Original Research Article

Forest clearance and fragmentation for charcoal production: the case BimbiaBonadikombo forest South West Region, Cameroon

Abstract

The exploitation activities of man on natural resources have hardly been sustainable. This study examined the implication of charcoal production on the BimbiaBonadikombo forest and it's environ. The study employed both direct field observationandquestionnaire administrationfor data gathering. Questionnaires were administered to charcoal producers and persons involved in charcoal related activities.Persons were selected using snowball technique.A total of 42 copies of questionnaires were administered to charcoal producers and related activities.Tree species used for charcoal production were noted, identified.The questionnaire was divided into five sections:(i) socio-demographic characteristics of charcoal producers, (ii)methods of charcoal production and species selected (iii)aspects influencing charcoal production and the implication on the ecosystem, (iv)seasonal trends and challenges faced (v)constraints and mitigation strategies used). Data collected were organized in Microsoft Exceland Statistical Package for Social Sciences (SPSS) was used for the analyses.Pearson (ρ)correlation association was used for the relationship between variables of production and the demand of charcoal. The result revealed that,majority of the respondents, 78.57%, were males while females were least 21.43%. Majority of the respondents (54.76%) were between the ages of 31-46 while the least with ages >47.*Lophira alata*14 (35.71%) was the tree species ranked 1st while*Irvingiagabonensis*1(2.38%) was the least and ranked 8th. The main aspect that influenced production was revenue generated 14 (33.33%) while weak institutions 2(4.76%) and crises situations 2(2(4.76%) were the least.Deforestation 12(28.57%) and habitats destruction 8(10.04%) were the main effects reported for charcoal production. Production and the demand of charcoal variables showed a positive association (0.153±.361).The management strategies employed were: only matured trees were used for charcoal production, permanent charcoal pit kiln are dug out of forest canopy and only few tree species are used for charcoal production. For mitigation purposes used are:domestication, protecting wild charcoal trees in their farms and nurseries establishment. This study recommends that charcoalis a major source of energy and alternative source of energy when others failed or insufficient. Therefore, this source of energy can be enhanced to be more eco friendly and environmentally sustainable.

Key words: charcoal, deforestation, trees, pit kiln method, energy, forest resource

1. Introduction

Energy is the main back bone that drives any country's social, cultural and economic development [1]. In many developing countries most of their primary energies are limited to fuel wood and charcoal for socio-cultural development and establishment. According [2] and [3], wood fuel is Africa's primary energy source for at least 70% of households. It is the major source of energy in rural areas both for domestic uses, in small-scale traditional industries and commercial enterprises.

Charcoal is the solid residue derived from controlled combustion of a wide range of materials under condition of limited supply of oxygen [4]. Charcoal has been used as heat source for ironing, cooking, heating or warming houses, as well as for drying and roasting food, fish and meat in rural and urban areas. Moreover, it is a cheap source of fuel to purchase and use. It is also a source of generating income through exportation and local sales in both local and urban markets[4]. Globally, 2.4 billion people rely on wood fuel, including charcoal as their main energy source for cooking, and smaller enterprises use fuel wood and charcoal as vital energy providers [5]. Though inefficient, wood charcoal provides a reliable, convenient and accessible source of energy for rural and urban uses. Electrical,kerosene and gas energies may be considered the most desirable cooking fuels in urban areas, but sometimes the availability and affordability makes it difficult for poorer households to procure.

The alarming rate of natural forest resources degradation and depletion, especially across the tropical rainforest is a call for concern in recent years [6] and [7].The exploitation activities of man on natural resources (charcoal, fuel wood timber, farming, fishing and mining) have hardly been sustainable based on the high demand and the increasing population that depend on this energy source [8].

The BimbiaBonadikombo forest reserve is a major part of this tropical forest resource and is the last remnantof a lowland forest on the hilly slopes of mount Cameroon[9]. Its vegetation is an important part of the physical environment. It provides necessities to humanity such as food, local materials for construction, medicine (goods) and shelter, clean air, water cycle, water sheds etc (services)[10]. It is worth mentioning that this vegetation provides fuel energy essential for humanity survival. Of these forms of energies, charcoal has been steadily produced over the years[11]. The growing demand for charcoal, due to population growth and urbanization, has led to increased wood extraction and rapid forest encroachment. Charcoal energy is highly demanded for roasting of fish, meat, pork, and foodstuffs in the touristic town of Limbe[12].

BimbiaBonadikomboh forestwhich is a stone throw to the rapid growing city of Limbe, provide a number of these natural resources to the environs and beyond. The large touristic city of Limbe offers huge markets for the sale of charcoal. The economic benefits of charcoal have encouraged tree felling resulting to habitat fragmentation, habitats destruction, species loss and above all forest degradation and depletion[9]. This situation has further been exacerbated by the influx of youths from crises zones, who have mostly settled close to this natural resource for faster and cheaper means of generating income for themselves through its exploitation. Moreover,the demand keeps exerting pressure on the wood for charcoal production in the forested area.

Almost all activities associated with charcoal production in this areaare illegal; production, transportation and distribution remain informal and unregulated. There is little or no regulation from the forestry department and the eco- guards to re-enforced security in the forested area. However, it is for these reasons this study aimed to: to identify the socio-demographic characteristics of charcoal producers , and those involved in charcoal related activities (loaders, transporters, engine saw operators etc) in the study area, identify the trees which are used for

charcoal production and their local and international statuses, study the impact of charcoal production on the forest ecosystem and its environ, evaluate the season for high charcoal production, identification of the main problem faced by forest dwellers in charcoal production and the strategies used for mitigating the environmental effects.

2. Materials and Methods

2.1 Study site

The study was conducted in the Bimbia-Bonadikombo Forest which is situated in the eastern part of Limbe, South West Region (Figure 1). The Bimbia-Bonadikombo community forest (BBCF) was created on May 18, 2002. It has a surface area of 3,735 hectares[12].The forest is bordered by Mandolin to the north, through Mile Four and Tomatal behind MoliweCameroon development corporation (CDC) palms plantations. It stretches from the Ombe River down through Camps 3 and 2 of the CDC Rubber Plantations to the road. Six main vegetation types are reported in this area, these include:the coastal bar forest, mangrove, littoral vegetation, freshwater swamp forest, freshwater ecosystems and lowland forest that dominate the BBCF.The community is peri-urban, located on the fringes of the Limbe (Victoria) urban community. They are five villages located at the periphery of the forest (Bonadikombo, Bonabile, Bonangombe, Liwanda and Dikolo). The population is cosmopolitan and their main activities are agriculture and non timber forest products (NTFPS) collection. Rainfall, temperature and humidity are high [13]. Annual rainfall is between 4000 and 5000 mm per annum. A short dry season is experienced between Decemberand February.

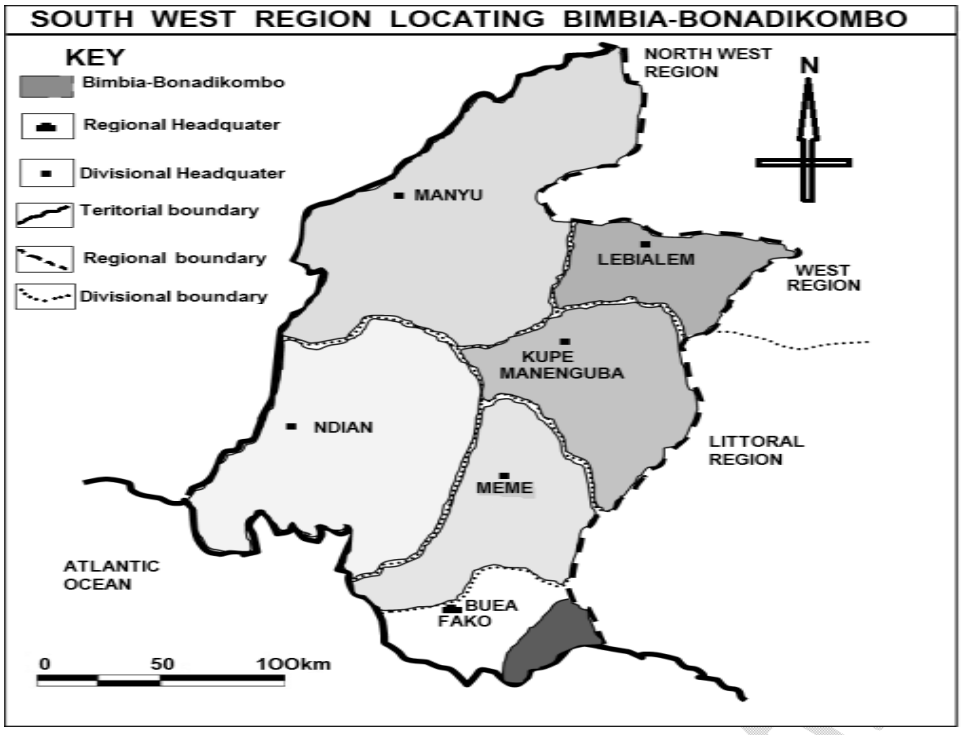

Figure 1: Map of study area showing BimbiaBonadikobo forest reserve

2.2 Sampling technique and data collection

This study employed both direct field observationandquestionnaire administrationfor data gathering. Questionnaires were administered to charcoal producers and persons involved in charcoal related activities (chain saw operators, potters, transporters and whole sale buyers) in communities around the periphery of the BimbiaBonadikombo community forest.The snowball technique was used to select all charcoal producers and persons involved in the charcoal producing activities.This technique gives room for; the first charcoal producerhelps locate the next till all were reached.All identified persons were administered copies of questionnaires.A total of 42 copies of questionnaires were administered to charcoal producers and persons involved in charcoal related activities in the study areas.

During the field observation, photos on the processes of charcoal production and bagging were taken. Tree species used for charcoal production were noted, and unidentified species were taken to the Limbe Botanic garden herbarium for identification.

The questionnaire was divided into five sections. Section I involved: the socio-demographic characteristics of charcoal producers and persons involved in charcoal related activities. The following questions were asked in the section: age range, sex, educational level, marital status, region of origin and main occupation. Section II comprised: the methods of charcoal production and species selected for charcoal production. Section III involved factors that influence charcoal production and the implication of charcoal production on the ecosystem or environment. Section IV involved: seasonal trends and challenges faced by charcoal producers. Section V dealt with mitigating strategies used by producers

2.3 Data Analysis

The data collected were organized in Microsoft Excel and exported to the Statistical Package for Social Sciences (SPSS) for the analyses. Descriptive Statistics were used for the summarization of data into frequencies and percentages. The Pearson (ρ)correlation association was used to test the relationship between variables of production and the demand of charcoal.

3. **Results**

3.1 Demographic characteristics of respondents

The demographic characteristics of the forty-two (42) respondents are shown in Table 1. The majority of the respondents, 78.57%, were males while 21.43%, were females (Table 1). Since charcoal production is an energy demanding activity, it is dominated by males. This finding is in line with works of [5] and [14] who noticed more of male than female in activities that demand

more energy. Majority of the respondents (54.76%) were between the ages of 31-46, and were closely followed by respondents between the age ranges 15-30 (28.57%). This is an active age group and charcoal production is an energy demanding activity requiring individuals in their productive ages (Table 1). This finding collaborates with the work of [15] who observed that the age range, (31-46) is an active age group in human life. The least respondents (16.66%) were` between the ages above 47years [15] also reported that this age group and above are more sessile and less energetic with activities that requires more energy. Seventy five percent (75%) of the respondents were married while 25% were not married. The higher number of married to unmarried could be attributed to labour force provided by the family than unmarried. This finding is in conformity with[16] who mentioned that married person's offer division of labour in any task which makes the job lighter. Seventy six percent and above (76.18%) of the respondents had attained secondary and high schools, while 16.66% just had the primary school leaving certificate (Table 1). Most of the charcoal producers had some level of education but most of them are school drop outs. Probably, the high number of drop out could be lack of finances to further their education into higher institutions. Ninety percent (90%) of the respondents were mainly farmers, 5% were NTFPs gatherers and the other 5% were bike riders (Table 1). This is because of proximity to resources and during off seasons in farming, most of the farmers are engaged in other activates to make more money. This finding is in line with [17] who mentioned forest income and poverty alleviation through gathering of forest products. [18] also reported that individual closer to natural forests depend on the resources such as NTFPs for their livelihoods. Most of the farmers regions of origin were North West and South west region with percentages of 54.76%and 45.23% respectively. The high percentages of these two regions

could be attributed to crises in these two regions. Most of the respondents flee to find refuge close to areas where they could generate monies for livelihoods

Table 1: Demographic characteristics of charcoal producers

Variable		Number of respondent (42)	Frequency (%)
Sex	Male	33	78.57
	Female	9	21.43
Age range	15-30	23	54.76
	31-46	12	28.57
	>47	7	16.66
Marital status	Married	32	76.19
	Singled	10	23.8
Level of education	No education	3	7.14
	Primary	7	16.66
	Secondary	22	52.40
	High school		23.80
Occupation	Farmers	30	71.42
	Transporter (bike man)	7	16.66
	NTFPs gatherers	5	11.9
Region of origin	NW	23	54.76
	SW	19	45.23

3.2 Tree preference and local status in charcoal production

*Lophira alata*15 (35.71%) was the tree species ranked first (1st) by charcoal producers within the study area (Table 2). It was also noted that this tree species status was locally threatened in the study area (Table 2). The high use of this tree species was attributed to its high density that makes it a hard wood over other tree species. It was also noticed that the high density of the wood gives better and high quality charcoal over other tree species. [15], confirmed this finding that hardwood gives higher charcoal yield than soft woods. *Rhizophora racemosa*7 (16.66%) was closely followed and ranked second (2nd) by charcoal producers within the study area (Table 2). It was noticed that the tree species status was locally threatened in the study area.*Irvingiagabonensis* was the species utilized least in charcoal production at the study site. It was observed that the tree species was available within the study area (Table 2). This may be due to the fact that*Irvingiagabonensis*is highly used as NTFPs than being exploited for charcoal production. [19], reported on the marketing and the livelihood potential of*Irvingiagabonensis* as NTFPs that makes the tree species least used. Most forest communities used it as a soup thickener. Most farmers reported that only the older trees of *Irvingiagabonensis* were used for charcoal production since productivity of the species drops as the plant ages.

Table 2: Tree species used for charcoal production ranks, and frequency in the study site

Family	**Species/rank**	**Local status**	**Frequency**	**Percentage (%)**
Ochuaceae	*Lophira alata* (1)	T	15	35.71
Rhizophoraceae	*Rhizophora racemosa*(2)	VT	7	16.66
Olacaceae	*Strombosiagrandifolia*(3)	R	5	11.90
Sapindaceae	*Allophylus africanus* (4)	T	4	9.5
Rutaceae	*Zanthoxylum gilletii*(5)	T	3	7.14
Phyllanthaceae	*Margaritariadiseoidea*(5)	T	3	7.14
Myristicaceae	*Staudtiakamerunensis*(7)	T	2	4.76
Olacaceae	*Stombosiapustulata*(7)	T	2	4.76

Irvingiaceae	*Irvingiagabonensis*(8)	A	1	2.38

*(T = Threatened, V= Very threatened, R= rare, A= Available)

3.3 Procedure of charcoal production in the study site

In this study area, charcoal was produced solely by the earth pit kiln method (Figure 2f). This was done by digging a large pit in which wood are piled in a systematic manner (Figure 2c). The charcoal producers mainly farmers and forest gatherers went to their farms with chainsaws, machetes, spade and hoes as the main tools for the activity. This was the traditional method used to minimize effects of regeneration and to promote growth of seedlings and trees. [20], agreed wth the findings of this study that the traditional pit kiln method was far more sustainable than the earth mould method (earth are dug and mounded on arranged wood). Also, [21], mentioned the sustainability and innovation in charcoal production using the traditional pit method. The main tree species recorded for charcoal production are: *Lophira alata,Rhizophora racemosa,Strombosiagrandifolia,Allophylus africanus,Zanthoxylum gilletii,Margaritariadiseoidea*(Table 2). These charcoal tree producing species are ranked from top to bottom with the species at the top of the rank being the most desired. Most of the species were locally threatened and new tree species *StaudtiakamerunensisStombosiapustulata, Irvingiagabonenis* is currently being incorporated in the existing list of species used in producing charcoal. In the production process the tree species are initially split into large sizes and arranged in a manner to allow aeration during burning (Figure 2c). Then earth was applied to cover the wood and the stones at the sides to facilitate removal of combusted wood after a week or two of burning, depending on the type of tree species and the size of the pit. Thereafter, the charcoal is

then removed, allowed to cool, and bagged, ready to be supplied to the main markets of the town (Figure 2f).

Figure 2: (a) Forest clearance/logs felled for charcoal production, (b) logs split to desirable sizes (c) splitted logs arranged in the earth pit kiln (d) earth pit kiln are covered by stones at the side and earth on top (e) earth pit kiln opened at the side of stones to exposed ready combusted charcoal (f) bagged charcoal, transported from forest to market

3.4 Aspects influencing charcoal production

High demand for charcoal, lack of job, forest proximity, poor lawenforcement, weak institutions and crises situations were the main factors influencing charcoal production in the study site (Figure 3). High demand of charcoal product (revenue generated) 14 (33.33%) was noted as the main aspect that influencing charcoal production in the study site. Proximity to forest 9(21.42%) was the closely followed aspect influencing charcoal production in the study site. Weak institutions 2(4.76%) and crises situations 2(2(4.76%) were the least aspects influencing charcoal production in the study sites (Figure 3). [22], mentioned similar findings that the high demand for charcoal for revenue, lack of jobs and forest proximity were the main aspects that influenced charcoal production in the study site. [8] also reported that weak institutions and poor law enforcement in the study area influenced charcoal production.

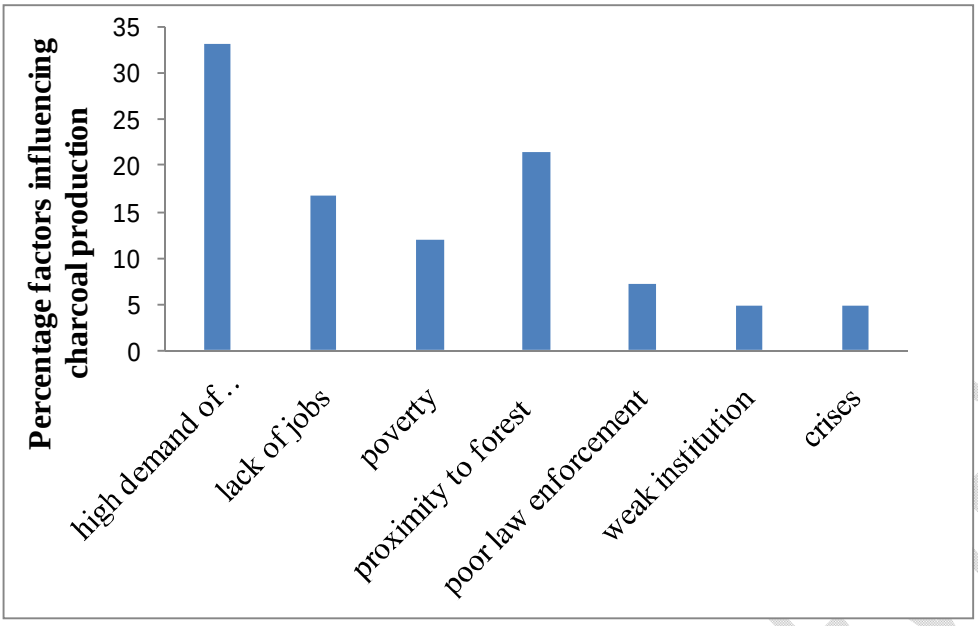

Figure 3. Factors influencing charcoal production in the study site

3.5 Effect caused by charcoal production on forest ecosystem

Deforestation, forest degradation, pollution, poor regeneration of trees, habitat destruction, and wildlife reduction/ loss were reported as the major effects of charcoal production at the study site (Figure 4).Deforestation 12(28.57%) and habitats destruction 8(10.04%) were the main effects mentioned by charcoal producers in the study site. Perhaps, this may be due to modification of habitats and niches thus resulting to wildlife reduction or loss. [23] findings were in line with the findings of this work that the main effects of charcoal production were deforestation, pollution and poor regeneration. [24], reported similar findings that deforestation and forest degradation were the major effects of charcoal production. Pollution 7(16.66%) was the closely followed aspect reported by charcoal producers in the study site (Figure 4). This may be due to the fact that, the high burning of wood resulted to huge pollution in the atmosphere. This may greatly influence the weather and the climate in the future. [25], reported similar finding in their work on biophysical of environment of Abuja council which resulted in variation in climate. Wildlife

reduction/loss 2(4.76%) was the least effect obtained on forest ecosystem in the study site. Perhaps this may be due to destruction and fragmentation of fragile habitats of these animals resulting to reduction in population or extinction

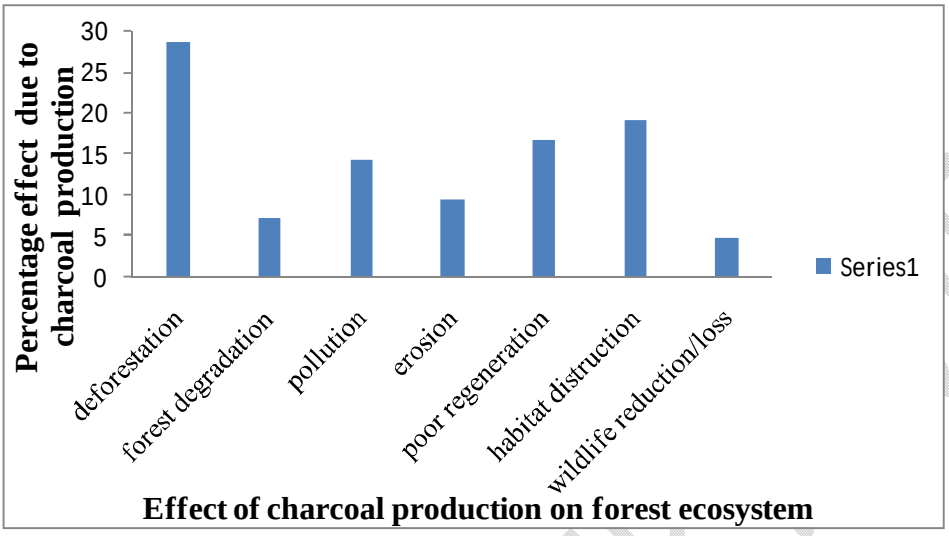

Figure 4. The effects of charcoal production on the study site

3.6 Monthly periodicity of charcoal production in the study site

The production of charcoal was noticed to be carried out throughout the year (Figure 5). The production of charcoal showed a V- shaped structure from January to December. However, the periodicity of charcoal production varied from January to December (Figure 5). This variability in production could be attributed to several factors such as: seasonality, road network, demand for charcoal and the distance covered by the producers for production. The highest period of production was noticed in the dry season (Figure 5). This finding may be due to easy accessibility to site of production. During dry periods the roads to these sites are more accessible than in the wet season which coupled with remoteness makes it difficult for moto bikes and trucks reach them. Moreover, the dry season has so many festive periods such as Christmas and New Year in which demand for charcoal is high. [26] reported similar challenges in their work in

Tete Mosambique which they mentioned that road network and topography of the area as factor affecting charcoal production. The trend rises from October to December with the main peak 6.3 (15%) recordedin January and was closely followed with the peak of 5.47 (13%) observed in December (Figure 5). The least period of production of charcoal was noted in the heart of the rainy seasons (Figure 5). Probably this was attributed to challenging topography and road network from forest to market. The trend of production deceases to steep troughs of 3(1.26%) obtained in August (Figure 5)

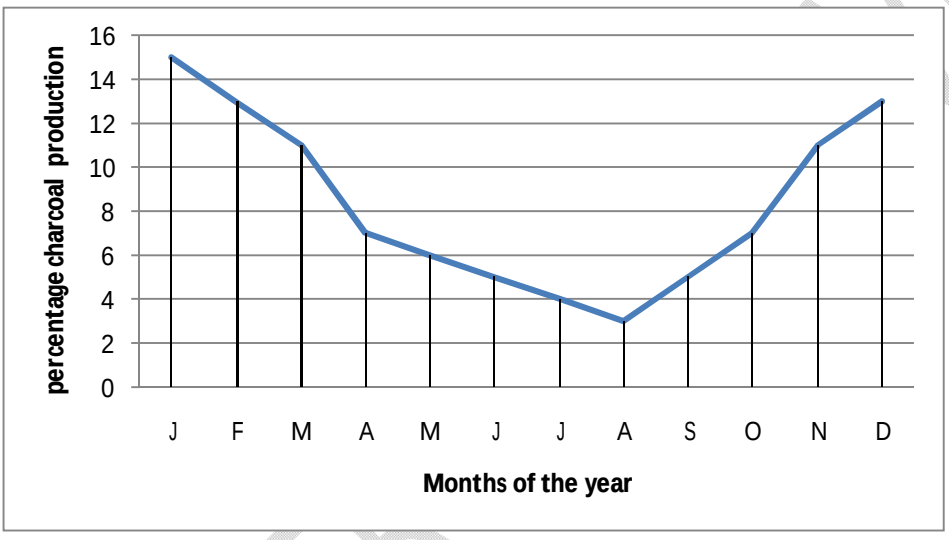

Figure 5: Variation in charcoal production across the study site

3.7 Periodicity of the demand charcoal in the study site

The demand of charcoal was noticed throughout the year in the study area. The periodicity of the demand of charcoal varied from January to December (Figure 6). The highest peak of 6.72(16%) was noted in August. Perhaps other sources of energy like firewood during August may not be efficient because of the poor weather as compared to charcoal usage. Secondly, the demand may be high but production was noticed to be low. This was attributed to poor road network from

forest to market and challenging topography to move charcoal from the forest. [5], also reported challenging conditions in Gummi local area Nigeria, they noticed that poor road network and lack of transport vessels influencing the impact of the demand of charcoal. It was closely followed by peaks of 5.04(12%) and 4.62(11%) reported in the months of December and January respectively. The lowest peak of 1.66(4%) was observed in April (Figure 6).

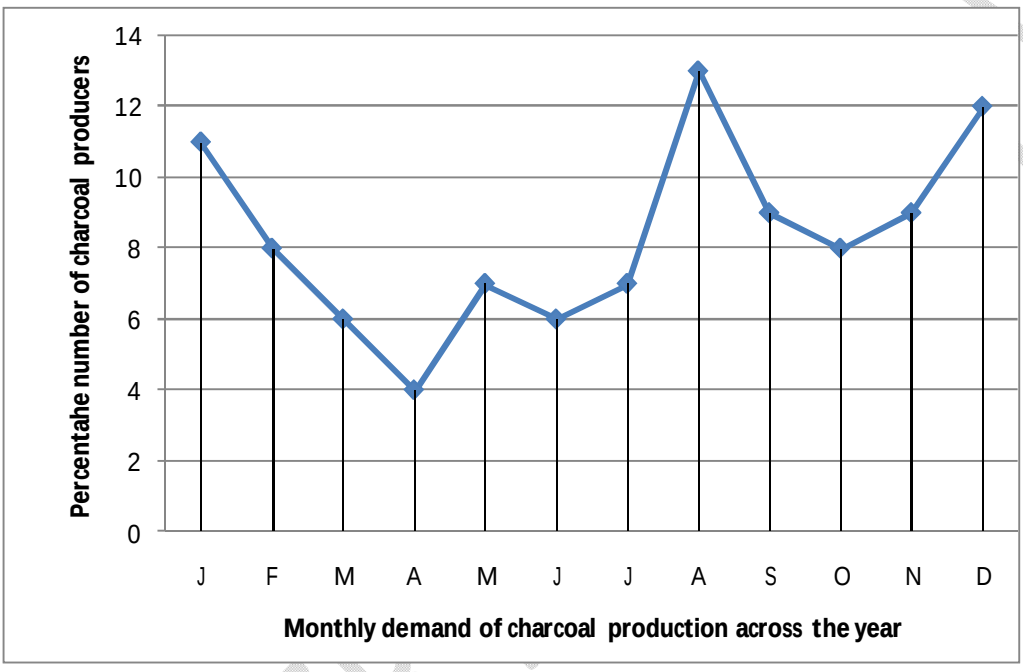

Figure 6: Variation in the demand of charcoal in the study site

3.8 Correlation between charcoal production and the demand of charcoal

Even though there was no correlation between charcoal production and the demand for charcoal had no correlation (P>0.05), there was a positive association (0.153±.361) between production of charcoal and the demand of charcoal in the study site (Table 3). Moreover, a positive association was noticed (0.158±.211) in the dry season for production and demand for charcoal. In the rainy seasons the production of charcoal and the demand of charcoal was showed to be significant P<

0.03), though negatively correlated (Table 3). This could be as a result of other factors that influencing the demand such as seasons, road network,

Table 3: Correlation between charcoal production and the demand of charcoal in the study site

Variable	ρ	Standard error	P. values	Remarks
Overall	0.153	±0.361	0.61	No correlation
Dry season	0.58	±0.211	0.306	No correlation
Rainy season	-0.79	±0.177	0.031	negative Correlation

3.9 Major short comings of charcoal production in the study site

The main short comings reported by charcoal producers in the study site were; depletion of preferred tree for charcoal production depleted, remote roads, and confrontation with eco-guards, seasonality and distances covered in the forest (Figure 7). Preferred tree species for charcoal production 15(35.71%) was the main short coming observed by charcoal producers of the study site. This could be due to the fact that most of the tree species used for charcoal production were getting depleted. Most of the charcoal producers covered long distances to get preferred tree or wood for charcoal production. [15], reported a similar finding in their work in Borgu local

government area that most preferred species were being over exploited resulting to depletion.

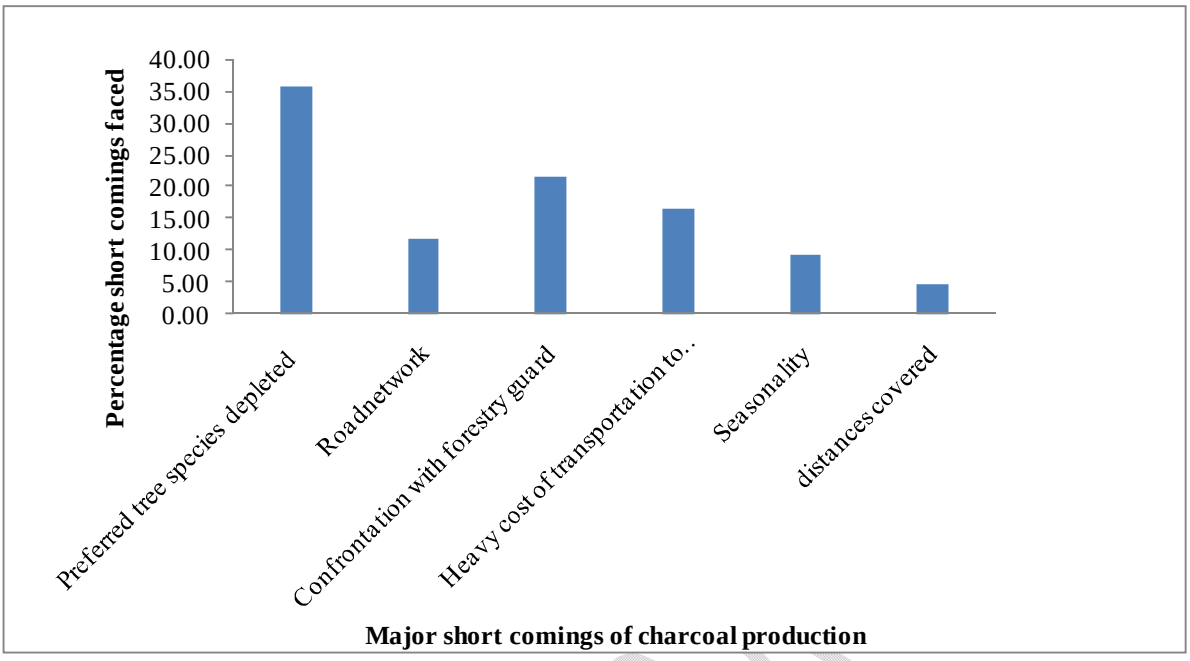

Figure 7: Main short comings faced by charcoal producers in the study site

4.0 Management and mitigation strategies charcoal producers used in the study site

The main management strategies employed by most charcoal producers as reported in the study site are: only matured trees are used for charcoal production, permanent charcoal pit kiln are dug out of forest canopy and only few tree species are used for charcoal production. For mitigation purposes few of the charcoal producers mentioned domestication, protecting wild charcoal trees in their farms and nurseries establishment of some of the charcoal trees in their farms. [5] and [20], mentioned related methods of mitigating the impact of charcoal production in their finding in in Sub Sahara Africa. They talked on agroforestry, afforestation and enlightenment on the danger of over exploitation.

4.1 Conclusion

This study concluded that the main drivers of forest clearance for charcoal production in the study site were: high demand of charcoal in the touristic site of Limbe, forest proximity, lack of job and the availability of tree species used in charcoal production. This study also revealed that the main trees exploited for charcoal production were:*Lophira alata,Rhizophora racemosa,Strombosiagrandifolia,Allophylus africanus,Zanthoxylum gilletii*and *Margaritariadiseoidea* most of which are locally threatened. Furthermore, charcoal producers covered longer distances in the forest in search of these tree species for charcoal production. The study also revealed that the activities of charcoal production cause the following ecosystem damages which were fragmentation of habitat and niches, loss of wildlife, erosion and poor regeneration. Although, major environmental problems are associated with charcoal production as noted in the present study, management options to mitigation them such as domestication, afforestation, agroforestry, protecting species used for charcoal production in their farm were noted. The study recommends that although charcoal production adversely hampered the environment, it is a major source of energy and alternative source of energy when others failed or were insufficient. Therefore, this source of energy can be enhanced to be more eco friendly (controlled burning, permanent charcoal pit, defected trees used etc) and environmentally sustainable for use in this site and other sites of the study area.

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