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Charcoal Production: A Major Threat to Sustenance of Woody Plant Species Biodiversity of Forest Ecosystems in Adamawa State, Nigeria

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Abstract: *This paper identified the woody plant species used for charcoal production in Adamawa state. Assessed the quantity of charcoal production and compared the production across 3 zones and 9 major centers. Major drivers of charcoal production threatening the sustenance of woody plant species were identified. It assessed the level of use of woody plant species, examined the monitoring policies and bodies in existence. Assessed the socio-economic characteristics of the respondents. Structured and open-ended questionnaire was administered on 300 respondent drawn from Adamawa North, Central and South. 41 woody plant species belonging to 16 families identified. Data were analyzed using percentages, Duncan's multiple range test (DMRT), barchart, Smith Saliency value and level of use model. The top 2 most preferred wood plant species for charcoal production were Anogeissus leiocarpus (60.0%) and Vitellaria paradoxa (12.0%). The highest level of use was recorded for Anogeissus leiocarpus (58.0%). Adamawa central (295,100kg) had the highest quantity of charcoal production in 6 months. Result of comparison showed no statistical difference for the 9 major charcoal producing centers (p=0.07) at 0.05 level of significance. For Socio-economic characteristics, majority of respondents were males in Adamawa North and Central (72.0% and 79.0% respectively), while Adamawa south had female as majority (69.0%). Those with annual income range of ₦400,000.00 - ₦500,000.00 were the highest across the zones. The study suggested planting of woody plant species use for charcoal production (66.0%) and enforcement of conservation through effective monitoring and patrol (42.0%) among others as adequate strategies if properly put to use.*

Keywords: Charcoal production, stump, woody plants, species, forest Ecosystems, family use

INTRODUCTION

Nigeria is fronting several challenges of natural resources conservation, however none is more worrisome than the impending danger associated with deforestation that could result from charcoal production and the unfriendly utilization of such resource by the majority of the human population, especially the rural communities of Adamawa State, Nigeria. Charcoal is a black lightweight partially processed substance of carbon origin produced from wood heated in a low oxygen

environment by carbonization of organic materials such as wood and other biomass (Getahun *et al*., 2024; Ahmed *et al*., 2022). Charcoal therefore is of utmost importance as bio-fuel in rural households and semi-urban areas for domestic and small scale industry use.

Food and Agricultural Organization, FAO (2020) estimated global charcoal production to be 53.2 million tons in 2018 of which 34.2 million tons representing approximately 64% were produced in Africa, a report that meant doom for the continent. Voice of Nigeria, Von (2023) buttressed the above report that Adamawa state is one of the leading charcoal producers in Nigeria which led to the banning of felling of trees by the executive governor of Adamawa state in 2023 in an attempt to curtail the process of destruction of trees and shrubs that could culminate in devegetation of forest areas of the state.

According to Adedotun (2024) the people of Adamawa state had been making use of fuelwood specifically firewood as the major source of energy for domestic cooking and bakery industries in the past without impacting much on the forest ecosystems but with the turn of events of massive shift to charcoal use, the felling down of trees has become an unstoppable exploitation consuming most remaining patches of forestlands of Adamawa state.

Rotowa *et al*. (2019) made a declaration that Nigeria is among the second largest producers of charcoal and one of the largest consumers of charcoal world-wide. This means that the extent of charcoal production in Adamawa state might have contributed to positioning of Nigeria as one of the destroyers of ecosystems across the globe. The massive felling of trees and the multiple use of charcoal may be responsible for such unfriendly act on the environment as a whole (Ekpo and Mba (2020): Ahmed *et al*. (2021).

Ahmed *et al*. (2021) observed that Man's attempt to provide energy for domestic and industrial use indulges in overexploitation of forest trees and shrubs thereby exerting pressure on the environment that usually lead to destruction, degradation and destabilization of ecosystems. This act of charcoal production causes serious environmental problems such as biodiversity loss, deforestation, flooding and the disruption of food supply chain that extends to human beings thereby threatening human existence.

According to Bashir (2023) the increasing demand for charcoal had led to loss of most valuable woody plant species such as *Vitellaria paradoxa, Vitex doniana* and *Parkia biglobosa* among others in most forests and woodland areas which are important as source of food for human, herbal medicine, climate management and wildlife conservation. This uncontrollable forest and woodland exploitation hastens deforestation, causes loss of productive environment and reduction of the bio-productivity of ecosystems by disrupting the habitats of many species that ends in transformation of forests into deserts (Azare *et al*., 2020).

Charcoal production and its use as bio-fuel is becoming more popular and highly acceptable by majority of rural dwellers and semi-urban people in Adamawa State, making any step to curtail deforestation difficult, hence a serious threat. The pattern of charcoal production in Adamawa state as at now is unsustainable and the industry do not mean well for the state. The incessant and overwhelming demand for bio-energy which is done more of traditional approach is being fueled by

lack of proper enforcement of forestry law to prohibit overexploitation of natural resources. This scenario does not hold future for Adamawa state residents.

To achieve the United Nations Sustainable Development Agenda 2030 and the goal 7 for environmentally sustainable and climate resilient economies as stated in the frame work of the African Union agenda 2063, the African Union Commission, AUC (2015) and FAO (2020) emphasized on the current issues of environmental threat and the need to tackle them in order to prevent the impending doom.

In general, policy formulation for effective forest conservation and management requires vital knowledge and adequate data on the forest ecosystem and pattern of charcoal production and utilization in order to guide in decision making. The research focused on providing the reliable data on charcoal production in Adamawa state through the identification of sites of operation, types of woody plants and forest areas under threat. It assessed the quantity of charcoal production for 6 months, evaluated the effectiveness of charcoal production monitoring policies/bodies and developed sustainable strategies for environmentally friendly charcoal production.

MATERIALS AND METHODS

Study Area

Adamawa state is located in the North-eastern part of Nigeria and the administrative headquarter of the state is Yola, which is geographically located on latitude 9^{o} 14 and longitude 12^{o} 28. The state has 21 local government areas and a population of 4.9million as at 2021 and is the eighth largest state in Nigeria (Adamawa State Planning Commission, ASPC, 2022). The state has a tropical climate with two seasons: the dry season (October to April) and the rainy season (May to September). The average annual rainfall is 79mm in the northern part of the state and 179mm in the southern region (Adebayo and Tukur, 1999; Umar and Ribadu, 2020).

The weather condition comprises moderate and extremely cold weather during the harmattan usually accompanied by dusty winds from Sahara (September to February) and extremely hot weather (March to April). The average temperature range from 15.2^{o}C to 43.0^{o}C and notable vegetation zone in the state are grouped as Sub-Sudan and Northern guinea savannah zones (ASPC, 2022). Figure 1 below is the map of Adamawa state of Nigeria.

Figure 1: Map of Adamawa State of Nigeria
Source: Adebayo and Tukur (1999)

Materials and Items Used
The materials required for the investigation were; long range tape, machete, survey umbrella, West African trees and shrubs manual, research recording books, boot and field survey hand gloves among others.

Data Collection
Identification of specific areas of activity was done using reconnaissance survey design through site visitation that helped to locate the forest areas. Survey was conducted for four (4) months and semi-structured questionnaire was administered on 300 hundred respondents. Physical assessment employing Participant Observation Technique (POT) was equally utilized. The pre-research test of the questionnaire and interview schedule for assessing the relevance and acceptability was also carried out in line with Tamene *et al*. (2023).

The investigation strictly adhered to purposive and quota sampling in getting respondents/informants who were actively involved and believe to be knowledgeable on charcoal production and business as adopted by Garedew and Simon (2018). The purposeful sampling method helped in the selection of respondents that were good representatives of the human population in the study area while quota sampling was done to get proportion of respondents in relation to the total charcoal producers in each Zone.

The quota sampling was done in each zone using modified Cochran (1977) Proportional Allocation Technique (PAT). The quota sampling was used because the population of charcoal producers in each zone were far more than the sample size required per zone. In the modification, **nh** was replaced by **M** and then **Nh** replaced by **h**. The modified formula is stated as:

$$M = \frac{h \times n}{N}$$

Where M = number of questionnaire administered in each zone.
n = Total number of questionnaire administered.
h = Estimated population of charcoal producers in each zone.
N = Total number of Charcoal producers in all the 3 zones.

Sample Size

For collection of data on socio-economic characteristics, semi-structured and open-ended questionnaire was administered on 300 charcoal producers/respondents sampled across the 3 zones (Adamawa North, Central and South) of the state to address some of the objectives. In line, field observation and assessment were also put to use by crisscrossing the study locations for interaction with the charcoal producers at production sites. The interaction helped in the validation of their activities and the process of production based on the spot assessment.

Respondents provided the checklist of woody plant species (trees and shrubs) used for charcoal production, their availability across the zones and the species richness determined. In line, the estimated quantity of charcoal production in 6 months was recorded across all the charcoal production centers to ascertain the level of woody plant utilization in each production center. Similarly, the process of charcoal production employed by individuals were captured using photographs and recording books.

Data Analysis

Woody Plant Species

The woody plant species identified and the species richness were presented using tables.

Comparison of Charcoal Production

Charcoal production across the study area for 6 months was compared using Duncan's Multiple Range Test (DMRT) and graphically presented using bar chart.

Level of Use of each Woody Plant Species

Assessment was carried out on the level of use of each woody plant species using the formula;

$$N_u = \frac{N_1}{N_{t1}} \times 100$$

Where N_u = level of use of woody plant species
N_1 = Number of people interviewed in favour of the use of the species
N_{t1} = total number of informants in each charcoal production area
(Kouami *et al*. 2009)

Using the above formula, the level of use of each species within the charcoal production area was assessed to help make better decisions in planning conservation strategies for sustainability.

Assessment of Major Drivers of Charcoal Production

The major drivers of charcoal production threatening the sustenance of woody plant species of forest ecosystems in Adamawa State were identified and assessed using percentage and Smith Saliency model.

The model was used to calculate the importance of items in a list based on how participants organize them. In this context, the value of the model is calculated by dividing the frequency of respondents in agreement with a factor by all the respondents sampled. Mathematically given as:

$$S = \frac{IR}{TR}$$

Where S = Saliency value
IR = Inverted rank (frequency of respondents in agreement with a factor)
TR = Total rank (total frequency of respondents sampled)

Socio-Economic Characteristics of Respondents

Socio-economic characteristics of respondents were assessed and presented using tables and percentage. The frequency of respondents in each socio-economic factor was effectively put to use.

Assessment of charcoal production monitoring policies and bodies

Assessment of the effectiveness of charcoal production monitoring policies and bodies were carried out using percentage and Smith Saliency model. In line, suggested strategies for sustainable charcoal production using woody plant species also identified and assessed using percentage and Smith Saliency model.

RESULTS AND DISCUSSION

Woody Plant Species used for Charcoal Production

The checklist of woody plant species utilizable for charcoal production in the 3 senatorial zones of Adamawa State, Nigeria is presented in Table 1 below. The result showed that 41 woody plant species belonging to 16 families were inventoried in the study area. The numbers of species in each family are as follows: *Combretaceae* (3), Sapotaceae (1), Malvaceae (6), *Meliaceae* (3), *Burseraceae* (2), lamiaceae (1), Myrtaceae (2), Zygophyllaceae (1), Fabaceae (12), Ebenaceae (1), Anacardiaceae (3) Bignoniaceae (1), Mimosoide (1), Papilionoideae (1), Moraceae (2) and Arecaceae (1).

Similarly, the distribution of woody plant species used for charcoal production across the study areas based on species richness indicated that Adamawa North top the list with 28 species, followed by Adamawa Central (21) and the least was Adamawa south (18). Respondents' report (Table 1) indicated that the most widely used woody plant species for charcoal production included; *Terminalia laxiflora*, *Managifera indica*, *Anogeissus leiocarpus*, *Khaya senegalensis*, *Vitellaria paradoxa*, *Balanites aegyptiaca*, *Azadirachta indica*, *Eucalyptus gunni* and *Parkia biglobosa*. The

present investigation observed that some of the species enumerated in Table 1 above agrees with that of Kouami *et al*. (2009) who conducted a study on the impact of charcoal production on woody plants.

The investigation further revealed that though charcoal producers used several trees and shrubs but some were used at a higher scale compared to others as presented in Table 2. The most preferred woody plant species for charcoal production arranged in order of importance were *Anogeissus leiocarpus* with 60.0%, *Vitellaria paradoxa* (12.0%), *Khaya senegalensis* (9.0%) and *Terminalia laxiflora* (5.0%) among others. The investigation also found that the preference of these species were solely due to high quality charcoal obtained from them, an observation earlier made by Adeniji *et al.* (2022). Majority of the respondents reported that most of their charcoal were produced using free forest and with a little from woodland.

Table 1: **Checklist of Woody Plant Species used for Charcoal Production across the Study Areas**

Family name	Scientific name	Local name	Adamawa North	Adamawa Central	Adamawa South
Combretaceae	*Anogeissus leiocarpus*	Marke	+	+	+
	Terminalia laxiflora	Baushe	+	+	+
	Guiera senegalensis	Sabara	+	+	-
Sapotaceae	*Vitellaria paradoxa*	Kadanya	+	+	+
Malvaceae	*Grewia bicolor*	Markin dutse	+	-	-
	Grewia tenax	Shiboli	+	-	-
	Grewia venusta	Dargaza	-	+	-
	Grewia mollis	Dargaza'a	+	-	-
	Sterculia setigera	Kare gatare			
	Azanza garckenea	Goron biri	-	+	+
Maliaceae	*Khaya senegalensis*	Madachi	+	+	+
	Khaya grandifoliola	Mala	-	-	+
	Azadirachta indica	Dogon yaro	+	+	+
Burseraceae	*Commiphora Africana*	Dashi	+	-	-
	Commiphora myriha	Mur	+	-	-
Lamiaceae	*Vitex doniana*	Dinya	+	+	+
Myrtaceae	*Eucalyptus Gunni*	Zaiti	+	+	+
	Psidium guajava	Goba	-	-	+
Zygophyllaceae	*Balanites aegyptiaca*	Aduwa	+	+	+
Fabaceae	*Isoberlinia angolensis*	Sanga-sanga	+	-	-
	Poliostigma reticulatum	Kalgo	-	+	-
	Tamarindus indica	Tsamiya	+	+	-
	Acacia sieberiana	Farar kaya	+	-	-
	Acacia seyal	Kerafi	+	-	-
	Faidherbia albida	Gawo	+	-	-
	Acacia kirkii	Bagaruwa	+	-	-
	Acacia hockii	Booni	+	-	-
	Acacia nilotica	Marje	+	-	-
	Parkia biglobosa	Daurawa	+	+	+
	Parkia filicoidea	Daurawa biri	-	-	+
	Detarium microcarpum	Taura		-	+
Ebenaceae	*Diospyros mespiliformis*	Kanya	+	-	-
Anacardiaceae	*Mangifera indica*	Mangwaro	+	+	+
	Anacardium occidentale	Cashew	+	-	+
	Haematostaphis barteri	Jini kafri	+	+	-
Bignoniaceae	*Stereospermum Kunthianum*	Sansami	+	-	-
Mimosoideae	*Prosopis Africana*	Kirya	-	+	+

Papilionoideae	*Pterocarpus erinaceus*	Madobiya	-	+	+
Moraceae	*Ficus platyphylla*	makarho	-	+	-
	Ficus thonningi	Farin ganye	-	+	-
Arecaceae	*Borassus aethiopium*	Gingiya	-	+	-
Species Richness			**28**	**21**	**18**

Source: Field Survey (2025) Legend: + = Used - = Not used

Table 2: Woody Plant Species Preferred for Charcoal Production (% of Respondents

Scientific name	Local name	Frequency of Respondents	Percentage (%)
Anogeissus leiocarpus	Marke	180	60.0
Vitellaria paradoxa	Kadanya	36	12.0
Khaya senegalensis	Madachi	27	9.0
Terminalia laxiflora	Baushe	15	5.0
Azadirachta indica	Dogon yaro	12	4.0
Managifera indica	Mangwaro	12	4.0
Eucalyptus gunni	Zaiti	9	3.0
Balanites aegyptiaca	Aduwa	6	2.0
Parkia biglobosa	Daurawa	3	1.0
Total		**300**	**100**

Source: Analyzed field data (2025)

Forests and woodlands of Adamawa State

The study documented the forests and woodlands of Adamawa state where there's activity of charcoal production (Table 3. The details showed 20 utilizable forest in Adamawa North, 15 in Adamawa Central and 9 in Adamawa South. Similarly, the record of threatened forests were 9, 5 and 3 for Adamawa North, Central and South respectively. Respondents observed that if the current level of exploitation is maintained then the threatened forest will disappear because most of the key trees and shrubs used for charcoal production is fast depleting.

The fear of the respondents have confirmed the report of threat of charcoal production to Nigerian forests by Rotowa (2019). According to Kiruki *et al*. (2017) the disappearance of forest areas have become inevitable because charcoal production impedes regeneration and most a times changes the species composition in a given forest. The difficulty in restoration is attributed to the commercial felling of trees and shrubs which usually culminates in deforestation (Eniola, 2021). In Adamawa state, one area that has experience dramatic transformation is the forests because most of the forests have moved from their natural state to transitional zones that could lead to total transformation if not curtail.

Table 3: Utilizable Forest Ecosystems and those under Threat due to Charcoal Production

Zone	Utilizable Forests and Woodland for charcoal production	Total	Forests ecosystems under threat	Total
Adamawa North	Mbahuli, Kwaja, Duda, Gaja Modova, Pallam, Wanu hills, Hildi, Muchalla, Wudili Gella-Kwaja hills, Vimtim Hills, Mayo-bani, Kwarantsa, Mujilu, Dirbishi hills, Bitiku, Wuro Larde and Bakin Dutse	20	Mbagira, Mujilo, Gaja Mbahuli, Pallam hills Vimtim hills, Modova , Kwarantsa and Pallam hills	9
Adamawa Central	Furfore, Dassim, Tashan turmi Zumo, Dzangula, Golantabal, Hussama, Bangshika, Aljanso, Wuro-doli, Hawa, Gabon, Lugga and Bagale	15	Zumo, Bagale, Dzangula, Hawa and Mayo-yini	5
Adamawa South	Mayo-yini, Balle, Mayo-belwa Mapeo, Toungo, Koma, Maliki, Ngurore and Bille,	9	Mayo-belwa, Bille and Ngurore	3

Source: Analyzed field data (2025)

Comparison of Charcoal Production across Major Centers

Comparison of charcoal production across 9 major production centers namely; Kwarantsa, Vimtim hills, Gaja, Bagale, Hawa, Mayo-yini, Maliki, Balle and Mayo-belwa using data of 6 months (June – November, 2025) was carried out using Duncan's Multiple Range Test (DMRT). The result indicated that though charcoal production was highest in Hawa but was not statistically significant from others ($p=0.07$) at 0.05 level of significance. Similarly, comparison was made based on months and the result showed that the production was highest in October but was not significantly different from the other months where $p=0.129$ at 0.05 level of significance.

Figure 2 below is the graphical representation of the charcoal productivity of the 3 zones (Adamawa North, Central and South) for 6 months using a Bar chart. The visual explanation of the graph showed that Adamawa central (295,100kg) was highest, followed by Adamawa North with 268,006kg while the least was Adamawa south with 215,716kg. This result indicates a twist in charcoal production because despite that Adamawa North had more forest and woodlands (20) but had lower charcoal production compared to Adamawa central with only 15. This result buttress the earlier findings of Nyarko *et al*. (2021) that charcoal production is a function of density of trees and shrubs and similarly need and does not necessarily reflect the number of forest used or harvested. The high productivity recorded in Adamawa Central might be linked to the above factors outlined above.

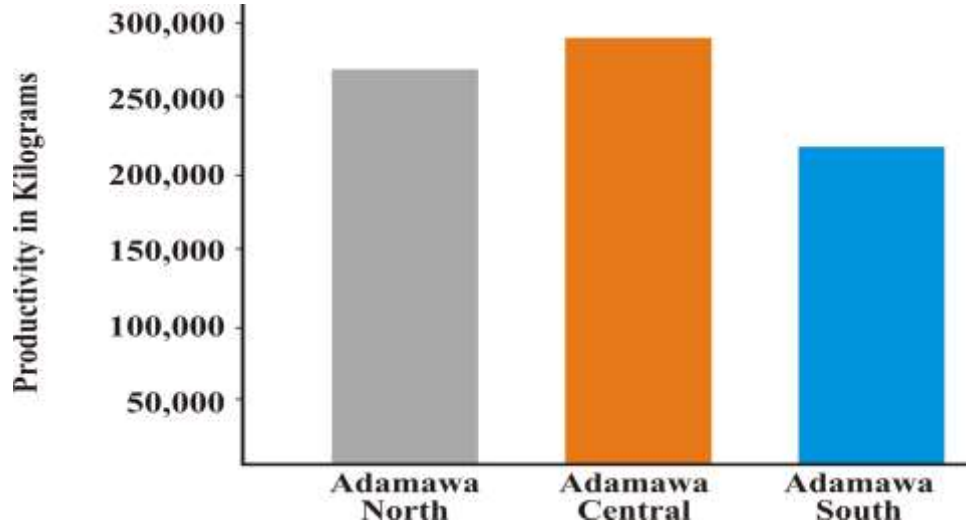

Figure 2: Bar chart showing 6 months estimated charcoal production in kilograms per zone

Assessment of Level of Use of Woody Plant Species

The level of use for 41 woody plant species identified were evaluated and the result presented below (Table 4). The cross-section of the utilization of various species in Adamawa North showed that *Anogeissus leiocarpus* with 58.0%, followed by *Parkia biglobosa* (52.0%), *Azadirachta indica* (44.0%) and *Mangifera indica* (42.0%) top the list. In Adamawa Central *Anogeissus leiocarpus* with 34.0% was the highest, followed by *Prosopis africana* (32.0%) and all others ranged from 2.0% to 12.0%. The result of Adamawa South did not show much difference as *Anogeissus leiocarpus* (26.0%) and *Prosopis africana* (20.0%) made the top list while others had their use values that ranged from 2.0% to 16.0% respectively.

The level of use of woody plant species is fundamental for biodiversity conservation, improvement of forest ecosystem in times of productivity, stability and sustenance of species richness, as well as its overall health. It provides vital information on the level of exploitation of every species based on preference (Hamidou et al., 2015). According to Shumi *et al*. (2019) the knowledge of level of use of woody plant species helps in developing management strategies that could guarantee the thriving of species, sustainability and maintenance of biodiversity.

Table 4: Level of use of Woody plant species in each Zone (% of Respondents)

Woody Plant Species Scientific name	Local name	Adamawa North (%)	Adamawa Central (%)	Adamawa South (%)
Anogeissus leiocarpus	Marke	58.0	34.0	26.0
Terminalia laxiflora	Baushe	12.0	8.0	6.0
Guiera senegalensis	Sabara	14.0	2.0	-
Vitellaria paradoxa	Kadanya	34.0	12.0	8.0
Grewia bicolor	Markin dutse	26.0	-	-
Grewia tenax	Shiboli	12.0	-	-
Grewia venusta	Dargaza	-	-	10.0
Grewia mollis	Dargaza'a	14.0	2.0	-
Sterculia setigera	Kare gatare	-	2	
Azanza garckanea	Goron biri	-	4.0	4.0
Khaya senegalensis	Madachi	36.0	4.0	-
Khaya grandifoliola	Mala	-	-	6.0
Azadirachta indica	Dogon yaro	44.0	2.0	16.0
Commiphora africana	Dashi	14.0	-	-
Commiphora myriha	Mur	8.0	-	-
Vitex doniana	Dinya	36.0	3.0	6.0
Eucalyptus Gunni	Zaiti	10.0	2.0	2.0
Psidium guajava	Goba	-	-	2.0
Balanites aegyptiaca	Aduwa	18.0	6,0	2.0
Isoberlinia angolensis	Sanga-sanga	10.0	-	-
Poliostigma reticulatum	Kalgo	-	6.0	-
Tamarindus indica	Tsamiya	28.0	5.0	-
Acacia sieberiana	Farar kaya	8.0	-	-
Acacia seyal	Kerafi	12.0	-	-
Faidherbia albida	Gawo	10.0	-	-
Acacia kirkii	Bagaruwa	12.0	-	6.0
Acacia hockii	Booni	10.0	-	-
Acacia nilotica	Marje	12.0	-	8.0
Parkia biglobosa	Daurawa	52.0	4.0	10.0
Parkia filicoidea	Daurawa biri	-	-	8.0
Detarium microcarpum	Taura	-	-	4.0
Diospyros mespiliformis	Kanya	10.0	-	-
Mangifera indica	Mangwaro	42.0	2.0	6.0
Anacardium occidentale	Cashew	22.0	-	8.0
Haematostaphis barteri	Jini kafri	14.0	2.0	-
Stereospermum Kunthianum	Sansami	14.0	-	-
Prosopis africana	Kirya	-	32.0	20.0
Pterocarpus erinaceus	Madobiya	-	2	6.0
Ficus platyohylla	Makarho	-	8.0	-
Ficus thonningi	Farin ganye	-	2.0	-
Borassus aethiopium	Gingiya	-	4.0	-

Source: Analyzed field data (2025)

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Man as Enemy of the Environmental Resources

Historically, the unfriendly behavior to nature exhibited by man had position him as the enemy of the environmental resources. Generally, habitat destruction, degradation, fragmentation and deforestation are caused due to overexploitation through unsustainable charcoal production, firewood collection and logging among others in our forest areas. This unsustainable consumption of forest ecosystem resources mainly woody plant species by man cause loss of wildlife species which contribute immensely to the health of forest ecosystems. The increased charcoal production reduces forest performance and sustainability of trees and shrubs (woody plants) that mainly form the canopy and vegetation composition of forest ecosystems. Charcoal being a promoter of deforestation should be considered a major threat to sustenance of forests ecosystems (Isese, 2019).

Over the years, logging for charcoal production or timber had been a strategic human-driven factor for the reduction of forest cover in Africa leading to loss of biodiversity (plants and wildlife species) especially the woody plant species that ends in deforestation (Isese, 2019). Below (**Plate 1**) is the process involved in charcoal production in rural areas of Adamawa state, Nigeria, where the cut tamarin tree cannot regenerate. The use of hand-handled machine to cut the major part of the trunk has left only the degenerated stump that cannot regenerate.

Plate 1: **Process of charcoal production in rural areas of Nigeria, West Africa**
Source: Field Survey (2025

Drivers of Charcoal Production Threatening the Sustenance of Woody Plant species Biodiversity of Forest Ecosystem

In most rural communities and semi-urban centers of Adamawa state and Nigeria as a whole, charcoal is considered as primary source of energy for domestic and small scale business use. This wood product is central in economic growth and a driving force in the economies of the major segment of the society who are the low income earners. According to Ansah (2022) charcoal production in Africa is on the rise contributing significantly to forest degradation. Arnold *et al*. (2006) earlier reported that with the rapid growth in human population, expansion and the incessant increase in cost of alternative fuel, charcoal production in Africa is projected to increase by twofold in 2030.

The current study identified and assessed 8 drivers of charcoal production as threat confronting the sustenance of woody plant species biodiversity of forest ecosystems in Adamawa state. Nigeria as presented below in Table 5. The leading drivers arranged in order of perceived importance based on responses were; lack of employment making charcoal production and business as the available alternative (91.0%), followed by weak monitoring bodies characterized by corruption thereby encouraging charcoal production (82.67%), excessive cutting of trees for charcoal production (75.0%) and charcoal being more economical for use and profitable (72.0%). Some of these drivers are among those mentioned by Arko *et al*. (2024) and Zera (2019).The respondents considered these drivers of charcoal production (Table 5) as serious threat and highly detrimental to the sustenance of the woody plant species biodiversity of forest ecosystems. The threat drivers identified during the course of this investigation perhaps add to those identified earlier by Bunde (2018) and Ansah (2022). The high Smith Saliency values recorded for the top 4 threat drivers above is an indication that the woody plant species biodiversity of forest ecosystems in Adamawa state is facing a serious challenge of sustainability.

Table 5: Drivers of Charcoal Production Threatening the Sustenance of Woody Plant Species Biodiversity of Forest Ecosystems in Adamawa State

Components of charcoal production threat	No. of Respondents	Percentage (%)	Smith Saliency Value (SSV)
Excessive cutting of trees for charcoal production	225	75.0	0.7500
Weak monitoring bodies characterized by corruption thereby encouraging charcoal production	248	82.67	0.6867
Claim of ownership of forest areas by support zone community permitting overproduction of charcoal	134	44.67	0.4467
High desire for charcoal as excellent biofuel because of high energy and its relative cheapness	187	62.33	0.6233
Easy preservation and utilization of charcoal	206	68.67	0.8267
Economic benefits	177	59.0	0.5900
Lack of employment making charcoal production and business as the available alternative	273	91.0	0.9100
Charcoal being more economical for use and profitable	219	72.0	0.7200

Source: Analyzed field data (2025)

Socio-Economic Characteristics of the Respondents

The socio-economic characteristics of 300 respondents engaged in charcoal production and business is presented below in Table 6. The details of the result for gender indicated that the majority of the sampled population for Adamawa North and Central were males with 72.0% and 79.0% respectively, while Adamawa south had female (69.0%) as majority. The result on gender suggest that males and females are active members of charcoal production and business depending on location and exposure of individuals. The result of Adamawa South differs from the findings of Adeniji *et al*. (2022) who reported low value for female participation in charcoal production. The high participation recorded by female in Adamawa south could be linked to the rising needs of families which men could not meet

For age range, the majority of respondents in Adamawa north were within the age range of 20 - 50 years, Adamawa central 20 - 40 years and Adamawa south 20 - 50 years. This result suggest that people within the active age participated more in charcoal production and business probably because of the tediousness of the job that scares older people. The high participation of strong segment of the society as revealed by this investigation depicts the findings of Eniola and Odebode (2018) who reported that individuals within youthful age are machineries used for exploitation of natural resources.

The result of occupation of respondents indicated that trade was the main occupation represented by 42.0%, 62.0% and 61.0% of the sampled population for Adamawa North, Central and South respectively. This was followed by farming indicating Adamawa North (34.0%) as highest, followed closely by Adamawa Central (31.0%) while Adamawa south trails with 25.0%. No respondent was recorded for fishing occupation in Adamawa Central. This results advocate that people of different occupation tend to participate in charcoal production and business for economic benefits although the level of participation differ across the occupations.

Analysis of data based on educational qualification of the respondents indicated that those with secondary school qualification were dominant across all the zones shown by Adamawa North (50.0%), Adamawa Central (46.0%) and Adamawa South (40.0%) as presented below in Table 8. The result also revealed that those with no formal education trails with 18.0% for Adamawa North and 32.0% each for Adamawa Central and South respectively.

The interpretation of this result could be that those with no formal education and secondary school qualification having relatively low level of qualification could be unemployed or underemployed, hence they resolved to undertake charcoal production as an alternative option to augment their income for sustainability of life making them threat to woody plant species biodiversity in forest ecosystems. The interpretation of this finding is in line with Sampson *et al*. (2019) who observed earlier that the unemployed or underemployed members of the society are capable of using any means of sustaining life and this could include destruction of forest ecosystems

The respondents' annual income was investigated and the results showed that those within the range of ₦400,000.00 - ₦500,000.00 were highest across all the zones (16.0%, 44.0% and 37.0% for Adamawa North, Central and South respectively) as presented in Table 6. The polled result for the 3 zones showed that 56.0% of the total respondents had their annual income ranging from

₦400,000.00 - ₦800,000.00. The details indicated that all the annual income percentages ranged from 2.0% to 44.0% for the zones.

No respondent was recorded in annual income range of ₦1,601,000.00 - ₦1,700,000.00 and ₦1,901,000.00 - ₦2,000,000.00 for Adamawa North. Similarly, no respondent was recorded in ₦1,301,000.00 - ₦1,400,000.00, ₦1,701,000.00 - ₦1,900,000.00 for Adamawa Central. The result also indicated that no respondent was recorded in annual income range of ₦1,401,000.00 - ₦1,900,000.00 for Adamawa South.

The relatively low annual income earning of the respondents is clear indication that they need to explore more avenue for better opportunity in order to meet their needs. This could probably be the reason why they engage themselves in charcoal production and business thereby posing threat to sustenance of the woody plant species biodiversity of the forest ecosystems. This assertion agrees with Asian Development Bank, ADB (2020) report that the relatively poor and low income earners of the society are mostly involved in exploitation of natural resources disregarding the consequences because of the desire to survive.

Table 6: Socio- Economic Characteristics (% of Respondents)

Socio-economic Characteristics	Percentage of Respondents (%)			Total
	Adamawa North	Adamawa Central	Adamawa South	
Gender				
Male	72.0	79	31.0	60.67
Female	28.0	21	69.0	39.33
Total	**100**	**100**	**100**	**100**
Age range (years)				
20 – 25	12.0	24.0	13.0	16.33
26 – 30	10.0	22.0	9.0	13.67
31 – 35	10.0	8.0	12.0	10.0
36 – 40	20.0	20.0	14.0	18.0
41 – 45	16.0	8.0	16.0	13.33
46 – 50	14.0	8.0	14.0	12.0
51 – 55	8.0	2.0	3.0	4.33
56 – 60	4.0	2.0	11	5.67
61 – 65	6.0	6.0	8	6.67
Total	**100**	**100**	**100**	**100**
Occupation				
Farming	34.0	31.0	25.0	30.0
Civil servant	10.0	4.0	3.0	5.67
Fishing	6.0	-	7.0	6.50
Artisan	8.0	3.0	4.0	5.00
Trade	42.0	62.0	61.0	55.0
Total	**100**	**100**	**100**	**100**
Educational qualification				
No formal education	18	32	32	27.33
Primary school	12	8	8	9.33
Secondary school	50	46	40	45.33
Tertiary	20	14	20	18.0
Total	**100**	**100**	**100**	**100**
Annual income				
₦400,000.00 – ₦500,000.00	16.0	44.0	37	32.33
₦501,000.00 – ₦600,000.00	10.0	7.0	9.0	8.67

₦601,000.00 – ₦700,000.00	4.0	6.0	10.0	6.67
₦701,000.00 – ₦800,000.00	10.0	8.0	7.0	8.33
₦801,000.00 – ₦900,000.00	4.0	2.0	8.0	4.67
₦901,000.00 – ₦1,000,000.00	14.0	8.0	2.0	8.0
₦1,001,000.00 – ₦1,100,000.00	2.0	2.0	5.0	3.0
₦1,101,000.00 – ₦1,200,000.00	6.0	4.0	3.0	4.33
₦1,201,000.00 – ₦1,300,000.00	8.0	2.0	6.0	5.3
₦1,301,000.00 – ₦1,400,000.00	4.0	-	4.0	2.67
₦1,401,000.00 – ₦1,500,000.00	4.0	2.0	-	2.0
₦1,501,000.00 – ₦1,600,000.00	6.0	2.0	-	2.67
₦1,601,000.00 – ₦1,700,000.00	-	3.0	-	1.0
₦1,701,000.00 – ₦1,800,000.00	2.0	-	-	0.67
₦1,801,000.00 – ₦1,900,000.00	2.0	-	-	0.67
₦1,901,000.00 – ₦2,000,000.00	-	2.0	5.0	2.33
₦2,001,000.00 – above	8.0	8.0	4.0	6.67
Total	**100**	**100**	**100**	**100**

Source: Analyzed field data (2025)

Assessment of Charcoal Monitoring Policies and Bodies in Existence

Respondents reported 2 monitoring policies and 4 bodies vested with responsibility of managing and checking the activity of charcoal production and business in the state with the view to curtail excesses (Table 7). The policies and bodies saddled with the task for sustenance of woody plant species biodiversity of forest ecosystems was assessed using Likert scale of 4-point effectiveness following the order of Kagerbauer and Magdolen (2024).

The details of result showed that all the monitoring bodies and policies were underscored by the respondents where; very and highly effective rating had 0.67% to 6.0% for all the monitoring bodies and policies. The low percentage rating indicates their weaknesses in monitoring charcoal production in Adamawa state. The failure of the monitoring bodies and policies might be attributed to lack of proper enforcement that could scare the operators. The weakness in enforcement believed to be the situation in this study is similar to Ansah (2022) who reported that policies to effectively govern charcoal production in many countries of Africa are either weak or lacking.

This study observes that patrol by local government forestry officials, payment of fine to local government authority by defaulters and patrol by civil defense, police and military could have been adequate strategies for such assignment but the enforcement according to respondents were poor done due to corruption.

Table 7: Charcoal Production Monitoring Policies and Bodies in Existence (% of Respondents)

Monitoring body	Percentage of Respondents (%)			
	Not effective	Fairly effective	Very effective	Highly effective
Patrol by local government forestry officials	14 (4.67)	36 (12.0)	11 (3.67)	16 (5.33)
Fire service patrol	-	6 (1.0)	-	-
Payment of fine to local government authority by defaulters	4 (1.33)	14 (4.67)	12 (4.0)	2 (0.67)
Banning of charcoal production by State government in 2023	4 (1.33)	2 (0.67)	-	-
Patrol by civil defense, police and military	18 (6.0)	20 (6.67)	18 (6.0)	10 (3.33)
Patrol by hunters and vigilante	-	-	12 (4.0)	2 (0.67)
Environmental monitoring agency	5 (1.67)	-	10 (3.33)	17 (5.67)

Source: Analyzed field data (2025)
***** Figures in parenthesis are in percentage (%)

Suggested Strategies for Sustainable Charcoal Production using Woody Plant Species

Below (Table 8) is the result of respondents' multiple responses across the zones for sustenance of woody plant species that could guarantee the sustainability of charcoal production in Adamawa State. Respondents indicated that: planting of woody plant species use for charcoal production (66.0%), followed by enforcement of conservation through effective monitoring and patrol (42.0%) and establishment of more forest areas by the state government (40.0%) among others could be adequate if properly adopted.

The high Smith saliency value (0.6600) recorded for planting of woody plant species use for charcoal production is an indication that the strategy could help lessen the threat confronting the sustenance of woody plant species biodiversity of forest ecosystem if effectively put to use. According to Olushola and Adekunle (2020) government is central in developing policies for conservation at local and global scale, hence the need for stakeholders to embrace this approach.

Table 8: Suggested Strategies for Sustainable Charcoal Production

Strategies	No. of Respondents	Percentage (%)	Smith Saliency Value (SSV)
Planting of woody plant species use for charcoal production	198	66.0	0.6600
Enforcement of conservation through effective monitoring and patrol	126	42.0	0.4200
Establishment of more forest areas by the state government	120	40.0	0.4000
Creation of awareness on the need to harvest matured trees by forestry officials	116	38.67	0.3867
Establishment of individual woodland/orchards	112	37.33	0.3733
Issuance of tariff to monitor charcoal production	84	28.0	0.2800
Payment of specified amount by defaulters	33	11.0	.0.110
Involvement of traditional council in forest management	18	6.0	0.6000
Prohibition of charcoal production	5	1.67	0.1667

Source: Analyzed field data (2025)

CONCLUSION

This study has identified 41 woody plant species used for charcoal production in Adamawa State, Nigeria. Of these species 8 of them (*Anogeissus leiocarpus, Vitellaria paradoxa, Khaya senegalensis, Terminalia laxiflora, Azadirachta indica, Managifera indica, Eucalyptus gunni, Balanites aegyptiaca and Parkia biglobosa*) are the most preferred and exploited more across the 3 zones for charcoal production.

On a general scale, the high desire for biofuel by the state inhabitants and the relatively poor economic state of majority of the respondents that are considered as the cross-section of the society is a serious threat to woody plant species biodiversity of forest ecosystems in Adamawa state. The continuous charcoal production without replacement could put some of the vulnerable woody plant species and wildlife to extinction.

The present pattern of charcoal production and the in-efficient monitoring policies and bodies currently in place could put even human existence to jeopardy, hence the need to adopt the suggested strategies above for sustainable charcoal production while ensuring the continuous availability of woody plant species.

Recommendations

Based on the findings of this study, it recommends the following:

(i) There is need to develop a compendium of woody plant species that matures within short

time for establishment of individual forest/orchards for sustainable charcoal production

(ii) Government should establish more forest areas to accommodate the human growing Population

(iii) Provision of alternative fuel through the use of other plant biomass is advocated

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