forest sustainability

Seventeen tree species from 14 families were identified by respondents as being used for charcoal production (Table 5). The Combretaceae family had the highest number of species, followed by the Fabaceae family (Table 5). About 40% of the respondents preferred *Viterllaria paradoxa*, followed by 21.2% for *Anogeissus leiocarpus* (Figure 3) with *Terminalia ivorensis* had 12.9%, *Afzelia Africana* had 9.8%, *Albizia zygia* had 5.3%, *Terminalia superba* had 4.5%, *Ficus exasperata* had 3.8% and *Daniellia oliveri* had the least with 3.1% (Figure 3). The preferred species (eight out of 17) belong to the Combretaceae family, with rank from Fabaceae, Caesalpiniaceae, Leguminosae, and Moraceae families. The main reason for these preferences, (Figure 4) was the species' availability (76.5%), others were their high calorific value (22%), and ease of carbonization with 1.5% (Figure 4). Tree species selection is crucial in charcoal production due to factors like solid, hard charcoal and high calorific value (Izekor & Modugu, 2011). The heavy reliance on species such as *Vitellaria paradoxa* and *Anogeissus leiocarpus* in the study area raises concerns about overharvesting and the possible extinction of these species, leading to a shift toward less-preferred alternatives, which could contribute to forest degradation. Suitable tree species for charcoal production are expected to catch fire easily, have high calorific value, produce less ash and smoke, and not explode, as noted by the Ministry of Energy (2019). Some of the preferred species, including *Vitellaria paradoxa, Anogeissus leiocarpus*, *Afzelia africana, Albizia zygia,* and *Terminalia superba* among others, also produce high-quality charcoal and are often fruit or timber species protected by traditional laws or restricted for use (Lurimuah, 2011; Lurumuah *et al.,* 2012). As reported by Azeke *et al.,* (2001), lack of regulation on harvesting trees from natural forests as common property, undermines sustainable forest management. Thus, unsustainable exploitation of preferred tree species (Figure 3) for charcoal production; the environmental risks associated with overharvesting, and the need for better forest management policies therefore pose a threat to the study area's indigenous tree species due to deforestation and environmental degradation.

Table 5: Indigenous tree species utilized for charcoal production identified by the charcoal producers in the study area

S/N	Trade name	*Scientific name*	Family
1	Orindudu	*Anogeissus leiocarpus*	Combretaceae
2	Idigbo	*Terminalia ivorensis*	Combretaceae
3	Afara	*Terminalia superb*	Combretaceae
4	Apa	*Afzelia Africana*	Fabaceae
5	Etinrin	*Erythrina abyssinica*	Fabaceae
6	Iya	*Danellia oliveri*	Caesalpiniaceae
7	Ayinre	*Albizia zygia*	Leguminosae
8	Epin	*Ficus exasperata*	Moraceae
9	Emi	*Vitellaria paradoxa*	Sapotaceae
10	Ire	*Funtumia elastical*	Apocynaceae
11	Idin	*Millingtonia hortensis*	Bignoniaceae
12	Ata	*Zanthocylum zanthoxyloides*	Rutaceae
13	Apapo	*Lonchocarpus sericeus*	Papilionoideae
14	Isin	*Blighia sapida*	Sapindaceae
15	Opepe	*Nauclea diderrichii*	Rubiaceae
16	Oori	*Vitex doniana*	Lamiaceae
17	Dongoyaro	*Azadiractha indica*	Meliaceae

Source: Field survey result, (2021/2022)

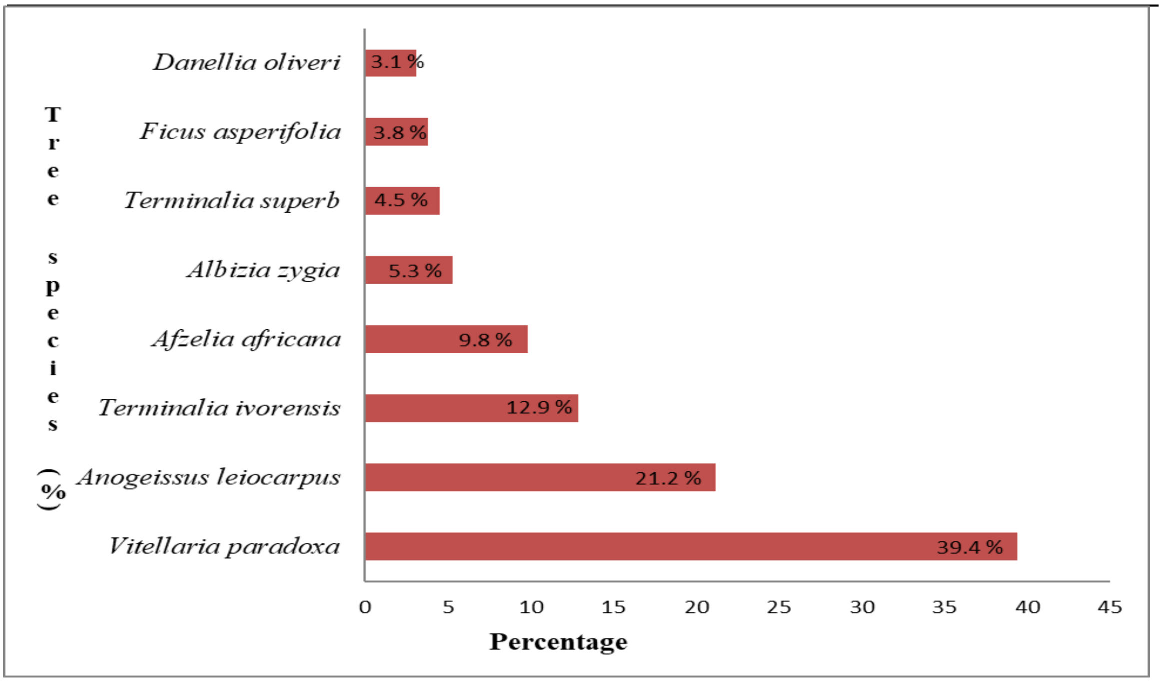

Figure 3: Preferred tree species used for charcoal production in the study area
Source: Survey result, (2021/2022)

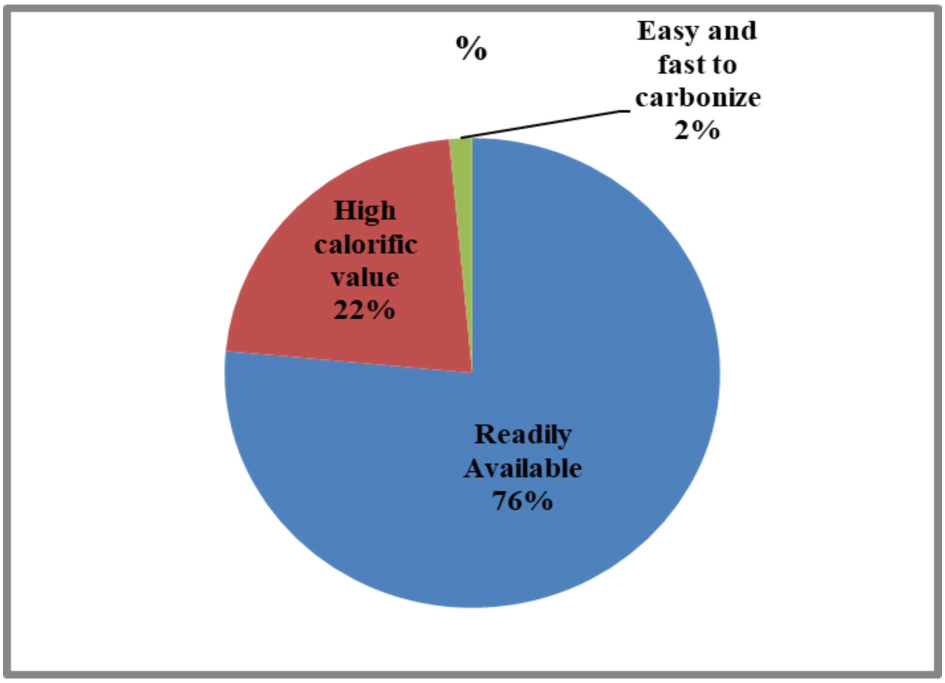

Figure 4: Reasons for choice of tree species for charcoal production
Source: Survey result, (2021/2022)

Trends of charcoal production

Majority of the charcoal producers (77.3%) rely on charcoal as household energy while 15.1% used gas, about 6.1% use kerosene fuel energy and 1.5% used both kerosene and firewood fuel energy as source of energy for cooking (Table 6). The use of charcoal may depend on the easy accessibility and the economic level of the household (Table 6). In all cases, the level of charcoal consumption, despite the use of other energy sources, remained high and gives the dominance of forest-based energy sources, posing a serious threat to sustainable forest management. As reported by the Food and Agricultural Organization (FAO, 2014), there is a steady increase in annual production of charcoal in Nigeria from 2,131,778 in 1990 to 4,193,352 metrics tons in 2013. It is important to raise awareness of the alternative use of wood and charcoal which would reduce wood and charcoal consumption.

Table 6: Source of household fuel energy

Variable	categories	F	%
Type of fuel energy	Charcoal	102	77.3
	Gas	20	15.1
	Kerosene	8	6.1
	Firewood	2	1.5

F= Frequency; %= Percentage

Source: Survey result, 2021/2022

Environmental Challenges of Charcoal Production: Threats to Sustainable Forest Management in Local Communities

A significant proportion of respondents (87.1%) reported challenges in the production process, with only 12.9% experiencing none (Table 7). The most common challenges include tree scarcity (42.4%), government interference (25.8%), wildfires (17.4%), and competition from saw millers (14.4%). Over-exploitation of indigenous tree species has made many of the trees to be rare, as noted by 66.7% of respondents. The earth kiln method of charcoal production exacerbates environmental degradation, causing soil erosion, land degradation, and air pollution. The research highlights the risk of tree species extinction, with 66.7% of respondents affirming that certain species are in danger. About 52% acknowledged that their activities contribute to forest degradation (Table 7), primarily through tree felling and charcoal burning (Kissinger *et al.,* 2012; Jamala *et al.,* 2013).

Table 7: Problems faced by the charcoal producer and its causes in the study area (n=132)

Variables	Category	F	%
Encountered challenges	Yes	115	87.1
	No	17	12.9
Challenges in charcoal production	Scarcity of tree	56	42.4
	Wildfire	23	17.4
	Government disturbance	34	25.8
	Competition by the saw-millers	19	14.4
Species of trees endangered of extinction due to deforestation	Yes	88	66.7
	No	38	28.8
	Maybe	6	4.5
Contribution to forest degradation	Yes	69	52.3
	No	63	47.7
Activities carried out	Tree feeling	39	29.5
	Burning of woods to charcoal	30	22.7
	undecided	63	47.7

F= Frequency; %= Percentage
Source: Result of survey, 2021/2022

Charcoal production and its associated environmental effect

In addition to cutting the trees for charcoal manufacture, smoke generating during burning of woods into charcoal and also leaves were collected and used as combustible materials during production process (Oguntunde *et al.,* 2008) causing deforestation and environmental degradation in the study area. The surface mound kilns, also damage the top soil, through digging and burning during the production cycle. Notably, 56.1% of respondents cited harsh weather as a challenge, 29.5% reported smoke coming out from kiln method during charcoal production causing eye problems, and 14.4% mentioned air pollution (Table 8). The carbonization process, which can last weeks, can also lead to bushfires, harming local flora and fauna (Kass-Yerenchi, 2002). The area where surface mound kilns are erected/ established will not be re-vegetated even if rain soaks.

Table 8: Charcoal production and its associated environmental effects in the study area (n=132)

Variables	Category	F	%
Environmental effects	Harsh weather	74	56.1
	Eye problem	39	29.5
	Air pollution	19	14.4

F= Frequency; %= Percentage
Source: Result of survey, 2021/2022

In order to mitigate environmental effects, about 60% of respondents suggested enrichment planting, 33% advocated for government intervention, and 7% recommended afforestation (Table 9). Traditional charcoal production methods, such as the earth mound, are unsustainable, leading to loss of vegetation, destruction of ecosystems, and threats to wildlife habitats (Agyeman *et al.,* 2012). The process also negatively impacts water bodies and local climate patterns, as reported in previous studies (Ottu-Danquah, 2010; Msuya *et al.,* 2011).

Table 9: Suggested solutions to alleviate problems encountered by the charcoal producers (n=132)

Variables	Category	F	%
Solution to alleviate current problem	Enrichment planting	79	59.8
	Government intervention	43	32.6
	Planting of trees (afforestation)	10	7.6

F= Frequency; %= Percentage

Source: Result of survey, 2021/2022

These findings indicate severe environmental consequences of unregulated charcoal production, including deforestation, biodiversity loss and degradation of the ecosystem. This is compounded by reliance on inefficient traditional methods and lack of reforestation policies, which threaten both the environment and the sustainability of local communities. Therefore, immediate action is required to implement sustainable forest management practices, including afforestation and stricter regulations on tree harvesting, to prevent further environmental degradation and ensure long-term ecological balance.

CONCLUSION

The study assessed the effect of socio-economic activities of charcoal production in deforestation and forest degradation in Yewa division Ogun state. It can be concluded that the study area has experienced a decreased in total forest area and an increase in non-forest land area in the last 20 years. The result from the image analysis showed that forest in the past was more as at the period 2000 in the study area. The change detection result shows an increase in non-forest area from 2000 to 2020 period. This increase in non-forest can be attributed to continuous cutting down of tree with a resultant increase in deforestation activities leading to conversion of forest area to non-forest area. Deforestation in the study area had greatly reduced forest resources which result to loss of natural vegetation in the study area due to people participation in charcoal making, farming and other activities. It has further showed that traditional method of charcoal production contributes to deforestation and environmental degradation as well as hazard to human wellbeing. Environmental hazard such as biodiversity loss, air pollution, harsh weather and eye problem had been identified as effect of charcoal production activities. These contribute to human wellbeing social imbalance and increase in carbon emission in the atmosphere. Also, wind erosion resulting from deforestation. If these continue, it could worsen the environmental, social and even economic conditions of people in the study area. Effort should be made to formulate policy that will promote afforestation through community participation and charcoal producers should be trained on how to replant the logged and degraded area as part of their contribution toward afforestation programme of the deforested area. Enactment of policy such as operation cut one and plant five should be enforced. Area deforested and degraded can be replenished and enriched with fast growing tree species. Increase efforts in forest rejuvenation can bring about a healthy forest that is required. This, alongside with education and awareness on how to sustainably managed forest land would prevent further forest loss and environmental degradation. More so, heavy dependency on the indigenous tree species by the charcoal producers in charcoal making can be shifted to alternative use of residue from logged area or sawdust from sawmilling industry for briquetting, thereby reducing the pressure on forest trees. With the use of remote sensing data and questionnaire survey, important and accurate databanks and information on the existing land use/land cover of the study area can be built for subsequent monitoring and environmental protection. Charcoal business had contributed to the welfare of the people both in and out of the study area. Government intervention on enactment of policies on afforestation programme as well as enrichment planting of degraded area, these would improve and make charcoal industry sustainable as well as sustainable use of forest land.

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