IMPACT OF CHARCOAL PRODUCTION ON FOREST DEGRADATION IN MOKWA LOCAL GOVERNMENT AREA, NIGER STATE, NIGERIA

BY

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A THESIS SUBMITTED TO THE POSTGRADUATE SCHOOL, FEDERAL UNIVERSITY OF TECHNOLOGY, MINNA, NIGER STATE, NIGERIA IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE AWARD OF MASTER OF TECHNOLOGY (MTech) DEGREE IN GEOGRAPHY (ENVIRONMENTAL MANAGEMENT)

JUNE, 2023

DECLARATION

I hereby declare that this thesis titled **"Impact of Charcoal Production on Forest Degradation in Mokwa Local Government Area, Niger State, Nigeria"** is a collection of my original research work and it has not been presented for any other qualification anywhere. Information from any other sources (published or unpublished) have been duly acknowledged.

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Signature & Date

CERTIFICATION

This thesis titled **"Impact of Charcoal Production on Forest Degradation in Mokwa Local Government Area, Niger State, Nigeria"** by MOHAMMED, Shiru Kpakiko (MTech/SPS/2019/10416) meets the regulations governing the award of the degree of Master of Technology of the Federal University of Technology, Minna, and it is approved for its contribution to scientific knowledge and literary presentation.

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DEDICATION

This research thesis is dedicated to the Grace and Bounty of the Almighty Allah. He gave me life, wisdom and blessing to finish this thesis. I will forever remain glorious to Him.

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ABSTRACT

The study assessed the impact of charcoal production on forest degradation in Mokwa Local Government Area, Niger State, Nigeria. Four objectives were raised and formulated to guide the study. The primary sources of data used in this study include questionnaire administration, oral interview and reconnaissance survey. The population of the study respondents were 399 and simple random sampling was used to distribute the questionnaires among the respondents. The instrument administered was analysed using 3 point likert rating scale, mean, percentage and frequency was used to analysed the data. The findings of the study revealed that 48.2 % is high prices of alternate energy sources for cooking as the causes of charcoal production. It was further revealed that trees commonly used for production are from inherited farms and most of the trees used are *Butyrosopermum paradoxium, Dialium guineense, Terminalia glaucencens, Acacia* species and *Khaya ivorensis.* It was revealed that the woodland often selected for charcoal production in the study area are private or family owned and communal lands, 48.2 % of charcoal producer had a strong feeling that establishment of specific tree species plantations in the study area would improve and make the charcoal industry sustainable. The study also revealed that the socioeconomic benefits are used in acquiring assets such as bicycles, motor bikes, and roofing materials with charcoal money. It was also revealed that charcoal production (24 %) is second to land clearance (66 percent) in its negative contribution to forest degradation in the study area. The study recommends that charcoal policy innovations should address the negative images and controversial image of charcoal through concerted and targeted evidence-based advocacy, highlighting the wood-fuel sector's benefit as an important productive economic sector, deserving higher prominence in key economic development proposals. It was also recommended that from the short-term perspective, it is possible by offering the local market charcoal produced from faster growing tree species, e.g., Eucalyptus. This can be attained through awareness and improvement of the efficiency of cooking stoves to minimize energy losses

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CHAPTER ONE

1.0 INTRODUCTION

1.1 Background to the Study

Deforestation and forest degradation are the principal causes of forest cover change and account for a large proportion of global carbon emissions (Achard *et al.,* 2017; Van der Werf *et al.,* 2019). Deforestation, defined as the long-term or permanent conversion of land from forest use to other non-forest uses (Global Observation of Forest Cover and Land-use Dynamics, GOFC-GOLD, 2016), represents an abrupt and rapid change in land cover.

Charcoal made from wood has been in use as energy source since ancient times and is still widely used nowadays in many countries. As a locally available and relatively

clean fuel compared to burning wood or agricultural residues, charcoal provides basic energy services for cooking and heating to millions of people with limited options of alternatives, particularly those who live in the urban and peri-urban areas in sub-Saharan Africa (FAO, 2014).

Globally, more than 2.4 billion people rely on the use of woodfuel, including charcoal, for cooking, and small enterprises use fuelwood and charcoal as important energy providers (FAO, 2014). FAO estimates that the global production of wood charcoal was about 53.2 million tons in 2018, of which 34.2 million tons (or around 64 percent) were produced in Africa. Data from FAOSTAT indicate that around 90 percent of the wood removed from the forests and woodlands in Africa are used as fuels, of which about 29 percent are converted into charcoal. Due to steady increase in market demand, the production of wood charcoal in Africa has almost doubled in 20 years from 1998 to 2018 and accounted for roughly two-thirds of the global production.

Charcoal production and consumption have multiple social, economic, and environmental impacts that are closely linked to at least eight sustainable development goals, including poverty reduction, food security and nutrition, health, gender equity, clean water, sustainable energy and including elements such as sustainable management of forests, reducing forest and land degradation and deforestation, land degradation neutrality, biodiversity conservation (GOFC-GOLD, 2016). The sector also has linkages to climate change, through its impacts on forest degradation or deforestation, or due to emissions of greenhouse gases during charcoal production. The production and use of fuelwood and charcoal contributes between two and seven per cent to the global emission of greenhouse gases, with SSA accounting for one-third of these emissions, mainly due to unsustainable forest management, insufficient charcoal manufacture and woodfuel combustion (FAO, 2017).

Charcoal production is very prominent in Benue, Kogi and Niger States of Nigeria where there are guinea belts that support its production. Forests are decimated; economic trees meant for fruit production are felled for charcoal production and farm lands have been used excessively without considering its future implications on the environment. Charcoal business as well as other ventures relating to renewable energy sources is an important part of rural economy, basically because domestic energy consumption is a very important aspect of the economies of most developing Africa nations including Nigeria. However, there is a limit to the usage of other forms of renewable energy sources as a result of inadequate technological development (Kalu, 2017). In an attempt to earn more living among rural poor, charcoal production has been considered a good business for income generation, prompted by free access to forest resources, until such forest area is being depleted.

Charcoal and Fuel wood are the most widely used energy sources in Nigeria, they are mostly used for household cooking. In terms of production, Nigeria ranks the highest in Africa, and second in the world. There is a steady increase in annual production of charcoal in Nigeria and yet Nigeria is not among the world's leading nations in the exporting of charcoal meaning that the nation consumes almost all that it produces. Indonesia, China and Poland led in exportation with 21.8%, 10.6% and 8.8% respectively; Nigeria is the 25th exporting nation with only 0.9% (FAO, 2014). In Nigeria, there is no controlled supply of charcoal in urban areas, and this has contributed to deforestation in rural areas. Increase in population these urban areas also resulted to an increase in demand for charcoal from rural areas. Also due to the cost of transporting charcoal from the rural areas where it is produced to the urban areas where it is widely consumed, there has been a steady increase in its price and this have

inhibited the growth of small-scale traders who use wood, such as fish sellers, and has also affected household budgets. Furthermore, the use of wood presently surpasses the regrowth of forests and reforestation efforts globally (FAO, 2014). As reported, charcoal consumption is higher among individual and families that has low income with charcoal and fuel wood accounting for three-quarters of their total household energy expenditure (Kambewa *et al.,* 2017). In weight, charcoal might be heavy or quite light depending on the weight of the dry wood of the various species used in its production. One of the reasons why several households prefer charcoal to firewood is the fact that transporting charcoal over a long distance is less expensive when compared to firewood and also when compared to firewood it doesn't require much storage space and it can't be easily deteriorated by insects or fungal attack (Adegoke and Ogunsanwo, 2011), it is also known to burn hotter and to contain twice the energy of an ordinary firewood which makes it cook faster than most other fuels such as kerosene.

1.2 Statement of the Research Problem

Charcoal production in the study area results in different forms of impacts some of which are environmental pollution arising from smoke, deforestation as a result of tree harvest and erosion which exposes the soil to direct sunshine, it also leads to reduction in the soil fertility and health problems to people around the production site. Due to the steady increase in the demand for charcoal as a result of different industrial revolutions and urbanisation, production of charcoal has been largely carried out with an unsustainable approach across the study area.

Charcoal production for rural and urban energy consumption is a main driver of forest degradation in the study area and Nigeria at large. Urban growth projections for Niger State suggest that the relevance of this process will increase in the coming decades.

Forest degradation associated to charcoal production is difficult to monitor due multiple players involved and commonly overlooked and underrepresented in forest cover change and carbon emission estimates. As urban population projections for Africa indicate unprecedented growth in the coming 40 years (Kalu, 2017), the magnitude and relevance of this forest degradation process is likely to increase unless important shifts are made in energy consumption patterns. These highlights the relevance of studying charcoal production as a separate process, therefore this study will assess the impact of charcoal production on forest degradation in Mokwa Local Government Area, Niger State, Nigeria.

Several researches have been conducted on the impact of charcoal production on forest degradation both nationally and internationally and they include Sedano *et al.* (2016); Zulu (2015); Kalu (2017); Odunayo *et al.*, (2019); Tunde *et al.,* (2013) and Adegoke and Ogunsanwo (2011). Based on published theses and journals, no study has examine the impact of charcoal production on forest degradation in Mokwa Local Government Area, Niger State, Nigeria which has created a paucity of knowledge about the study area. This study intend to fill this gap created.

1.3 Research Questions

The research questions for this study will include

i. What are the causes of charcoal production in the study area?
ii. What are the tree species used for charcoal production in the study area?
iii. What are the impact of charcoal production on forest degradation in the study area?
iv. What are the afforestation practices in the study area?

1.4 Aim and Objectives of the Study

The aim of this study is to assess the impact of charcoal production on forest degradation in Mokwa Local Government Area, Niger State, Nigeria. The objectives are to:

i. Examine the causes of charcoal production in the study area;
ii. Investigate tree species used for charcoal production in the study area;
iii. Assess the impact of charcoal production on forest degradation in the study area; and
iv. Analyse the afforestation practices in the study area.

1.5 Justification for the Study

There is currently insufficient capacity within the utilities and other stakeholders, including the domestic private sector, to properly tackle the issue of challenges of forest conservation in the study area and other parts of Niger State. Forest conservation is integral to urban improvement and environmental health, yet there is disconnect between forest resource management and the housing and urban development sector in the study area. Rapid population growth pose major challenges in forest resources conservation in Mokwa Local Government Area. It is therefore timely to undertake detailed studies and make concerted efforts toward the improvement and co-ordination in the challenges of forest conservation and other parts of forest resource management into development planning of the study area. There will be a review of existing literature, reports and publications and research on forest resource management issues.

A study of this kind is therefore necessary to fill the gap existing between charcoal production and forest degradation in Mokwa Local Government Area of Niger State.

1.6 Scope and Limitation of the Study

The scope of this study is to evaluate the impact of charcoal production on forest degradation in Mokwa Local Government Area, Niger State, Nigeria. It cover the causes of charcoal production in the study area; tree species used for charcoal production in the study area; the impact of charcoal production on forest degradation in the study area; and the afforestation practices in the study area. The temporal scope of this study is from 2010 to 2020 and spatial scope cover the entire Mokwa Local Government Area where forest resources are undergoing destruction. Getting information from some of the respondents was difficult. Nevertheless, information generated through this study were considered sufficient, important and worthy for this study.

1.7 The Study Area

1.7.1 Location

The study area is located in Mokwa Local Government Area and lie between longitude 5^{o} 20’27”E - longitude 6^{o} 15’55”E and latitude 9^{o} 12’45”N - latitude 9^{o} 50’29”N, on a geological base of undifferentiated complex of mainly gneiss and magnetite situated at the base of prominent gorges in an undulating plan. It has an area of 4,338 km² and a projected population of 416,600 in 2022.

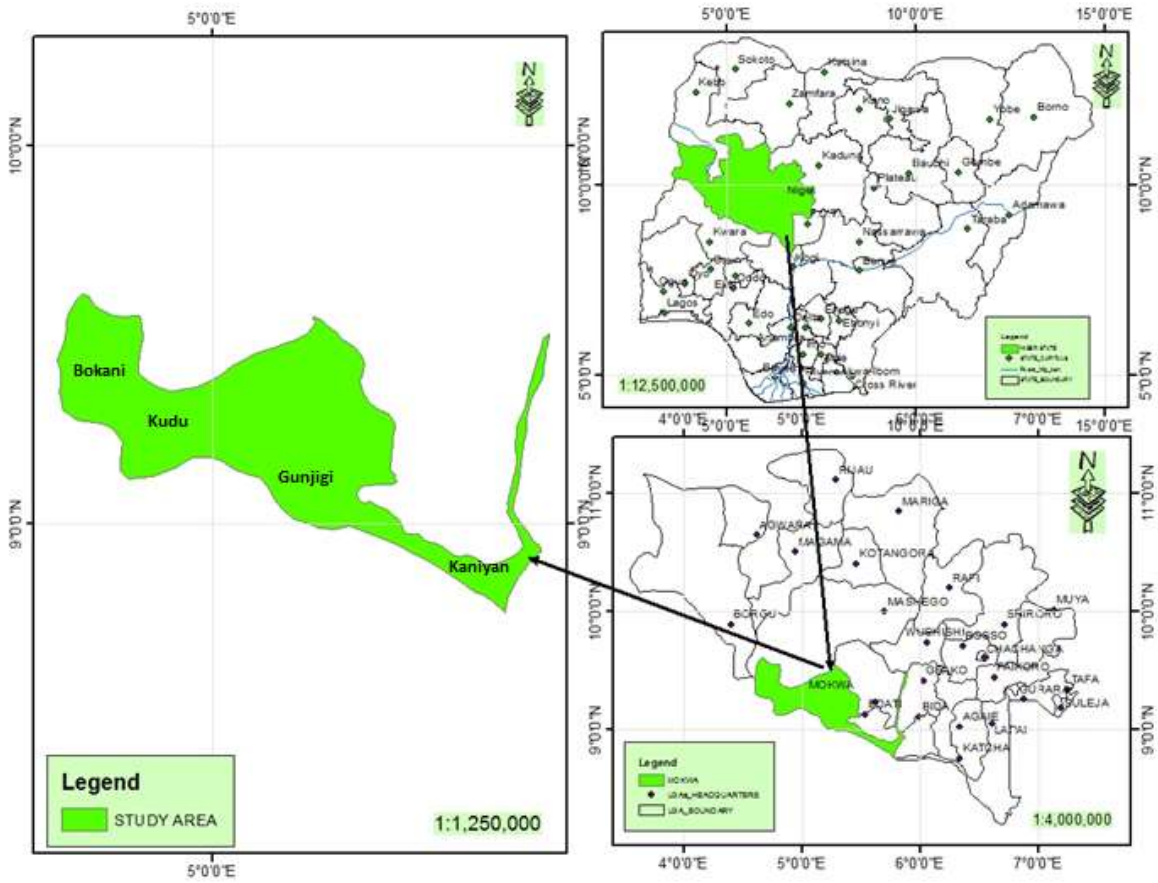

Figure 1.1: Location of Mokwa Local Government Area

Source: Niger State Geographic Information System (2021)

1.7.2 Vegetation

The study area falls within the savanna zone vegetation of the West Africa sub-region but patches of rain forest, however, occur in the plains that form one of surviving North-most occurrences of the nature forest vegetation in Nigeria. The vegetation of the study

area is divided in to three savanna types of park or grassy that occupies about 53 percent of the total area and where the vegetation is annually savanna wood land that occur mostly in the rugged and less accessible parts on the Robo and Rubochi plains and same ending hills, they cover 12.8 percent and the shrub savanna that occurs extensively in rough terrain close to hills ridges in all parts of the study area and covers about 12.9 percent of the land area (Anon, 2011).

1.7.3 Climate of the study area

The study area has two distinct climate, namely the rainy season that begins around late March and runs through late October and the dry season which begins from November and end in early March. However, within these seasons is a brief hamattan season that is occasioned by the northeast. Weather conditions in the study area are influenced by its location within the Niger Benue trough on the windward side at the climate transition zone between the essentially humid south and the sub-humid north of the country. The climatic dictates of the study area essentially from the south-west to the North West due to rising elevation from the valley in the southwest the high temperatures and the relative humidity in the Niger-Benue through give Niger state a heating affect but the increasing elevation toward north. Rainfall in the study area reflects the location on the wind ward side while the monthly rainfall distribution intensified during the month of July, August and September (Anon, 2011).

1.7.4 Soil of the study area

The study area has two main classes of soil, sedimentary belt in the southern and south western extremities of the area and the pre-Cambrian basement complex rock of the country which account for more than 80percent of the area.

The sedimentary formation, being part of the nupe land sandstones consists mainly of fine grained sandstones with inclusion of grits, siltstones and clay lines; and basement complex consists of wide variety of rock types which can be classified in to three broad groups. Schist, including biotite/muscoriote schist, muscorite and tale schist's with quartzite intrusive account for most of the rugged landscape in the southern parts of the study area. The igneous rocks made up of biotite granite, rhyolite, and syenite. The granite account for most of the rock domes and massive hills in the north-eastern and north-western parts of the study area. The magnetite's and gneiss complex, which are metamorphic rocks consisting mostly of magnetite's, granite, gneiss and biota granite underline the site of the area. These are rocks of medium to high strength which were not expected to present serious engineering problems and the rocks of study area are generally quartz rich, acidic types which account for the generally sandy nature of the soil especially on the Robo and Rubochi Plains. The plains have the most fertile soils and the best agricultural lands of all plains of the study area while the high sand content of most soils within the study area accounts for the relatively high erosion status. There is however, one major advantage about the type of rocks and soils found in the study area because of the ability of construction materials in the form of building stones quartz and pistol tic gravel, building sands and earth for use as foundation materials (Adebisi, 2011).

1.7.5 Geology

The study area geology consists of pre- Cambrian basement with an elevation which range between 273m to 333m in the west and 200m to 364m in the East. The landscape of the region is relatively flat; this means it is located on a plain. North South direction divides the plain into two Western and Eastern part. Mokwa L.G.A geology can,

therefore, be broad Meta-sediments occurring in more than 7.5 per cent of the state Basement complex rocks occurring higher ground further away. The study area has proven deposits of a wide range of mineral resources including marble, tin, mica, clay, wolfromite, tantalite and talc (Adebisi, 2011).

1.7.6 Population and economic activities

The number of inhabitants in Mokwa has shown a steady and gradual rise as follows: 98,234 in 1991; the population census for 2006 is 242,858, with a projected population of 416, 600 by 2022. Mokwa is situated in Niger State, Nigeria, a local government area. Its base camp is situated in the town of Mokwa on the A1 parkway in the west of the country, this street links the town to another part of the nation, and the town also has a railway that runs to the west of Nigeria. Mokwa has a prominent organization like Flour Mills of Nigeria Plc, Sunti Golden Sugar Estate, which has brought individuals from various parts of the world and Nigeria. Approximately 85 percent of the populations of the State are farmers, while the remaining 15 percent are occupied with various jobs, such as salaried workers, manufacturing, trade, specialty development and phrases.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Conceptual Framework

2.1.1 Concept of charcoal production

Charcoal refers to a solid residue derived from the carbonisation, distillation, pyrolysis and torrefaction of wood (trunks and branches of trees) and wood by-products, using continuous or batch systems (pit, brick and metal kilns) (Hosier, 2013). Humankind's first source of energy is considered to be wood-fuel (Hosier, 2013). Fuel wood and charcoal are the most globally used for energy supply. Wood is an important type of biomass, with annual global utilization at 3.3 billion m3, of which more than half is used for energy (FAO, 2017).

The use of natural wood charcoal is approximately dated back to 30,000 years ago commonly in cave drawings (van Beukering *et al.*, 2007). Over 2 billion people globally rely on fuel wood as their main energy supply, especially rural households in developing countries (FAO, 2014). Wood charcoal production globally was in the year

2009, estimated at 47 million metric tons; 9% increase since 2004 (FAO, 2010). Fuel wood and charcoal, provides more than 14% of the world‟s total primary energy and more significant in developing countries. This demonstrates the importance wood-fuel plays in meeting the energy requirements of developing countries. Africa accounts for 63% of the global charcoal production (FAO, 2014). About 94% of the African rural population and 73% of the urban population use wood-fuels as their primary energy source (Bailis *et al.*, 2017) with the urban area heavily dependent on charcoal and rural areas dependent on firewood (Seidel, 2018).

Charcoal production systems are also characterized by the production technology that is used. Charcoal can be produced by a range of methods, from simple earth kilns to brick or metal kilns (Amanor *et al.*, 2012). The three most common methods of charcoal production are earth kilns, masonry kilns and metal kilns. The earth kiln is the most common method of making charcoal in Nigeria, as well as in the rest of sub- Saharan Africa. Earth kilns are of various types but the most common are the traditional earth kiln, improved earth kiln and the Casamance kiln. Improved charcoal production technologies have been introduced in order to increase production efficiency and reduce the emissions of potentially harmful pollutants. However, the use of these technologies remains very low because of limited awareness, weak technical capacity, and high risks to investment. Traditionally, charcoal is being made in mound or pit kilns (Amanor *et al.*, 2012). This technology is still used in both developing countries and in industrialized countries. Improved kilning techniques are widely used currently for instance the beehive kilns found in Brazil large industrial complexes used for making charcoal for the steel industry. In the USA this technique was also widely used for the manufacture of metrallurgic charcoal, but abandoned during the first half of the 20th century. Missouri kilns were widespread up until 1975 in the state Missouri with yields

are usually in the range of 5%-20%, and they vary with the skills of the operators (Amanor *et al.*, 2012).

Demand for forest products has place pressure on forest resources which eventually has resulted in degeneration, deforestation, desertification and subsequently lead to environmental degradation (van Kooten and Bulte, 2010). Deforestation is one of the major factors affecting the forest as a result of urbanization. It refers to the conversion of forest to an alternative permanent land use such as agriculture, grazing, industries, etc. (van Kooten and Bulte, 2010). However, it influences the micrometeorological processes, concentration of carbon dioxide in the atmosphere, resulting to global change. This effect disrupts the normal weather patterns; create hotter and drier weather, drought, and desertification, crop failures, melting of the polar ice caps, coastal flooding and displacement of major vegetation regimes. In Africa, charcoal production is considered as the major drive for deforestation; almost all charcoal is produced in rural areas, especially in forested areas surrounding the urban centers (Chidumayo, 2011). It contributes greatly to the deterioration of the environment in Nigeria resulting in increase of carbon-dioxide in the atmosphere where these trees are being felled causing global warming and health problems (Tunde *et al*., 2013). Broad issues such as poverty, population pressures, unequal political power, and lack of opportunities have led to charcoal production which serves as a means of livelihood.

The growing demand for charcoal has resulted in deforestation in vulnerable areas (Salau and Keshinro, 2015). It has been predicted that if the present trend continues the tropical rainforest would completely disappear by the year 2050 due to deforestation induced by fuel wood, charcoal production and conversion of forest to other uses. Rural people who are the major custodians of forest resources survive by exploiting wood

resources without caution and concern (Mogaka, 2011), causing economic trees to disappear. Omoogun and Odok (2013) argued that there is a direct link between environmental awareness and human activities on the environment.

Deforestation and the general despoliation of the planet continue to accelerate. It is often contended that overpopulation, playing itself out through a 'Tragedy of the Commons', as the primary cause (The Wild Peak, 2012). The theory was written by an ecologist Garrett Hardin in 1968. The theory is about the despoliation of common resources in a manner that it does not allow for the regeneration and or reproduction of those resources (Abdul, 2017). Therefore, the theory underpins the activity of charcoal producers based on wood exploitation for charcoal burning resulting in forest destruction which charcoal producers are aware of, but they will continue to explore it because of the selfish economic gains which at the long run has long term impacts on the environment and forest ecosystem. The tragedy of the commons can be avoided if it is appropriately regulated. Over time forest areas experience desert encroachment; which in turn alter the weather pattern. The use of trees for charcoal production presents a threat to the future of forest resources. Therefore, this study will assess the impact of charcoal production on forest degradation in Mokwa Local Government Area, Niger State, Nigeria.

2.2 Theoretical Framework

The tragedy of the commons concept is important in understanding of environmental degradation of our society. It is a dilemma in itself rooted to the situation in which multiple individuals, acting independently and rationally consulting their own self-interest, will ultimately deplete a shared scarce resource, even when it is clear that it is

not in anyone‟s long-term interest for this to happen (Hardin, 1968). The basic idea espoused by the tragedy of the commons concept is that if a resource is held in common for use by all, then ultimately that resource will be destroyed (Hardin, 1968). The resource shared in common in this case is the trees that are cut down for charcoal production. To avoid the ultimate destruction, the human values and ideas of morality must be changed (Foddy *et al*., 1999). This theory assumes that every human exploiter of the shared common resources is driven by self-interest (Ostrom *et al*., 2002). When the carrying capacity of the commons is fully reached, the exploiters might find themselves in a dilemma of whether to continue with their actions or not. The gain of doing so would go solely to them, but the loss from their actions would be "Communized", therefore they will not give up their actions (Hardins, 1968). Because the privatized gain would exceed his share of the communized loss, a self-seeking exploiter would not change his behavior (Hardin, 1968).

Others reasoning in the same way, would follow the suit and ultimately, the common property would be ruined Exploiters could be aware of the long term consequences of their actions, but generally they are powerless to prevent such damage without some coercive means of controlling the actions of each individual (Foddy *et al*., 1999). Idealists may appeal to individuals caught in such a system, asking them to let the long term effects govern their actions (Foddy *et al*., 1999). But each individual must first survive in the short run (Ostrom *et al*., 2002). If all decision makers were unselfish and idealistic calculators, a distribution governed by the rule "to each according to his needs" might work (Foddy *et al*., 1999). The spoilage process comes in two stages. First, the non-angel gains from competitive advantage of pursuing own interest at the expense of others. Then, once the noble angels realize that they are losing out, they try to get a share out of the commons before competitors do. This shows that, every

workable distribution system must meet the challenge of human self-interest. An unmanaged commons in a world of limited material wealth and unlimited desires inevitably ends in ruin. Inevitability justifies the epithet “tragedy,” (Hardin, 1968). This theory underpins the activity of charcoal producers. Unsustainable fuel wood exploitation for charcoal burning results in forest destruction which charcoal producers are aware of but continue because of the selfish economic gains which however have general ramifications. The long term adverse impacts of their actions thus do not matter to them. The theory is therefore relevant to the study as it explains how unsustainability comes in charcoal business as a result of the need to fulfill self interest.

2.3 Review of Related Literature

Walter *et al.* (2016) studied the effect of charcoal production and use on the transition to a green economy in Kenya. The purpose of this study was to assess the effect of charcoal production and use on the transition to a green economy in Kenya. This study identified the target tree species that are a source of charcoal consumed in Nairobi city, determined quantity of charcoal consumed in the city of Nairobi and estimated forest cover depletion from charcoal production and use. The study adopted a research survey design involving the use of semi-structured questionnaire, with a target of 100 respondents (20 large scale charcoal traders and 80 charcoal users) sampled through person-to-person interview, selected using a purposive/systematic random sampling technique. Descriptive statistical data techniques were used to analyze the field data. The findings revealed that about 1264 ha and 15174 ha of forest cover are depleted on monthly and yearly basis respectively. Forest cover depletion is predicted by charcoal consumption. The study also revealed that Kenya would lose about 65.6% of its forest cover to charcoal production and use by 2030. Taking measures to propagate the most

preferred Acacia species and ensuring massive tree planting exercise especially in order to protect arid areas of the country is important. Legislations on charcoal, reforestation/afforestation should be reinforced nation-wide if Kenya hopes to transition to a green economy within its vision 2030 agenda.

Sedano *et al.* (2016) studied the impact of charcoal production on forest degradation: a case study in Tete, Mozambique. Charcoal production for urban energy consumption is a main driver of forest degradation in sub Saharan Africa. Urban growth projections for the continent suggest that the relevance of this process will increase in the coming decades. Forest degradation associated to charcoal production is difficult to monitor and commonly overlooked and underrepresented in forest cover change and carbon emission estimates. We use a multitemporal dataset of very high-resolution remote sensing images to map kiln locations in a representative study area of tropical woodlands in central Mozambique. The resulting maps provided a characterization of the spatial extent and temporal dynamics of charcoal production. Using an indirect approach we combine kiln maps and field information on charcoal making to describe the magnitude and intensity of forest degradation linked to charcoal production, including aboveground biomass and carbon emissions. The findings reveal that forest degradation associated to charcoal production in the study area is largely independent from deforestation driven by agricultural expansion and that its impact on forest cover change is in the same order of magnitude as deforestation. The work illustrates the feasibility of using estimates of urban charcoal consumption to establish a link between urban energy demands and forest degradation. This kind of approach has potential to reduce uncertainties in forest cover change and carbon emission assessments in sub-Saharan Africa.

Absolom (2014) evaluated environmental implications of the charcoal business in Narok-South Sub-County, Narok County, Kenya. The forest cover in Kenya which is below the international required standard of 10% coverage is rapidly becoming depleted due to the ever increasing human demand for fuel wood. Unsustainable exploitation of forest resources for commercial charcoal production is a worrying phenomenon in Narok-South Sub-County, Narok County of Kenya. The fast disappearance of tree cover may influence climate change which may in the long run affect crop yields, tourism activities and deepen poverty levels, of which Narok County is not an exception. The research covered Narok-South Sub-County commercial charcoal production areas as the study area. The study assumed a descriptive design which employed pre field work, field work, review of relevant documents, data collection, analysis and interpretation as study approaches. The study aimed at assessing the socio-economic impacts of charcoal enterprise in Narok-South Sub-County, Narok County, the sustainability of the charcoal business, to examine the environmental implications of charcoal production in the Sub-County, and to come up with recommendations on sustainable management of charcoal business in Narok-South-Sub-County.

Vasco *et al.* (2018) assessed value chain of charcoal production and implications for forest degradation: case study of Bié Province, Angola. Forest degradation and forest loss threaten the survival of many species and reduce the ability of forests to provide vital services. Clearing for agriculture in Angola is an important driver of forest degradation and deforestation. Charcoal production for urban consumption as a driver of forest degradation has had alarming impacts on natural forests, as well as on the social and economic livelihood of the rural population. The charcoal impact on forest cover change is in the same order of magnitude as deforestation caused by agricultural expansion. However, there is a need to monitor the linkage between charcoal production

and forest degradation. The aim of this study is to investigate the sequence of the charcoal value chain as a systematic key to identify policies to reduce forest degradation in the province of Bié. It is a detailed study of the charcoal value chain that does not stop on the production and the consumption side. The primary data of this study came from 330 respondents obtained through different methods (semi-structured questionnaire survey and market observation conducted in June to September 2013–2014). A logistic regression (logit) model in IBM SPSS Statistics 24 (IBM Corp, Armonk, NY, USA) was used to analyze the factors influencing the decision of the households to use charcoal for domestic purposes. The finding indicates that 21 to 27 thousand hectares were degraded due to charcoal production. By describing the chain of charcoal, it was possible to access the driving factors for charcoal production and to obtain the first-time overview flow of charcoal from producers to consumers in Bié province. The demand for charcoal in this province is more likely to remain strong if government policies do not aim to employ alternative sources of domestic energy.

Karl (2010) studied effects of charcoal production management on woodland regeneration in Senegal. In Senegal, as in many parts of Africa, nearly 95% of its growing urban population depends on charcoal as their primary cooking energy. Extraction of wood for charcoal production is perceived to drive forest degradation. The Senegalese government and international donor agencies have created different forest management types with the ultimate goal of sustainably managing forests. This research combines local ecological knowledge, ecological surveys and remote sensing analysis to better understand questions related to how extraction for charcoal production and forest management affect Senegalese forests. Information derived from 36 semi-structured interviews suggests that the forests are degrading, but are depended on for income, grazing and energy. Interviewees understand the rules governing forest management

types, but felt they had limited power or responsibility to enforce forest regulations. Ecological survey results confirmed that plots harvested for charcoal production are significantly different in forest structure and tree species composition than undisturbed sites. Across harvested and undisturbed and within forest management types the Combretum glutinosum species dominated (53% of all individuals and the primary species used for charcoal production) and demonstrated robust regenerative capacity. Few large, hardwood or fruiting trees were observed and had insufficient regenerative capacity to replace current populations. Species diversity was higher in co-managed areas, but declined after wood was harvested for charcoal production. Proximity to villages, roads and park edges in harvested and undisturbed plots and within forest management types had little impact on forest structure and tree diversity patterns with the harvesting of trees for charcoal spread consistently throughout the landscape. Remote sensing analysis with the MISR derived k(red) parameter demonstrated its ability to accurately classify broad land classes and showed potential when differentiating between pre- and post-harvest conditions over a three year time period, but could not accurately detect subtle changes in forest cover of known harvest time since last harvest in a single MISR scene. This research demonstrated the utility of multidisciplinary research in assessing the effects of charcoal production and forest management types on Senegalese forests; concluding that the effects of charcoal production on forest characteristics and regenerative capacity are consistent throughout all forest management types.

Salifu (2013) evaluated impact of charcoal production on soil properties and vegetation in the Central Gonja District of the Northern Region, Ghana. This study assessed the impact of charcoal production on soil properties, vegetation and the perception of charcoal producers on the environmental impacts of their activities in the Central Gonja

District of the Northern Region, Ghana. Data acquired suggest significant differences in the proportions (or fractions) of clay and sand in soils sampled within 0-30 cm depth at sites of charcoal production referred to simply (as burnt sites) and sites with no observable indications of charcoal production (or unburnt sites). Soil silt fractions from 0-30 cm and 30-60 cm depths were, however, quite similar at both burnt and unburnt sites. The hydraulic conductivity of soils from 0-30 cm and 30-60 cm depths at burnt and unburnt sites also exhibited distinct differences ($P < 0.001$) and ($P < 0.029$) respectively. Soil chemical properties such as potassium ($P < 0.002$) and magnesium ($P < 0.011$) showed significant difference at 0-30 cm between burnt and unburnt. There was, however, no significant difference between burnt and unburnt sites within the 30-60 cm for same soil chemical properties, potassium ($P < 0.274$) and magnesium ($P < 0.076$). In terms of land use and (land) cover change in the Central Gonja District, analysis and interpretation of Remote Sensing and GIS data from Landsat TM images of 1990, 2000 and 2010 suggest reduction in the pristine or original guinea savanna (woody) vegetation of the area from 22,662 to 11,739 ha over the twenty-year period from 1990 to 2010, with grass/herbaceous and built-up areas increased from 23,088 to 95,148 ha and 6,355 to 81,702 ha, respectively. Even though charcoal production and marketing/trade are important economic activities for people in the district, providing income to the charcoal producers especially women, it appears to have had several environmental challenges in terms of deforestation, impact on soil parameters especially at burnt sites, bushfires and soil erosion.

Raymond *et al.* (2016) studied empirical evidence of the impact of commercial charcoal production on Woodland in the Forest-savanna transition zone, Ghana. The impacts of charcoal production on woodland were assessed in the Forest-savanna Transition Zone of Ghana to facilitate policy formulation for a win-win situation for both sustainable

woodland management and charcoal production. Twenty-three harvested sites in two charcoal producing communities were assessed in terms of the extent of harvested sites, changes in biomass carbon stock and tree basal area. The boundary of each site earmarked for charcoal production was mapped with a hand-held Global Positioning System, and the diameters at breast height (dbh) and the heights of trees of dbh ≥ 5 cm were measured, prior to harvest.

The extent of harvested sites was compared with the Intergovernmental Panel on Climate Change criterion of "devegetation" using Wilcoxon test, while the biomass carbon and basal area of the harvested trees were compared with those of the remnant trees using Mann Whitney t-test. The median of the extent of harvested sites (M = 0.23 ha, P = 1.00) was significantly higher than 0.05 ha, the Intergovernmental Panel on Climate Change minimum criterion for "devegetation", while the difference between median basal area of harvested and remnant trees was significantly greater than zero (Gh − Gr = 2.6 m2 ha−1 ; P = 0.001) at 95% significant level. The Mann Whitney test also provided sufficient evidence (n = 23; Mhc − Mrc = 12.07 t ha−1; P b 0.001) against the null hypothesis that the difference between the medians of the aboveground biomass carbon in the harvested and remnant is zero at 95% significant level. On the basis of the IPCC definition of "devegetation" and the changes in basal area, it suggests that intensive charcoal production has the potential of degrading woodlands. Nonetheless, it is worth highlighting that, none of the harvested sites had zero basal area or biomass carbon after harvest, which is a significant revelation for sustainable woodland management for charcoal production. The study further revealed that the extent of harvested site is not an appropriate measure of the impact of charcoal production on woodland since it does not account for the number and sizes of the trees harvested. Therefore, the impact of charcoal production on woodland may not be as alarming as it

is generally perceived when the extent of harvested site is used as a measure. The impact of charcoal production is often over-generalized and that, “devegetation” of harvested sites is an issue of post-harvest woodland management and not the impact of charcoal production per se. Therefore, the evidence of the impact of charcoal production on woodlands shown in this study should be basis for sustainable woodlands management and not basis for halting charcoal production in the study area (Raymond *et al.,* 2016).

Adebayo *et al.* (2019) examined the effects of charcoal production on deforestation in selected agrarian communities of Oyo State, Nigeria. Charcoal production is considered as one of the major drivers for deforestation .Its production is beginning to have negative impact on the environment. This study examined the assessment of charcoal production on deforestation in selected agrarian communities of Oyo State. Simple random sampling procedure was used to select 160 respondents from a sample frame of 320 charcoal producers in Saki West and Ibarapa North Local Government Areas. Interview guide and Focus Group Discussions were used to obtain data on charcoal producers’ socio-economic characteristics and their perception of deforestation. Primary data were analyzed using frequency counts, percentages and Chi-square. Findings revealed that 57.5% of the respondents were male, 32.5% were within the age group of 40-49 years, while 45.0% and 42.5% had primary and secondary school education, respectively. Also, 32.5 % of the respondents had 16 - 20 years’ experience in charcoal production. The study revealed that Vitellaria paradoxa (68.8%, 85.0%) , Anogeissus leiocarpus (77.5%,66.3%) and Bridelia ferruginea (58.8%,65.0%) were the most preferred tree species used for charcoal production in Ibarapa North and Saki West Local Government Areas respectively. Majority (73.8%) perceived that charcoal

production is a serious threat to the environment. Chi-square result showed significant ($p<0.05$) associations between charcoal producers' educational level ($\chi^2 = 11.938$, df = 3) and perceived effect of charcoal production on deforestation. The study concluded that charcoal production is one of the major causes of deforestation in the study area. It is therefore recommended that organize afforestation and reforestation programmes should be encourage and enlightenment campaign on the threat on charcoal programme on the environment.

Olasimbo and Johnson (2018) studied socio-economic impacts of charcoal production in Oke-Ogun area of Oyo State, Nigeria. Many households in developing countries experience low energy consumption and this make them depend upon wood fuels for their energy. This study examined socio-economic impacts of charcoal production in Oke-Ogun, Oyo State, Nigeria. Two Local Government Areas were selected based on the accessibility and the availability of charcoal farmers among ten Local Government Areas. Results show that 74% of the respondents were male while 26% were female that are into production of charcoal in the study area. 37.5% of the age range (41–50) of respondent produces more charcoal than other age range. The respondent did not go beyond primary school educationally and they are all married. However, respondents with over 11–20 years of experience in the production of charcoal have higher percentage of frequency. Some of the problem faced by the producers of charcoal in Oke Ogun area are scarcity of trees, wildfire, government disturbance and transportation. Trees commonly used for production are from inherited farms and most of the trees used are *Butyrosopermum paradoxium, Dialium guineense, Terminalia glaucencens, Khaya ivorensis.* Production is once in a month and later exported. Energy provision is a basic human need and consumption is closely related to the level of a country's development.

Eniola and Odebode (2018) studied rural dwellers' perception of effect of charcoal production on the environment in Guinea savanna zone of Nigeria. Despite the law promulgated by the Federal Government of Nigeria prohibiting illicit felling of trees, the number of charcoal producers is on the increase coupled with a sharp rise in the quantity of charcoal produced with its attendants environmental consequences. Thus, this study investigated rural dwellers' perception of the effect of Charcoal Production (CP) on the environment in Guinea savanna Zone of Nigeria. Eighty five respondents were selected through multistage sampling procedure. Data were collected through the use of structured interview schedule and were analysed, using both descriptive and inferential statistics. Findings show that the mean age of charcoal producers was 43 years. Majority (90.5%) was males, 90.6% of the charcoal producers were married and 35.3% had no formal education. Majority (80.0%) of the respondents made use of earth mound method of CP and 52.9% of them produced between 32 kg and 32000 kg of charcoal per annum. Most of the respondents (62.7%) perceived that charcoal production could lead to erosion, while 62.4% of them perceived that charcoal production would not only reduce the available trees for future use but also reduce the available air in the environment (54.1%). Regression result showed that farming activities (β= 0.305), farming system (0.301), years of experience (β= 0.365) and sources of trees (β= 0.280) were implicated in the level of perceived environmental effects of charcoal production in the study area. Thus, high level of perceived environmental effects of charcoal production was recorded. Therefore, charcoal producers should be educated on the effects of CP on the environment and to participate actively in the replacement of trees.

Odunayo *et al.* (2019) assessed the effect of indiscriminate charcoal production on Nigeria Forest Estate. Half of the world's population, and up to 95 percent in poor

countries, rely on solid fuel including biomass fuel and charcoal to meet their energy needs. Fuel wood and charcoal are by far the most heavily consumed energy sources in Nigeria, rural dwellers who are the custodians of forests resources depend solely on it for livelihood and increase in demand for charcoal. Nigeria ranked the highest producer of charcoal in Africa and second in the world and the production trend of charcoal in Nigeria has over the years shown a steady increase yet Nigeria is not among the world leading nations in the exporting of charcoal which means the nation consumes a larger percentage of its annual produce locally. The continuous production is promotional to continuous deforestation and desertification which in-turns are a threat to sustainable environment. Thus the uses of forest trees for charcoal production still represent a threat to the future of the resources in local terms, especially in certain situations with high demand. With adequate forest management, supervision and control practices, however, the growth of charcoal use will no longer have serious impact on forested areas that supply consumption centers. Also, if measures are introduced to improve the supply of raw materials for charcoal production (through tree planting initiatives and participatory forest management), unsustainable production would gradually be replaced by regulated production on a sustainable basis.

2.4 Impact of Charcoal Production and Utilisation on Environment

Charcoal making involves felling down of trees and subsequent removal of vegetation cover that leads to loss of biodiversity. Trees removal results in alteration of plant community structures in terms of species diversity, distribution of different species and plant density (Mugo *et al*., 2017). According to Kiage (2018), possible disruption of essential ecological processes is associated with accelerated and irreplaceable depletion of genes, populations, species and ecosystems. Biodiversity is the basis of ecosystem

health and of the provision of ecosystem services (Mugo *et al.*, 2017). There exist species inter-dependence in an ecosystem therefore decline or loss of a species population impacts on the life cycle of other species and the ecosystem at large.

Selective cutting of trees for charcoal making results simplification of the habitat linked with observed thinning of woodlands. For instance a tree species can support many plant and animal species on an obligatory basis and one fruit tree can provide food for many birds and mammals (Kiage, 2018). Charcoal industry if unsustainable may lead to deforestation and environmental degradation therefore disrupting the rich biodiversity ecosystem (Mugo *et al.,* 2017). Nearly all charcoal consumed in Kenya and elsewhere in sub-Saharan Africa is made from local indigenous tree species (Mutimba and Barasa, 2015). Forestry or trees are endowed with important ecological benefits including soil erosion control, catchment protection and wildlife conservation (O'keefe, 2019).

Charcoal production in Nigeria results in different forms of problems some of which are environmental pollution arising from smoke, deforestation as a result of tree harvest and erosion which exposes the soil to direct sunshine, it also leads to reduction in the soil fertility and health problems to people around the production site (Ajadi *et al.*, 2018). Due to the steady increase in the demand for charcoal as a result of different industrial revolutions and urbanisation, production of charcoal has been largely carried out with an unsustainable approach.

2.4.1 Air pollution

Charcoals consist of carbon and any remaining ashes, it is an adulterated form of carbon containing ash (Ajadi *et al.,* 2018). Pollutants like carbon monoxide, sulphur and other minute particles are released into the atmosphere from the incomplete and inefficient combustion of wood fuels. Chronic respiratory diseases such as pneumonia,

tuberculosis, and acute respiratory infection are associated with indoor air pollution which could be caused by charcoal. The wood smoke produced during charcoal production contains small particles of matter such as PM_{10} (10 Microns in diameter or less) made up of creosote soot and ash, they transport some viruses and bacteria into the lungs and blood, other constituents also include Nitrogen, Sulphur dioxide and volatile organic substances (VOCS) which poses risk to exposed persons. These pollutants have a serious effect on the human health, it can result in cancer, heart and lung disease and it can inhibit the ability of the body to transport oxygen (FAO, 2014).

2.4.2 Increase deforestation and desertification

Forest degradation, Deforestation and outbreak of respiratory disease have been reported to be some of the major effects of relying on wood fuel and charcoal, and efforts directed at ameliorating its impact has proved abortive. The production of charcoal involves the cutting of wood over a large forest area, depletion of land covers and soil structure, this escalates the rate of wind and water erosion which can later lead to destruction of the soil fertility. More so, the use of wood for energy increases deforestation which directly escalates the problem of deforestation and desertification and also leads to the loss of forest which protects the watersheds (Ajadi, Alabi and Adebisi, 2018).

2.4.3 Loss of biodiversity

The production of charcoal has led to a massive forest depletion in Congo where it is reported to threaten the survival of mountain gorillas, similar threat was also reported in Zambia and Nigeria. In Brazil, Charcoal production is a big illegal industry for the manufacture of pig iron. Despite the fact that it gives the benefit heat efficiency, issues of deforestation and pollution from its smoke will always be an area of concern.

Pollutions from smoke and its constituents during the process of production requires an immediate attention across every disciplines especially forestry and environmental toxicology (Kaliyan and Morey, 2019).

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Sources of Data

The sources of data for this study include primary and secondary data sources.

3.1.1 Primary source of data

The primary sources of data used in this thesis include questionnaire administration, oral interview and reconnaissance survey. These were used to achieve the stated objectives.

3.1.2 Secondary source of data

The secondary data are those data that have been used by previous researchers as well Niger State Government documents on deforestation about the study areas. Other secondary sources include journals, textbooks, newspapers, unpublished and published theses, and the internet.

3.2 Instruments for Data Collection

The instruments for data collection of this study include questionnaire design, oral interview and reconnaissance survey.

3.2.1 Questionnaire design

The structured questionnaires design is part of the instrument for data collection which is aimed at obtaining detail information on how to achieve the stated objectives of the study. Structured questionnaires were administered to the residents within the study area. The questionnaire was structure into five sections based on the research objectives. The sections include the followings:

Section A: Demographic characteristics of the respondents

Section B: Causes of charcoal production in the study area

Section C: Investigate tree species used for charcoal production in the study area

Section D: Assess the impact of charcoal production on forest degradation in the study area

Section E: Analyse the afforestation practices in the study area

3.2.2 Oral interview

An oral interview is an effective research technique which help the interviewer access his or her information needed to carry out his research effectively and efficiently. This method involved personal meetings with designated tourism officials in Niger State Ministry of Environment and stakeholders that are into aforestation programmes in the study areas. This information derived from the oral interview was integrated into that of questionnaire analysis during results and discussion.

3.2.3 Reconnaissance survey

The reconnaissance survey revealed those areas within the study areas that are charcoal production sites as well as their constraints. Thus, some of the residents were selected

randomly in a way that adequately represents the widening of the charcoal production sites. And the observations was based on the aim and objectives of the research work. This instrument was used to add value to the information to be generated in questionnaire and oral interview.

3.3 Sample Size and Technique

Sample size was drawn using Yamani's formula. This formula is concerned with applying a normal approximation with a confidence level of 95% and a limit of tolerance level (error level) of 5%.

Sample points for this study include some officials of Niger State Ministry of Tourism (12 staffs) and residents as well as stakeholders of the study areas.

To this extent the sample size was determined by $n = \frac{N}{1+Ne^2}$ (3.1)

Where: n = the sample size

N = population (This include residents of Gunjigi, Bokani, Kaniyan and Kudu)

e = the limit of tolerance (0.05)

Therefore, $n = \frac{244,937}{1 + 244,937(0.05)^2} = \frac{244,937}{1 + 244,937\ (0.0025)} = \frac{244,937}{1 + 612} = \frac{244,937}{613}$

n = 399 respondents

The study respondents were 399 and simple random sampling was used to distribute the questionnaires among the respondents. Three hundred and forty (340) respondents returned questionnaires which were used for data analysis.

3.3 Method of Data Analysis

3.3.1 Examine the causes of charcoal production in the study area

This objective was achieved using a 3-point Likert type scale with response options as strongly agree (SA) = 3; agree (A) = 2; and disagree (D) = 1

$$\text{Mean value } (x) = \frac{3+2+1}{3} = \frac{6}{3} = 2 \quad (3.2)$$

Therefore any variable with mean score ≥2 was considered a good option while those with mean scores less than 2 was regarded as not good option. Each of the three responses would have a numerical value which was used to measure the attitude under investigation.

3.3.2 Investigate tree species used for charcoal production in the study area

To achieve objective two, frequency-percentage technique was adopted as the techniques for the analysis. The analysis of frequency percentage is one of the first techniques for analyzing research data that were collected through the use of questionnaire. The frequency-percentage technique is relatively easy to present, analyze and interpret. Frequency-percentage was used to achieve objective two of the study.

$$Frequency - Percentage = \left(\frac{number\ of\ observed}{Total\ Number}\right) 100\% \quad (3.3)$$

3.3.3 Assess the impact of charcoal production on forest degradation in the study area

To achieve objective three, statistical mean and standard deviation was used for data analysis. The data collected were analyzed using mean and standard deviation. The decision rule used on the mean was 2.50. This means that any item with a mean score of

2.50 and above was considered important impact of charcoal production on forest degradation in the study area and as such accepted. The equation for statistical mean as well as standard deviation is as follow:

$$x = \frac{\sum x}{n} \quad (3.4)$$

Where x is the impact of charcoal production on forest degradation in the study area and n = number of respondents.

$$\partial = \sum (x_i - x)^2 = \sqrt{=\frac{(X-X)^2}{N}} \quad (3.5)$$

i.e. where x – x represents the deviations of each of the impact

N = Number of respondents

X = the mean for the data

∂ = Standard deviation. Thus standard deviation is the root mean square of the deviation of each of the number of x, from the mean x.

3.3.4 Analyse the afforestation practices in the study area

This objective was achieve through 4-point rating scale with numerical response options in descending order of Very Good Afforestation Practice (VGAP)-4 points, Good Afforestation Practice (GAP)-3 points, Low Afforestation Practice (LAP)-2 points and Very Low Afforestation Practice (VLAP)-1 point.

Statistical Package for the Social Sciences (SPSS 21.0) software was used in analyzing the descriptive statistical techniques (frequency-percentage, statistical mean, standard deviation and likert) were adopted in this study.

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

4.1 Examine the Causes of Charcoal Production in the Study Area

Table 4.1 revealed socioeconomic characteristics of the respondents in the study area and they include gender, age, educational level, occupation and years of experience.

Table 4.1: Socioeconomic Characteristics

Socioeconomic characteristics	Options	Frequency	Percentage (%)
Gender	Male	215	63.2%
	Female	125	36.8%
Age	16 – 29	151	44.4%
	30 – 45	125	36.8%
	46 – and above	64	18.8%
Educational level	Non formal	13	3.8%
	Primary	137	40.3%
	Secondary	150	44.1%
	Tertiary	40	11.8%
Occupation	Farmers	239	70.3%
	Traders	20	5.9%
	Civil servant	55	16.2%
	Artisans	26	7.6%
Years of experience	1 – 5	55	16.2%

	6 – 10	151	44.4%
	Above 10 years	134	39.4%

Source: Field Survey (2022)

The results in Table 4.1 revealed that 63.2 percent of the charcoal producers were males while 36.8 percent were females. The mean age of the respondents is 42.9 years and most of them were native of the study areas. Results show that respondents have basic education and their major occupation is farming (70.3 percent). Due to their early involvement in the charcoal enterprises, respondents' years of experience fall between 16-29 years (44.4 percent). Most of the respondents in the study area were native of the communities; this suggests that respondents were familiar with the terrain of the area and will be able to explore other forest areas in the study area. Farming is the predominate occupation of the respondents, this infers that respondents will have the opportunity to venture into charcoal production during the off-farm season.

As indicated in Table 4.1, there is an indication that there are more males than females in charcoal production; this is due to the rigorous activity involved in charcoal production. The study also revealed that majority (55.9 percent) of the respondents had elementary education (secondary and primary school), which implies the low level of formal education will influence charcoal producers into the enterprise early since the skill acquisition does not require rigorous process and this will make them more experienced in the business. This study supports that of Adejumobi and Eniola (2011) findings about charcoal producers in Oke-Ogun, that their level of education is low. Also, the active group falls between 16-29 years (44.4percent), this denotes that respondents within this age active group suite the enterprise because of the energy exertion required during production.

The causes of charcoal production in the study area include population growth, poverty, urbanization and the relatively high prices of alternate energy sources for cooking in the study area as indicated in Table 4.2.

Table 4.2: Causes of Charcoal Production

Causes	Frequency	Percentage (%)
Population growth	47	13.8%
Poverty	106	31.2%
Urbanization	23	6.8%
High prices of alternate energy sources for cooking	164	48.2%
Total	**340**	**100**

Source: Field Survey (2022)

As indicated in Table 4.2 of the study, high prices of alternate energy sources for cooking ranked the highest causes of charcoal production with 48.2 percent respondents, poverty ranked second cause with 31.2 percent respondents, population growth ranked third with 13.8 percent and urbanization ranked the least with 6.8 percent respondents. This revealed that high prices of alternate energy sources for cooking was the major cause of charcoal production in the area as kerosene and gas where very expensive for average household head in the study area.

4.2 Investigate Tree Species Used for Charcoal Production in the Study Area

Trees commonly used for production are from inherited farms and most of the trees used are *Butyrosopermum paradoxium, Dialium guineense, Terminalia glaucencens,* Acacia species, no preference and *Khaya ivorensis* as indicated in Table 4.3 of the study.

Table 4.3: Tree species used for charcoal production in the study area

Tree species	Frequency	Percentage (%)
Butyrosopermum paradoxium (Shea butter tree)	67	19.7%
Dialium guineense (Velvet tamarind tree)	45	13.2%
Terminalia glaucencens (Black Afara or Nut tree)	31	9.1%
Acacia species	50	14.7%
No preference	124	36.5%
Khaya ivorensis (Mahogany)	23	6.8%
Total	**340**	**100%**

Source: Field Survey (2022)

As revealed in Table 4.3 of the study, no preference ranked the highest with 36.5 percent of the respondents, Shea butter tree (Plate I) ranked second with 19.7 percent of the respondents, Acacia species ranked third with 14.7 percent and Mahogany ranked the least with 6.8 percent of the respondents. The results on Table 4.3 shows that

respondents prefer to use trees like *Butyrosopermum paradoxium, Dialium guineense, Terminalia glaucencens,* Acacia species, no preference and *Khaya ivorensis.* Other species used in the study area in little quantity include *Vitellaria paradoxa, Anogeissus leiocarpus, Bridelia ferruginea, Terminalia spp,* and *Pericopsis laxiflora*. This is because of the unique features of these trees to produce good quality charcoal. These trees are endangered and the exploitation of these few species of tree will adversely affect biodiversity. However, the tree species are very much important in the production of charcoal as there are specific trees species known to favour charcoal production due to dense and hard charcoal they produce, with higher calorific value (Izekor & Modugu, 2011).

Plate I: Shea butter tree frequently used for charcoal production in Gunjigi-Bokani

Source: Field Survey (2022)

They have a high economic value such as timber, food and fruits etc; some are protected but are fell illegal. This study affirms with Tunde *et al.* (2013) that trees such as Axle wood (*Anogeissus leiocarpus*), Burkea (*Burkea africana*), Shea butter (*Vitellaria paradoxa*), Hymenocardia (*Hymenocardia acida*) and Pericopsis (*Pericopsis laxiflora*) were good and strong wood that will give good quality of charcoal.

Plate II: Charcoal Carbonization Process (earth mound kiln) in Kaniyan Community
Source: Field Survey (2022)

Plate II revealed charcoal production precisely earth mound kiln process in Kaniyan community of Mokwa Local Government Area of Niger State. This finding is in line with Netherlands Programmes Sustainable Biomass study (BTG, 2010), that charcoal producers prefer tree species with slow-burning features for charcoal, however, these tree species are majorly economic trees, which are slow growing and are therefore

particularly vulnerable to over exploitation. Also, the study confirms that Vitellaria paradoxa and Anogeissus leiocarpus are the most preferred tree species used in the study area. The study is in line with Olarinde and Olasimbo (2018) that these trees are mostly used in Oke-Ogun area of Oyo State.

The woodland often selected for charcoal production in the study area are private or family owned and communal lands. Thus, they often harvest without acquiring a permit. Charcoal producers (28 percent) interviewed had a strong feeling that establishment of specific tree species plantations in the study area would improve and make the charcoal industry sustainable as shown in Figure 4.1. legalization (22 percent) of sustainable commercial charcoal production and movement will be a boost to the industry and an end to illegal and unsustainable charcoal practise in the study area. Strengthening and formation of more charcoal producers associations (16 percent) in the study area will ensure sustainable charcoal production as members are trained and equiped with necessary knowledge to ensure sustainability in charcoal industry as shown in Figure 4.1 of the study.

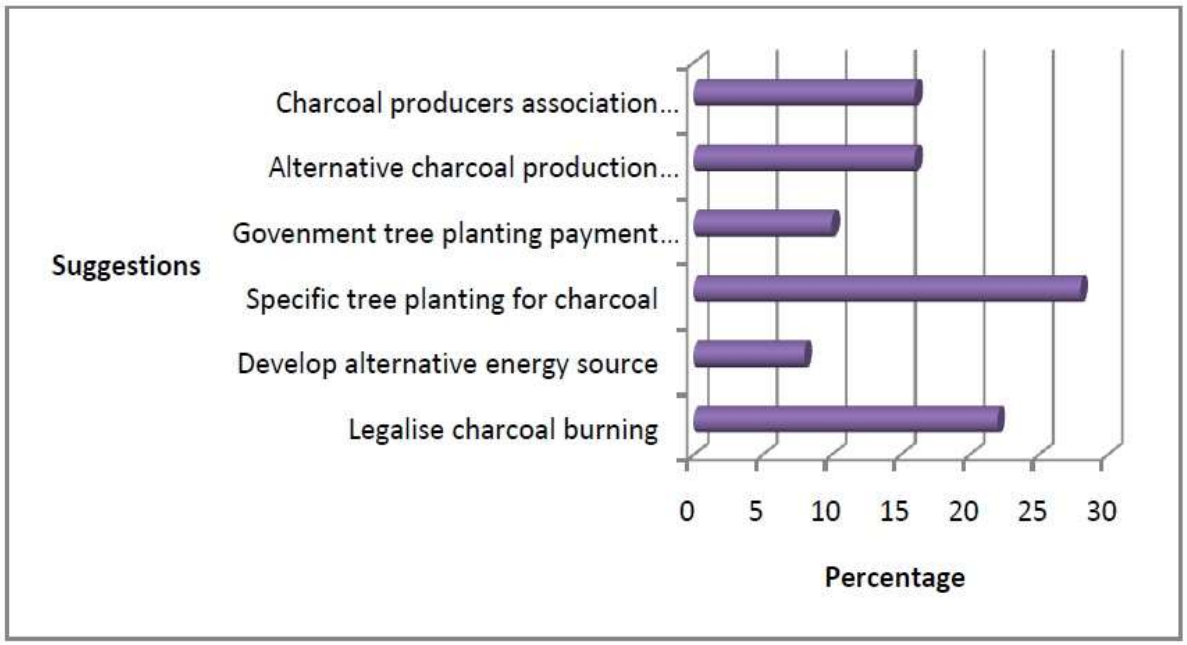

Figure 4.1: Suggestions for Sustainable Charcoal Production in the Study Area

Source: Field Survey (2022)

As shown in Figure 4.2, charcoal industry has been beneficial to the lives of charcoal producers. The industry enables them to acquire basic items necessary for their sustenance (Figure 4.2). They have acquired such assets as bicycles, motor bikes, and roofing materials with charcoal money. They use charcoal money to buy livestock for keeping, and source capital for farming. Charcoal has also made it possible to buy consumer goods like food stuffs, clothing, children's educational needs, and hospitals bills.

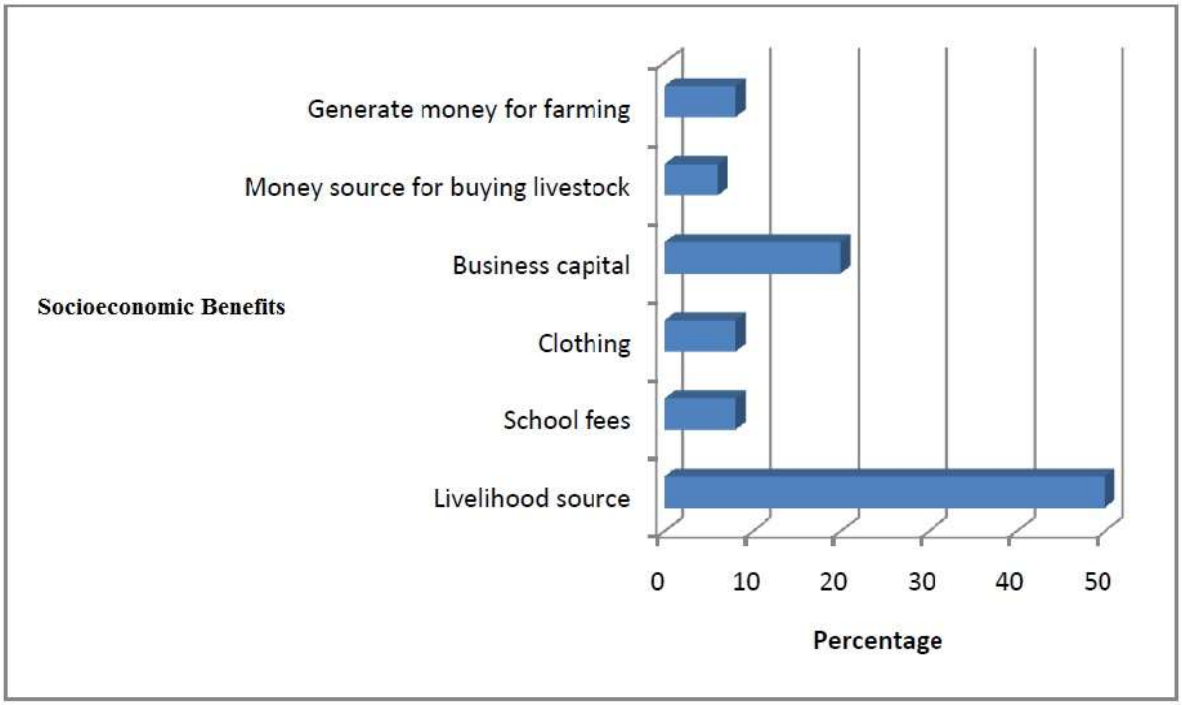

Figure 4.2: Socioeconomic Benefits Associated with Charcoal Enterprise in the Study Area

Source: Field Survey (2022)

As revealed in Figure 4.2 of the study, livelihood source ranked the highest with 49 percent of respondents, business capital ranked second with 20 percent of respondents, generate money for farming ranked third with 10 percent and money source for livestock ranked the least with 5 percent of the respondents. This implies that

respondents have benefited from the charcoal business socioeconomically which have improved the standard of living of the respondents in the study area.

Plate III: Charcoal used for Economic Benefit in Kudu Community of the Study Area

Source: Field Survey (2022)

As revealed in Plate III and Figure 4.2 of the study, charcoal produced in the study area were used for socioeconomic benefits and these benefits includes acquiring assets such as bicycles, motor bikes, and roofing materials with charcoal money. They use charcoal money to buy livestock for keeping, and source capital for farming. Charcoal has also made it possible to buy consumer goods like food stuffs, clothing, children's educational needs, and hospitals bills.

4.3 Assess the Impact of Charcoal Production on Forest Degradation in the Study Area

Charcoal production (24 percent) is second to land clearance (66 percent) in its negative contribution to forest degradation in the study area (Figure 4.3). The study area is known for large scale groundnut, millet and maize farming, which causes opening up of more land to meet demand for agricultural production. Other drivers of forest degradation in the study area are livestock grazing (6 percent) and bush fires (4 percent) as indicated in Figure 4.3 of the study.

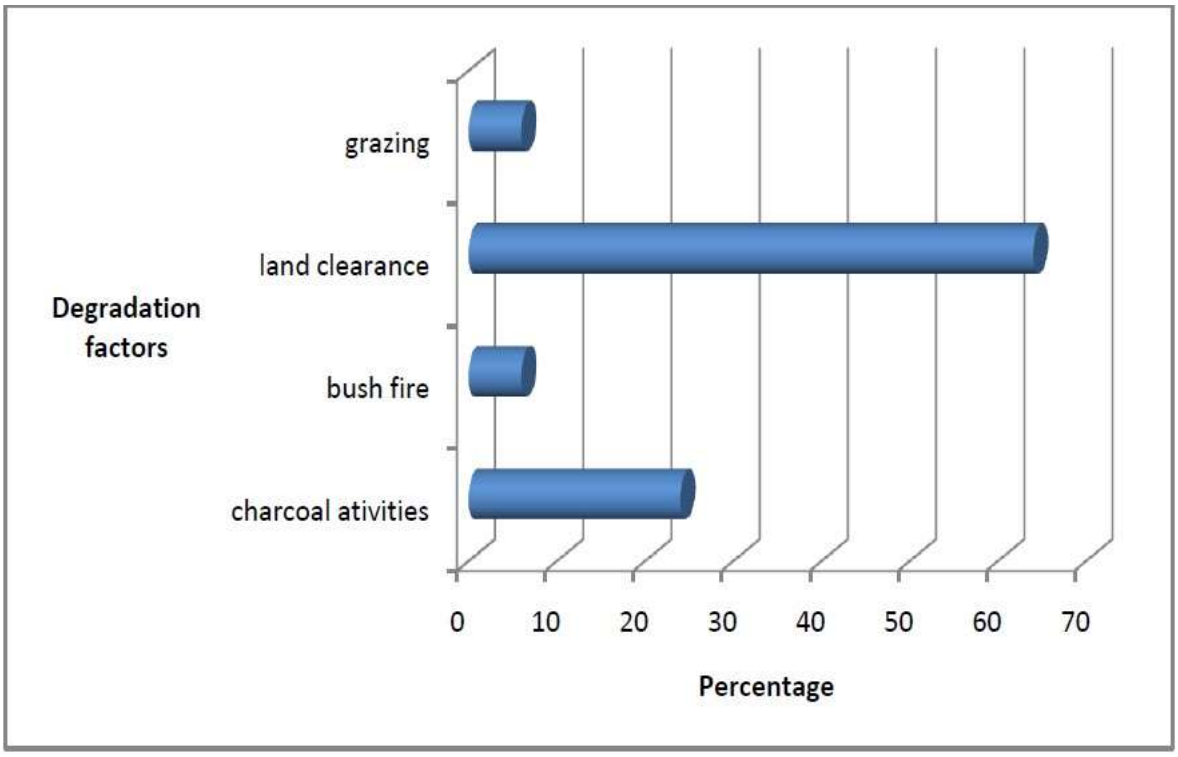

Figure 4.3: Forest Degradation Factors in the Study Area

Source: Field Survey (2022)

Majority of charcoal producers (76 percent) have limited knowledge of impacts of their activities on forest status (Figure 4.4). Only 24 percent believed charcoal production activities was a factor responsible for forest degradation in the area. They attributed the

change in forest status to other causes (76 percent) such as grazing, land clearance, and bush fires (Figure 4.3).

Plate IV: Forest Degradation in Kusoko Community of the Study Area

Source: Field Survey (2022)

As revealed in Plate IV of the study, the available trees were used for charcoal production and other tree uses. The charcoal producers surveyed acknowledged that deforestation was associated with negative impacts on their day to day livelihood activities. The selected communities in the study area are heavily reliant on rain fed agriculture as majority (36 percent) of the respondents talked of ever declining rainfall amount as compared to past relatively high amount of rainfall experienced in the area before clearance of the lands. The respondents also listed some of the impacts they experience directly or indirectly as a result of deforestation including loss of livestock

pastures (22 percent), soil erosion (14 percent), loss of biodiversity (8 percent), loss of wild food/fruits (4 percent), loss of medicinal plants (4 percent), and flash floods (12 percent) as shown in Figure 4.4 of the study.

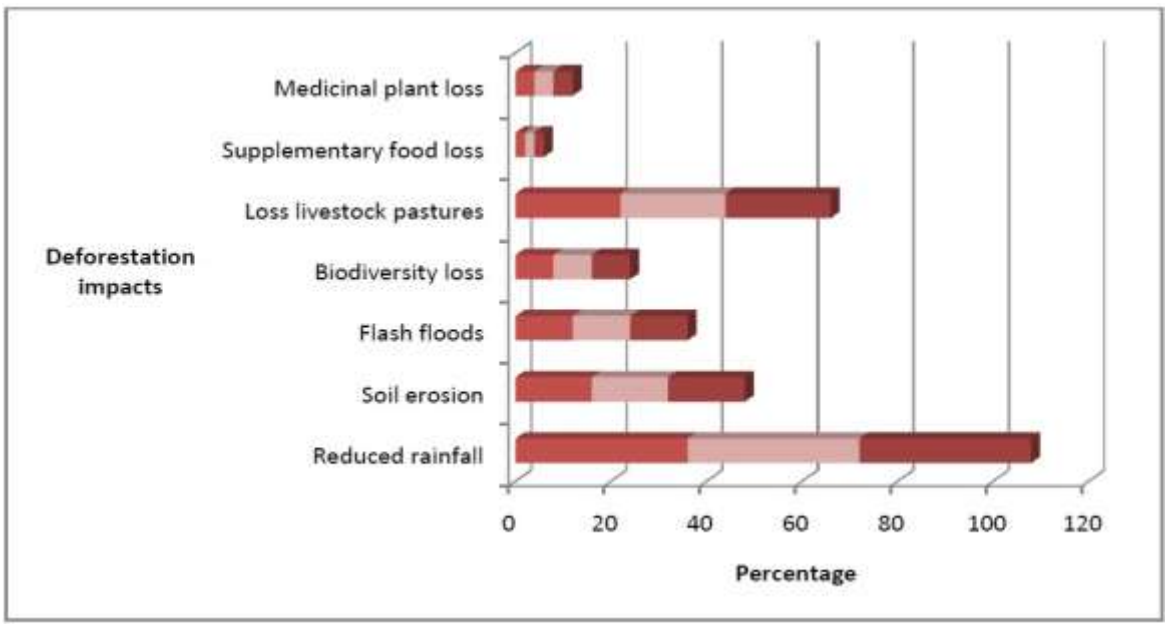

Figure 4.4: Negative Impact of Charcoal Production on Forest Degradation

Source: Field Survey (2022)

Most of the respondents perceived that there is no need to resuscitate the forest. This shows that the forest area will not regain its biomass on time and will suffer environmental degradation for a while. This study supports BTG (2010) that charcoal producers perceived that trees have a way of growing back once it is not uprooted from the soil.

Respondents agreed that charcoal production causes erosion and flood in the study area. This is because trees that are supposed to curb the washing away of the topmost soils had been removed during the process of charcoal production. Also, respondents affirmed that charcoal production causes land degradation in the study area. This implies that the deforestation activity that takes place in the study area will aggravates

land degradation in the study area. This study is in line with Jamala *et al.* (2013) that charcoal production is one of the primary causes of deforestation that leads to land degradation in areas involved in the business. Respondents affirmed that earth kiln method is not environmentally sustainable. This is because earth kiln method involves escalating top soil which will aggravate erosion and flooding. Also, the earth kiln method contributes significantly to atmospheric contamination and the emissions are usually released as part of the smoke into the atmosphere, posing an air-pollution problem.

4.4 Analyse the Afforestation Practices in the Study Area

As indicated in Table 4.4 of the study, the alternative use to charcoal include liquefied petroleum gas and fuel sawdust/biomass briquette.

Table 4.4: Alternative Use to Charcoal

Options	Frequency	Percentage (%)
Liquefied Petroleum Gas (LPG)	29	8.5%
fuel sawdust/biomass briquette	311	91.5%
Total	**340**	**100**

Source: Field Survey (2022)

As indicated in Table 4.4, fuel sawdust/biomass briquette ranked the highest with 91.5 percent of respondents and liquefied petroleum gas ranked the least with 8.5 percent of respondents. This implies that fuel sawdust is the major alternative use to charcoal in the study area.

As indicated in Table 4.5 of the study, 97.0 percent of the respondents affirmed that there is no appropriate afforestation programmes in the study area while 3.0 percent

affirmed that there are few afforestation programme which include planting of non-economic trees (Gmelina tree) in the study area. This implies that the forested areas will continue to undergoes depletion over time.

Table 4.5: Presence of Afforestation Programme

Options	Frequency	Percentage (%)
Agreed	10	3.0%
Disagree	330	97.0%
Total	**340**	**100**

Source: Field Survey (2022)

The afforestation programmes in Nigeria include Nigerian Forest Action Programme (NFAP, 1997) Great Green Wall and Forest Project (I and II). The numerous benefits of afforestation include addressing environmental degradation, more especially desertification, deforestation, erosion and flooding as well as reducing the effects of climate change. Afforestation also aids in increasing supplies of forest products for local consumption and supporting of local enterprises, as well as improving the socio-economic background of people through income generating activities such as sale of timber and non-timber products, enhancement of fuelwood availability, employment creation through planting, weeding, tending, thinning, protection and harvesting of tree species and expansion of raw materials base for industrial development.

As indicated in Table 4.6 of the study, the mitigation measures include afforestation and enrichment planting; tree planting campaign; agroforestry practices; enforcement of forest law and policy; forest education and forest conservation and management.

Table 4.6: Mitigation Measures for Forest Degradation in the Study Area

Mitigations	Frequency	Percentage (%)
Afforestation and enrichment planting	41	12.1%
Tree planting campaign	137	40.3%
Agroforestry practices	60	17.6%
Enforcement of forest law and policy	74	21.8%
Forest education	21	6.2%
Forest conservation and management	07	2.0%
Total	**340**	**100%**

Source: Field Survey (2022)

As revealed in Table 4.6 of the study, tree planting campaign ranked the highest with 40.3 percent of the respondents, Enforcement of forest law and policy ranked second with 21.8 percent of the respondents, agroforestry practices ranked third with 17.6 percent of the respondents and forest conservation and management ranked the least with 2 percent of the respondents. This implies that tree planting campaign was the major perceived selected mitigation measure that will address forest degradation due to charcoal production in the study area. Adequate education and knowledge about the importance of the forests and the roles in enhancing healthy life will reduce deforestation and forest degradation in the study area.

4.5 Summary of Findings

The summary of findings for this study include:

a. The results in Table 4.1 revealed that 63.2 percent of the charcoal producers were males while 36.8 percent were females. The mean age of the respondents is 42.9 years and most of them were native of the study areas. Results show that respondents have basic education and their major occupation is farming (70.3 percent). Due to their early involvement in the charcoal enterprises, respondents' years of experience fall between 16-29 years (44.4 percent). Most of the respondents in the study area were native of the communities; this suggests that respondents were familiar with the terrain of the area and will be able to explore other forest areas in the study area. Farming is the predominate occupation of the respondents, this infers that respondents will have the opportunity to venture into charcoal production during the off-farm season.
b. As indicated in Table 4.2 of the study, high prices of alternate energy sources for cooking ranked the highest causes of charcoal production with 48.2percent respondents, poverty ranked second cause with 31.2 percent respondents, population growth ranked third with 13.8 percent and urbanization ranked the least with 6.8percent respondents. This revealed that high prices of alternate energy sources for cooking was the major cause of charcoal production in the area as kerosene and gas where very expensive for average household head in the study area.
c. As revealed in Table 4.3 of the study, no preference ranked the highest with 36.5 percent of the respondents, Shea butter tree ranked second with 19.7 percent of the respondents, Acacia species ranked third with 14.7 percent and Mahogany ranked the least with 6.8 percent of the respondents. The results on Table 4.3 shows that respondents prefer to use trees like *Butyrosopermum paradoxium,*

Dialium guineense, Terminalia glaucencens, Acacia species, no preference and *Khaya ivorensis.* Other species used in the study area in little quantity include *Vitellaria paradoxa, Anogeissus leiocarpus, Bridelia ferruginea, Terminalia spp,* and *Pericopsis laxiflora*. This is because of the unique features of these trees to produce good quality charcoal.

d. Charcoal producers (28 percent) interviewed had a strong feeling that establishment of specific tree species plantations in the study area would improve and make the charcoal industry sustainable as shown in Figure 4.1. legalization (22 percent) of sustainable commercial charcoal production and movement will be a boost to the industry and an end to illegal and unsustainable charcoal practise in the study area. Strengthening and formation of more charcoal producers associations (16 percent) in the study area will ensure sustainable charcoal production as members are trained and equiped with necessary knowledge to ensure sustainability in charcoal industry as shown in Figure 4.1 of the study.

e. As revealed in Figure 4.2 of the study, livelihood source ranked the highest with 49 percent of respondents, business capital ranked second with 20 percent of respondents, generate money for farming ranked third with 10 percent and money source for livestock ranked the least with 5 percent of the respondents. This implies that respondents have benefited from the charcoal business socioeconomically which have improved the standard of living of the respondents in the study area.

f. Charcoal production (24 percent) is second to land clearance (66 percent) in its negative contribution to forest degradation in the study area (Figure 4.3). The study area is known for large scale groundnut, millet and maize farming, which

causes opening up of more land to meet demand for agricultural production. Other drivers of forest degradation in the study area are livestock grazing (6 percent) and bush fires (4 percent) as indicated in Figure 4.3 of the study.

g. The charcoal producers surveyed acknowledged that deforestation was associated with negative impacts on their day to day livelihood activities. The selected communities in the study area are heavily reliant on rain fed agriculture as majority (36 percent) of the respondents talked of ever declining rainfall amount as compared to past relatively high amount of rainfall experienced in the area before clearance of the lands. The respondents also listed some of the impacts they experience directly or indirectly as a result of deforestation including loss of livestock pastures (22 percent), soil erosion (14 percent), loss of biodiversity (8 percent), loss of wild food/fruits (4 percent), loss of medicinal plants (4 percent), and flash floods (12 percent) as shown in Figure 4.4 of the study.

h. As indicated in Table 4.4, fuel sawdust/biomass briquette ranked the highest with 91.5 percent of respondents and liquefied petroleum gas ranked the least with 8.5 percent of respondents. This implies that fuel sawdust is the major alternative use to charcoal in the study area.

i. As indicated in Table 4.5 of the study, 97.0 percent of the respondents affirmed that there is no appropriate afforestation programmes in the study area while 3.0 percent affirmed that there are few afforestation programme which include planting of non economic trees (Gmelina tree) in the study area.

j. As revealed in Table 4.6 of the study, tree planting campaign ranked the highest with 40.3 percent of the respondents, Enforcement of forest law and policy ranked second with 21.8 percent of the respondents, agroforestry practices

ranked third with 17.6 percent of the respondents and forest conservation and management ranked the least with 2 percent of the respondents. This implies that tree planting campaign was the major selected mitigation measure that will address forest degradation due to charcoal production in the study area.

CHAPTER FIVE

5.0 CONCLUSION AND RECOMMENDATION

5.1 Conclusion

Land use in the study area is driven by the socio-economic needs of the communities in Mokwa Local Government Area of Niger State. There is need to balance the economic and livelihood needs of the local people with environmental sustainability of the forestland system, as degradation of the environment will feedback directly on the livelihood options of the inhabitants. This would require working with the local communities in Mokwa Local Government Area and other stakeholders to identify criteria and indicators of a sustainable forestland system while taking into account the diverse views, interests, preferences and expertise of the stakeholders. Based on this engagement, holistic guidelines on forestland resource management and use can be developed towards an integrated land use management approach in order to balance the various land uses and ensure sufficient regeneration of woodland species valuable for the livelihood of the inhabitants and the ecological values of the study area.

From a very long-term perspective, this activity (production of charcoal) will continue to take alarming directions due to the rising demand of charcoal for domestic uses in urban areas of the State and Nigeria as a whole. Therefore, the degraded land could be used to plant fast-growing species for charcoal production to minimize the impact of charcoal production on natural forest.

Degradation of natural forest without adequate measures to restore or conserve reduces its ecological and economic benefits capacity. Charcoal producers are motivated by the

financial benefits arising from their activities to carry on with the destruction of natural environment. Further uncontrolled indigenous wood species extraction without corresponding replacement measures will reduce the capacity of trees cover to provide pasture, control soil erosion, medicine and energy requirement for society and livestock. Therefore alleviate the existing human sufferings.

The resultant impacts from vegetation cover destruction will be imminent and adversarial on ecological balance and wildlife survival. The reduction of natural forest cover and subsequent destruction of plant species will mean threatening of wildlife species as a result of continuous destruction of their habitats. The unsustainable charcoal enterprise may disadvantage the future generations from enjoying benefits associated with natural forest.

5.2 Recommendations

Based on summary of findings and conclusion, the following were recommended to enhance forest resources in the study area and Niger State as a whole.

1) Charcoal policy innovations should address the negative images and controversial image of charcoal through concerted and targeted evidence-based advocacy, highlighting the wood-fuel sector's benefit as an important productive economic sector, deserving higher prominence in key economic development proposals.
2) From the short-term perspective, it is possible by offering the local market charcoal produced from faster growing tree species, e.g., *Eucalyptus*. This can be attained through awareness and improvement of the efficiency of cooking stoves to minimize energy losses. In the long-term, we suggest establishing a

timeframe of about 20 years, during which other fast-growing trees should be planted as a communal forest project in combination with agro-forestry systems.

3) There is need for an alternative source of energy in order to reduce the demand on charcoal and there is need for Government to encourage sustainable forest management in order to curb indiscriminate felling of trees.
4) With effective charcoal regulations implementation and controlled utilization of forest resources, charcoal production impacts on vegetation will be minimized whilst maximizing on economic benefits from the enterprise.
5) Development of good poverty reduction interventions and enhancement of alternative income sources (crop farming, ecotourism and livestock farming) in the study area will also prevent the situation of many people venturing in charcoal production which could have dire impacts on natural environment.

6) Forest resource management should be integrated into educational curricular as part of being considered a civic education to bring into attention the importance forest resource to the country's economy and stakeholders involved in forest resource conservation should emphasize on collaboration with local people in forest conservation.

7) Conservation plans and practical measures of replacing the extracted trees from the forest for charcoal production should form the basis for license issuance for charcoal production.
8) The introduction, promotion and utilization of briquette coupled with a good forest management, supervision and control practice will limit the effect of charcoal production on our forest estates.

9) Furthermore, the promotion of fuel-efficient stoves will also help in reducing the unsustainable production of charcoal and if there is an improvement through tree planting initiatives and preparatory forest management unsustainable charcoal production will soon be over.

5.3 Contribution to Knowledge

The study established that high price of alternate energy sources for cooking 48.2%, poverty 31.2%, population growth 13.8% and urbanization 6.8% as the driving factors of charcoal production in the study area. The study established that most of the trees used are *Butyrosopermum paradoxium, Dialium guineense, Terminalia glaucencens, Acacia* species and *Khaya ivorensis*. It was futher established that the woodland often selected for charcoal production are private or family owned and communal lands, 48.2 % of charcoal producer had a strong feeling that establishment of specific tree species plantations in the study area would improve and make the charcoal industry sustainable. The study also identified loss of livestock pastures 22%, soil erosion 14%, loss of biodiversity 8%, loss of wild food/fruit 4%, loss of medicinal plant 4% and flash floods 12% as the impacts charcoal production in the study area. The implication of this study is that persistent production of charcoal may have further aggravate its consequences on vegetal cover of the study area if drastic actions are not taking to curb the menace. Therefore, there is need to balance the economic and livelihood needs of the local people with environmental sustainability of the forestland system, as degradation of the environment will feedback directly on the livelihood options of the inhabitants.

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