

## Research Article

## Charcoal demand in Bosso Local Government, Niger State, Nigeria: Implication for Environmental Degradation

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**Abstract:** Charcoal is an important source of energy and income for thousands of people in Nigeria. Its production often drives environmental degradation and deforestation which have impacts on the environment that remain poorly understood. Findings from this study indicate that a large portion of the human population in Bosso LGA depend on charcoal for cooking, suggestive of high charcoal demand and the resultant consequences on continuous deforestation. Also, the majority of people in Bosso preferred using charcoal because it remained the cheapest source of domestic energy. But the quantity at which people are buying varies with individuals, suggestive of variability in their purchasing power. There is a high level of ignorance about the environmental effects of charcoal production by the people in the study area, posing a serious obstacle to environmental conservation. Although during the charcoal making, the carbon in charcoal combines with oxygen and forms carbon dioxide, carbon monoxide and other gases that deplete the ozone layer, these remained unknown by most peoples in the study area. The rate of deforestation is at its alarming rates, with many dense vegetation areas been completely cut down. While the economic benefits of charcoal production and marketing in Bosso has helped a lot of households out of poverty or unemployment, the rate of charcoal demand is unsustainable. Therefore, alternative sources of energy such as gas, kerosene and perhaps electricity are required to safeguard our forest resources.

**Keywords:** Charcoal production; Charcoal marketing; Deforestation; Environmental awareness.

### INTRODUCTION

The potential climax of most of the land areas of the globe that today support high human population is some type of forest areas, or at least an area in which tree cover form a significant component. Production and marketing of charcoal provide work for millions of people in Sub-Saharan Africa (IEA, 2014; Openshaw, 2010; Ryan *et al.*, 2016; Zorrilla-Miras *et al.*, 2018). Charcoal is the major cooking fuel in many urban centers in Sub-Saharan Africa (IEA, 2014; Zorrilla-Miras *et al.*, 2018) and its demand is increasing driven by demographic trend and continuous influx of people from rural to urban areas (IEA, 2014, Peter and Sander, 2009, Openshaw, 2010, Tomaselli, 2007; Zorrilla-Miras *et al.*, 2018). In Sub-Saharan African countries, particularly in rural areas (where 80% of residential energy demand is for cooking) more than 90% of the population use firewood for cooking and less than 5% use charcoal; in urban areas the figures change to 25%

relying on firewood and nearly 50% on charcoal (IEA, 2014; Zorrilla-Miras *et al.*, 2018).

Charcoal is a provisioning ecosystem service, and growing evidence suggests ecosystem services (ES), i.e. the benefits people get from ecosystems, contribute to the well-being of the rural population in Africa, e.g. provisioning services (firewood, charcoal, grass, fruits, water), regulating services (erosion control, water purification) and cultural services (sacred places, recreation) (Cavendish, 2000; Fisher, 2004; Kamanga *et al.*, 2009; Shackleton *et al.*, 2007; Zorrilla-Miras *et al.*, 2018). As such, charcoal can be an imperative woodland-based provisioning ES for African rural populations, but at the same time can be a driver of deforestation and Land degradation through intensive and selective wood extraction (Chidumayo and Gumbo, 2013; Luoga *et al.*, 2002; Ryan *et al.*, 2014; Zorrilla-Miras *et al.*, 2018). So, the land use and land cover change produced by charcoal production is a major

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driver affecting future provisioning of ES and subsequently can have a significant cost for human well-being. Irrespective of growing socioecological systems understanding, the consequential complications of charcoal production and marketing for sustainable land management and local livelihoods remain poorly understood (Zorrilla-Miras *et al.*, 2018).

The economic status of the charcoal sector in most countries in SSA (especially in Nigeria), fast-tracked investigation efforts to analyze the role which locally produced charcoal has on rural poverty alleviation. Most people engaged in the charcoal market are rurally based (Openshaw, 2010; Vollmer *et al.*, 2017), in the role of small-scale “casual” producers or transporters (Zulu and Richardson, 2013; Baumert *et al.*, 2016; Vollmer *et al.*, 2017), where producers have a workable opportunity to increase income from other livelihood activities (Jones *et al.*, 2016; Levy and Kaufman, 2014; Vollmer *et al.*, 2017).

But studies differ in their evaluation of the role of charcoal in poverty mitigation. Some studies (Ainembabazi *et al.*, 2014; Schure, *et al.*, 2014; Vollmer *et al.*, 2017), found charcoal fabricators to be economically better off, with good benefits from charcoal making that contributes to poverty lessening (Fisher, 2004; Schure *et al.*, 2014; Yemiru, *et al.*, 2014; Vollmer *et al.*, 2017). The welfare benefits were found in some cases to be sufficient to lift certain groups of fabricators above the poverty line (Ainembabazi *et al.*, 2014; Shackleton *et al.*, 2007; Vollmer *et al.*, 2017), which meant charcoal can be identified as a potential pathway or route out of poverty (Vollmer *et al.*, 2017). This has intensified calls for enhanced solemnizations of the charcoal industry (Jones *et al.*, 2016; Schure *et al.*, 2013; Schure *et al.*, 2014; Smith *et al.*, 2015; Vollmer *et al.*, 2017).

In SSA and particularly in Nigeria, charcoal has the potential to provide accessible, affordable and reliable energy to millions of households, in addition to supporting millions of rural and urban livelihoods through income generation, providing urban-rural financial flows and contributing to the national economy (Smith *et al.*, 2017). If managed effectively, charcoal is a sustainable energy source and can contribute substantially to reducing carbon emissions and greenhouse gases (Iiyama *et al.*, 2014; Smith *et al.*, 2017). Yet, the charcoal markets of smaller cities are severely under-researched and there is no evidence to suggest that their value chains, participants or governance structures are comparable to larger cities (Smith *et al.*, 2015; Smith *et al.*, 2017).

The growing demands for charcoal in Nigeria have riches a critical state, consequent to demographic trend. While it is seen as a cheap source of energy, the resultant consequences of deforestation and environmental degradation have not been well studied. Like most rural areas in Nigeria, communities such as

Bosso use their surrounding forests for various purposes including firewood, hunting for game and gathering of medicinal herbs and chewing sticks apart from logging (Madaki and Sayok, 2019). In view of these, a study on the charcoal demand and its implication on environmental degradation is necessary for better environmental management.

## 2.0 The study area

### 2.1. Location and climate

The study area is located between Longitude 9° 38'0 North and Latitude 6° 25'0 East (Figure 1). It covers a total area of about 297.5 km<sup>2</sup> and has a population of about 147,359 as at 2006 census. The study area has two distinct seasons the dry and wet season. Precipitation per year varies between 1000-1400 mm on the average. The duration of rainy season ranges from 150 to 210 days or more from the north to the south. Mean maximum temperature remains high throughout the year, hovering about 37 °C and 20 °C respectively (Adeoye *et al.*, 2018). However, the lowest minimum temperature occurs usually between December and January when most parts of the state come under the influence of the tropical continental air mass which blows from the north.

### 2.2. Soil and Vegetation

Geological mapping shows the study area is underlain by granite and schist with granite occupying a greater portion of the area. Specifically, three major soils types can be found in Bosso LGA. These include the Ferruginous tropical soils, hydromorphic soils, and ferrosols. Hydromorphic or waterlogged soils are largely found in the extensive flood plain of the Bida basin. These soils are poorly drained and are liable to heavy flooding. Ferrosols which developed on sandstone formations are commonly found within the Bida basin. Their characteristic red color enriched with a clay subsoil is noticeable in the landscape. Termite hills dot the landscape, particularly between Mokwa, Bida and Kontagora axis. The vegetation is mainly guinea savanna which is characterized by grasses shrubs and trees. The study area lies within the middle belt of Nigeria which is a transitional zone between the rainforest of southern Nigeria and the guinea savanna of northern Nigeria. This is characterized by tall grasses with light forest, evenly distributed trees along the major river channel. Almost all the Bosso LGA is occupied by a moist, so-called Guinean high-grass savanna. The plots of these savannas alternate with the park savannas and border the banks of the rivers with gallery forests. The so-called elephant grass predominates. Groups of trees rise above the grassy sea: drought-resistant *kaya*, *isoberlinia*, *mitragina*. Some of them have trunks twisted from annual fires. In the first half of the dry season, the savanna looks lifeless; the trees stand bare. In the middle of this season, a smoke screen rises over the savanna: the dry grass burns, which is burnt from year to year with the purpose of preparing the land for crops.

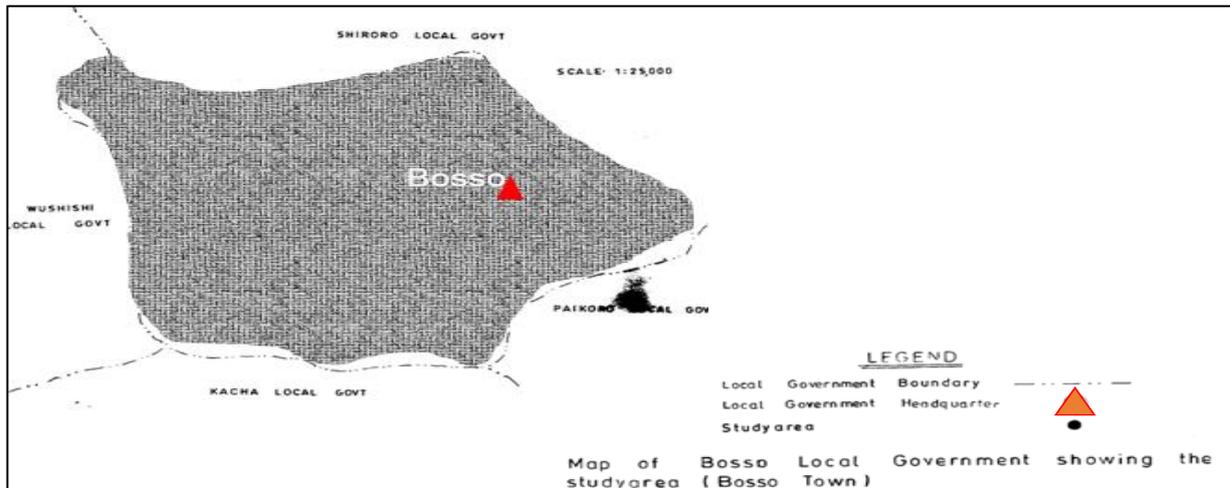


Figure 1. The study area. Source: Minna Survey Division

**2.3. Economic Activities**

Agricultural activities form the mainstay of the economy of the people. Majority of the people in Bosso LGA are farmers, while the remaining smaller portion is engaged in other locations such as white-collar job, manufacturing, business production of craft and art. The main crops grown are grain and tuber which include guinea corn, groundnut, cassava, and yam, etc. This is normally grown during the raining season. Minor occupation during the raining season includes blacksmithing and sell of labor to rich farmers. In the dry season immediately after the harvest, hunting, fuelwood exploitation, pottery making, etc. become the main economic activities

**3.0 MATERIALS AND METHODS**

This study employed both direct field observation and questionnaire administration. During

field observation, pictures were taken during the process of charcoal making. Likewise, charcoal demand was assessed by administering a questionnaire to selected respondents in the study area. A questionnaire comprising eight (9) questions was designed in order to evaluate the rate of charcoal demand in the study area.

The data gathered from their responses was organized and standardized using basic descriptive statistics (frequency, percentage). Further, the several samples test ANOVA (Kruskal-Wallis), was used to measure the variability of the respondent’s views about the questions asked. This method allows for comparing several independent random samples and can be used as a non-parametric substitute to the one way ANOVA (Critchlow and Fligner, 1991; Conover, 1999; Hollander and Wolfe, 1999). The Kruskal-Wallis test statistic for *k* samples, each of size *n<sub>i</sub>* is defined viz:

$$T = \frac{1}{s^2} \left[ \sum_{i=1}^k \frac{R_i}{n_i} - N \frac{(N+1)^2}{4} \right] \quad \text{Eq. 1.}$$

where N is the total number (all *in*) and *R<sub>i</sub>* is the sum of the ranks (from all samples drawn) for the *i*th sample and:

$$S^2 \frac{1}{N-1} = \left[ \sum_{all} R_{ij}^2 - N \frac{(N+1)^2}{4} \right] \quad \text{Eq. 2.}$$

The null hypothesis of the test is that all *k* distribution functions are equal. The alternative hypothesis is that at least one of the populations tends to yield larger values than at least one of the other populations (Critchlow and Fligner, 1991; Conover, 1999; Hollander and Wolfe, 1999). All the statistical analysis was conducted using the PAST @ <0.001 significant level.

**4.0 RESULTS AND DISCUSSIONS**

Figure 2 presents the general information of the respondents in the study area. A total of 58 respondents were interviewed. Based on the age composition (Fig. 3a), 5% of the respondents are below 18 years, 23% are between 19 and 24 years, 43% are between 25 and 34 years and 29% are above 35 years. Male constitutes 53% percent of the respondents, whereas, 47% are female (Fig. 2b). Based on occupation, 14% of the respondents are farmers, 52% are traders, 34% are civil servants (Fig.2c). This implies that charcoal in the study area is mostly used by traders

and civil servants. The farmers who are mostly engaged in their farms may have other sources of domestic energy, perhaps, firewood brought from farms and therefore spend less on charcoal. Despite women are

primarily known for domestic work, including cooking, there are more males buying charcoal in the study area. Possible reasons perhaps, include religious and cultural factors.

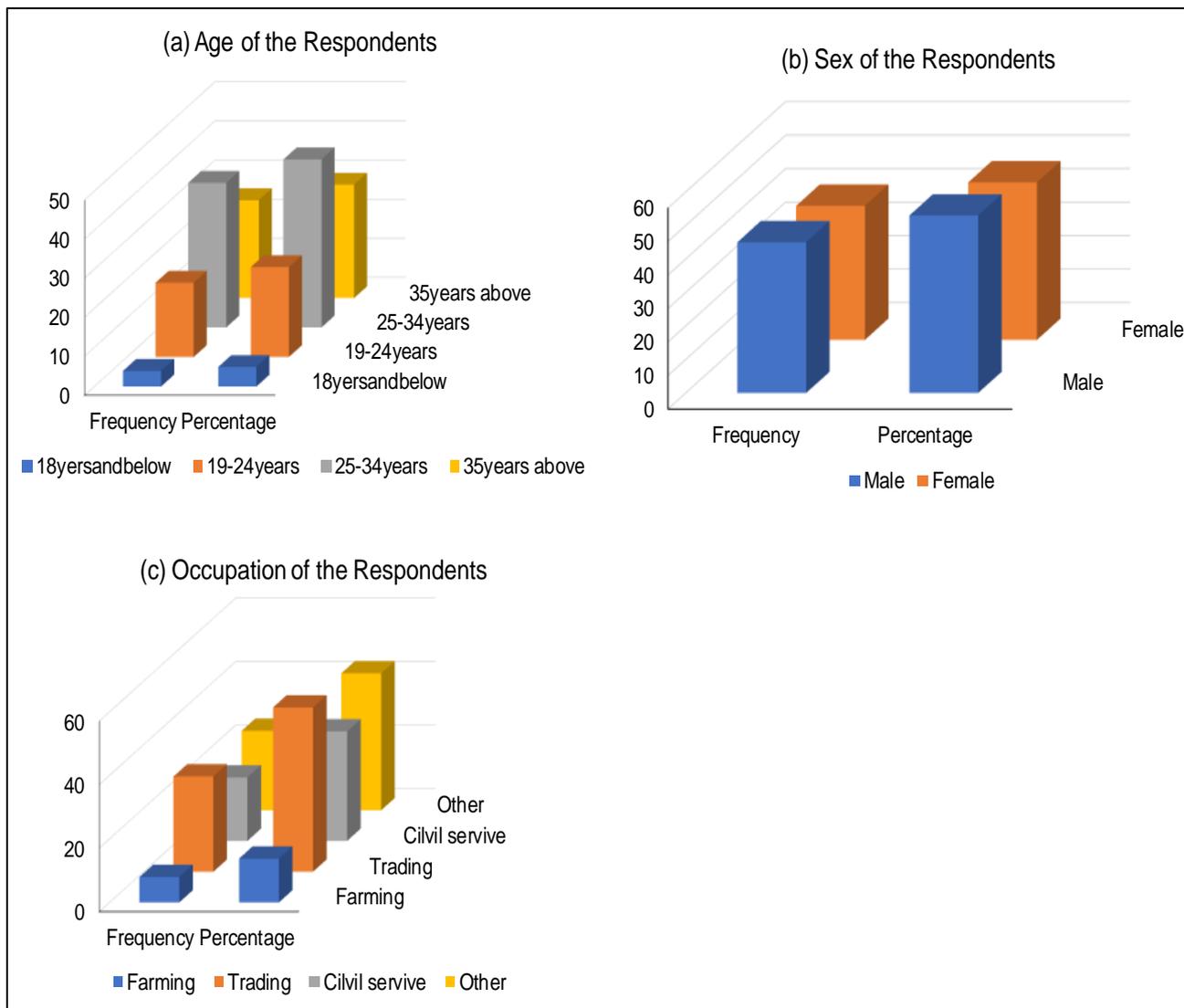
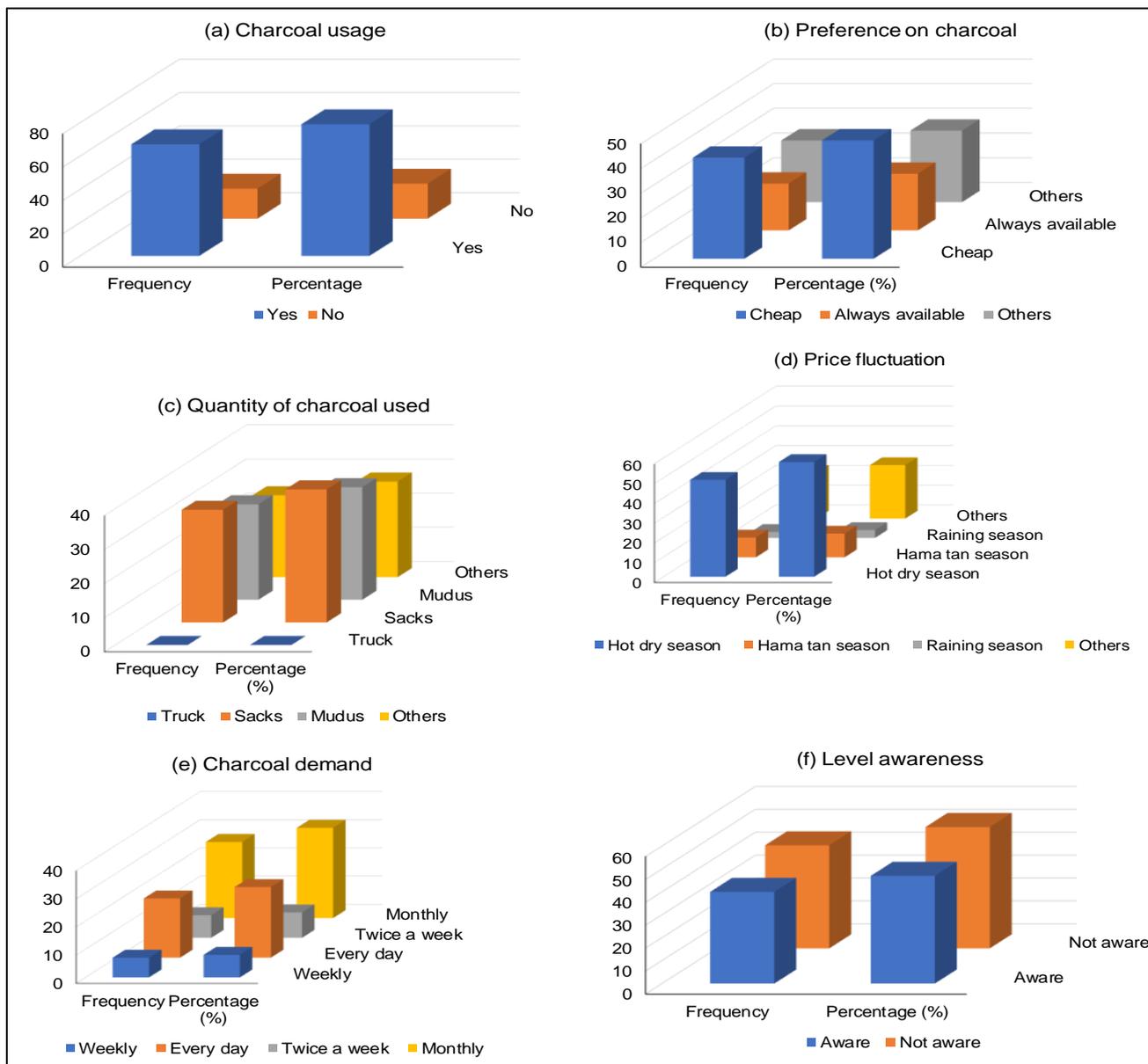


Figure 2. General information of respondents in the study area

Figure 3 summarized views of respondents regarding questions raised. Figure 3a shows the proportion of respondents using charcoal in the study area. Most of the respondents (79%) in the study area depend on charcoal for cooking, whereas, 21% are using other sources of energy. The implication is that there is a high demand for charcoal in the study area which can further accelerate the rate of deforestation for charcoal extraction or production. Also, 48% of the people in Bosso preferred using charcoal, because it is the cheapest source of domestic fuel in the area (Fig. 3b), whereas, 23% of the respondents preferred

charcoal because it's always available compared to other sources of cooking fuel whereas, 29% of the respondents in the study area depend on other sources of cooking fuel, perhaps, kerosene, gas or firewood. This has produced a bad signal to forest conservation since charcoal is on high demand owing to its preference by people over other sources of domestic energy. The rate of charcoal demand as illustrated in Figure 3c shows 39% of the respondents are buying charcoal in sacks, 33% buy charcoal in other smaller measures e.g. Mudu (local unit of measurement).



**Figure 3. Views of people on charcoal demand and usage**

The remaining 20% of the respondents do not purchase charcoal at all. Figure 3d shows that 57% of the respondents, buy charcoal in the dry season because it is relatively cheaper compared to the rainy season. Charcoal demand is at its lowest price during the dry season, because the weather condition allows for easy use of fire for charcoal production. The possible effects of charcoal production during the dry season may include the occurrence of bush fire or unnecessary burning of marginal lands.

Figure 3e shows how often people buy charcoal. Very few people, 8% buy charcoal on a weekly basis, 25% buy charcoal on daily basis, 9% buy charcoal at least twice a week, whereas, 32% of the inhabitant buy charcoal on monthly basis and the raining 26% do not have idea about the subject been studied, plus those who do not use charcoal. This

further, indicates high charcoal demand in the study area at all the time, indicative of continuous forest degradation. Figure 3e shows that the awareness of people about the environmental effects of charcoal production is very low compared to the ratio of people who are completely unaware of the possible consequences of deforestation and bush burning. The poor awareness revealed by this study, suggest the need for enlightenment about problems that may be associated with charcoal production in the study area, since forests provide a range of products and services, directly contributing to the livelihoods of an estimated 800 million people globally, living in or near tropical forests and savannahs (Chomitz *et al.*, 2007; Smith *et al.*, 2017).

#### 4.1 The process of charcoal making

Good charcoal is mostly pure carbon, called char, made by cooking wood in a low oxygen environment, a process that can take days and burns off volatile compounds such as water, methane, hydrogen, and tar. In commercial processing, the burning takes place in large concrete or steel silos with very little oxygen and stops before it all turns to ash. The process leaves black lumps and powder, about 25% of the original weight (Fig.3). When ignited, the carbon in charcoal combines with oxygen and forms carbon dioxide, carbon monoxide, water, other gases, and significant quantities of energy. It packs more potential energy per ounce than raw wood. Char burns steady,

hot, and produces less smoke and fewer dangerous vapors.

The process of making charcoal is ancient, with archaeological evidence of charcoal production going back about 30,000 years BP. Because charcoal burns hotter, cleaner, and more evenly than wood, it was used by smelters for melting iron ore in blast furnaces, and blacksmiths who formed and shaped steel. Commercial production was first done in pits covered with dirt by specially trained craftsmen called colliers. Figure 3 illustrates the steps involved in the charcoal making process.



Figure 3. Charcoal making and marketing process

The entire process starts with selective tree burning (Fig 2d). Sometimes trees are fell and put together before the burning process starts (Fig 2a). The burning process is simultaneously carried out with charcoal extraction (Fig. 2e). After cooling, the charcoal is bagged in sacks (Fig.2c), and ready for transportation to markets places.

#### 4.2 Impact of charcoal production on the environment

Charcoal is one of the most important sources of energy in many African countries; about 90% of urban households in some SSA countries (e.g. Tanzania) depend on charcoal for cooking and heating (Schure *et al.*, 2013; Zulu and Richardson, 2013; World Bank, 2011; Baumert *et al.*, 2016). Growing demand for charcoal, due to population growth and urbanization in developing countries like Nigeria, has led to increased wood extraction rates, mainly around urban centers (Baumert *et al.*, 2016) and contributes to expanding wood extraction in the woodland areas inhabited by

rural populations. Where this exceeds regrowth rates, forest or woodland degradation occurs (Cuvilas *et al.*, 2010; Baumert *et al.*, 2016).

Presently, thousands of rural and urban people in Nigeria derive part of their livelihood from the charcoal value chain (Zulu and Richardson, 2013; World Bank, 2011; Baumert *et al.*, 2016). This is done without considering the environmental consequences of deforestation in most parts of the country. Although the laws and institutions which regulates forest resources are in existence, the level of commitment required by both the institutions and individuals themselves is lacking. The rate of deforestation is at its alarming rates, with many dense vegetation areas in the country been completely wiped out (Fig. 3).

The economic importance of the charcoal sector in developing countries, e.g. Nigeria accelerated research efforts to evaluate the role locally produced charcoal has on rural poverty. Most people engaged in the wood fuel market are rurally based (Openshaw, 2010; Vollmer *et al.*, 2017) in the role of small-scale “casual” producers or transporters (Zulu and Richardson, 2013; Baumert *et al.*, 2016; Vollmer *et al.*, 2017), where producers have a viable opportunity to supplement income from other livelihood activities (Jones *et al.*, 2016; Levy and Kaufman, 2014; Vollmer *et al.*, 2017).

Studies, however, differ in their assessment of the role of charcoal in poverty alleviation. Some investigations found charcoal producers to be economically better off (Ainembabazi *et al.*, 2014;

Schure *et al.*, 2014; Vollmer *et al.*, 2017), with welfare benefits from charcoal making that contribution to poverty reduction (Fisher, 2004; Schure *et al.*, 2014; Yemiru *et al.*, 2010; Vollmer *et al.*, 2017). The welfare benefits were found in some cases to be enough to lift certain groups of producers above the poverty line (Ainembabazi *et al.*, 2014; Shackleton *et al.*, 2007; Vollmer *et al.*, 2017) which meant charcoal can be identified as a potential pathway or route out of poverty. This has intensified calls for improved formalizations of the charcoal industry (Jones *et al.*, 2016; Schure *et al.*, 2013; Schure *et al.*, 2014; Smith *et al.*, 2015; Vollmer *et al.*, 2017). While the economic benefits of charcoal production and marketing are well emphasized (Fig. 4f), the resultant consequences on the environment are eminent (Fig. 4c,d,e).



Figure 4. Example of environmental degradation resulting from charcoal production

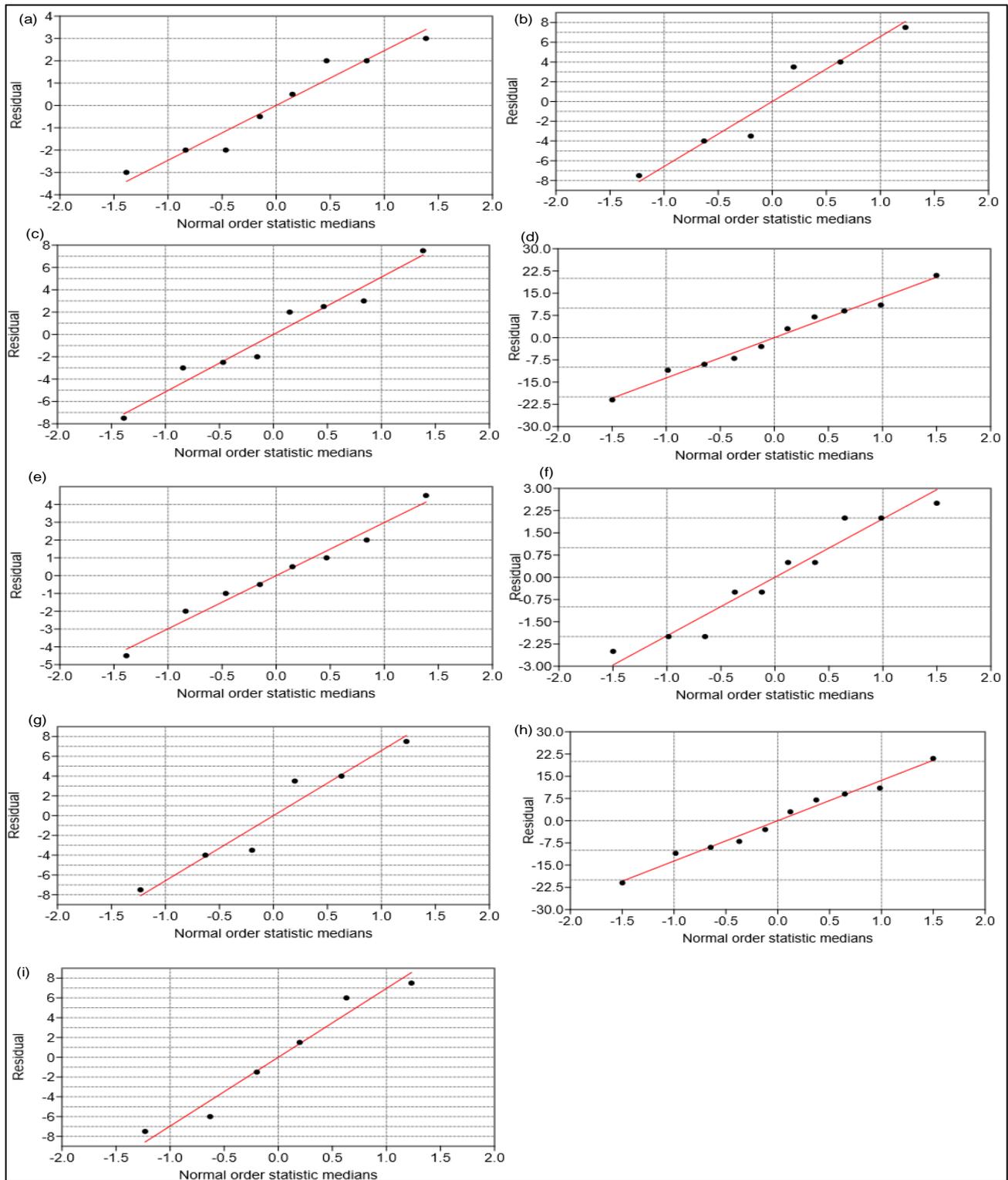
**Statistical application**

Table 1 presents the results of statistical analysis of responses of people regarding charcoal usage and its effects on the environment. The results

obtained from ANOVA (Kruskal-Wallis test), for equal medians, shows there is no significant difference between sample medians in people’s views about questions raised.

Table 1. Several samples test ANOVA (Kruskal-Wallis test; Post-hoc Mann-Whitney pairwise test)

S/no	Variables	Kruskal-Wallis		Post-hoc Mann-Whitney pairwise
		H(chi <sup>2</sup> )	P(same)	
1	Age of the respondents	6.667	0.8332	>0.001
2	Sex of the respondents	3.714	0.1561	>0.001
3	Occupation of the respondents	7.518	0.1154	>0.001
4	Charcoal usage	4.571	0.1017	>0.001
5	Charcoal preference	6.667	0.8332	>0.001
6	Quantity purchased	6.042	0.10028	>0.001
7	Price fluctuation	6.667	0.08332	>0.001
8	Rate of purchase	8.209	0.08253	>0.001
9	Awareness	3.714	0.1561	>0.001



**Figure 5. Residuals plot for homogeneity of people's views on charcoal usage and its effects on the environment**

Similarly, the Mann-Whitney pairwise test further confirms the homogeneity of people's responses in the study area. This is further illustrated using normal probability plot (Fig.5a-g). Normal probability plot of residuals is used to verify the assumption that residuals are normally distributed. The normal probability plot of the residuals should more or less follow a straight line, as shown in Figure 5. When the plot shows a non-

normal pattern, other residual plots can be used to check for other issues with the model, such as missing terms or a time order effect. Prediction intervals can be inaccurate if the residuals do not follow a normal distribution, owing to the smaller number of samples or variables ( $n < 15$ ), then confidence intervals for predictions, confidence intervals for coefficients, and p-values for coefficients can be inaccurate.

## CONCLUSION

There is a unanimous consensus on the importance of charcoal to the economy of rural and urban societies in the literature, yet the consequences of deforestation caused by increasing demand for charcoal is still debated since local charcoal production has helped in reducing rural poverty. Findings from this study indicate:

- Majority of the people in Bosso LGA depend on charcoal for cooking, indicative of high charcoal demand which can further accelerate continuous deforestation;
- Also, a large proportion of people in Bosso preferred using charcoal because it remained the cheapest source of domestic energy;
- People are buying charcoal both on daily, weekly and monthly basis indicative of variability in their purchasing power.
- The awareness of people about the environmental effects of charcoal production is very low, posing a great obstacle to environmental conservation policies.
- During charcoal making, the carbon in charcoal combines with oxygen and forms carbon dioxide, carbon monoxide and other gases that deplete the ozone layer; and
- The rate of deforestation is at its alarming rates, with many dense vegetation areas in Bosso being completely cut down.

Although the economic benefits of charcoal production and marketing in Bosso has helped a lot of households out of poverty or unemployment, the rate of charcoal demand is unsustainable. Therefore, alternative sources of energy such as gas, kerosene and perhaps electricity are required to safeguard our forest resources.

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