



The Socio-economic and Environmental Implications of Supplying Charcoal in Yaounde City

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Authors' contributions

This work was carried out in collaboration among all authors. Authors LD and MT designed the study. Author MT collected the data under the author LD supervision. All authors were involved in analyzing data and editing the paper. All authors read and approved the final manuscript.

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ABSTRACT

This article aims to identify and assess the socio-economic and environmental implications of supplying charcoal in the city of Yaounde. To achieve the above-mentioned goal, investigations based on a standardized questionnaire (130 charcoal producers and sellers), formal interviews (7 resource persons), informal discussions, field observations and floristic survey were carried out in Bikok between the last quarter of 2016 and the second quarter of 2017. Bikok, a subdivision located in the neighbourhood of Yaounde is one of the most important supply sites of charcoal for the city. Investigations revealed that, accelerated demographic growth over the past fifty years, unemployment and poverty constitute the main factors for the increase in the production and consumption of charcoal in the city. Poverty, unemployment and the urge for the satisfaction of basic needs constituted the main reasons for involvement of 98.8% of charcoal producers in the activity. The increase in urban demand for charcoal is at the origin of several significant biophysical impacts, including the degradation of forests and soils as well as the decrease in the availability of some Non-Timber Forest Products and animal species. In the survey villages, a total area of 3.1 hectares of forest is cut each year and the average distances from inhabited areas to harvesting areas, increased from 0.8 to 5 km in 10 years. 76.6% of charcoal producers believe that some animal species are increasingly rare in the locality. On the socio-economic level, this activity

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creates jobs, generates income thereby increasing the living standards of producers and sellers. More than 300 people are involved in this activity who earns on average an income of 3000 to 6000 Central African Franc (XAF) per day. Decrease in the availability of certain NTFPs and damage to the health of producers constituted some of the negative socio-economic impacts of this activity. It is imperative to adopt measures to limit the negative impacts of this activity while ensuring a sustainable supply of charcoal in the city or the use of alternative sources of fuel.

Keywords: Supply; charcoal; forest; implications; Yaounde.

1. INTRODUCTION

Woodfuel consumption is the major source of household energy in Sub-Saharan Africa with an estimated 93% of households in rural areas while 58% of households in towns and cities rely on it for daily cooking [1-2]. Over 80% of the energy supply in African countries comes from wood. Fuelwood accounts for about 90% of the total wood consumption in Africa, 81% of households use solid fuels while 70% depend on them as their primary energy source for cooking [3-4]. Nearly 60% of urban dwellers also use woody biomass as an energy source for cooking [5,4].

The most commonly cited impact of charcoal production is deforestation [6]. Apparently where high consumption levels are coupled with poor forest management and poor regulation of the charcoal trade, the impact of charcoal tends to be underestimated [7,6].

While some researchers argue that ecological damage from the extraction of fuelwood is not imminent [8], other recent studies suggest that fuelwood extraction for charcoal and firewood consumption may lead to forest degradation and loss [9,7,10]. Millions of urban dwellers in sub-Saharan Africa (SSA) cities, towns, and up-and-coming urban areas use charcoal daily to meet their cooking needs [10-12]. Charcoal is the main cooking fuel for millions of households in urban and peri-urban sub-Saharan Africa [13-14]. Numerous studies in certain large cities in Central Africa showed that, due to the increase in demand, peri-urban forests, already weakened by urbanization, play an essential role in the supply of wood and charcoal [15-18]. A study in Congo claimed that virtually all forest blocks and gallery forests around Brazzaville are largely overexploited or have disappeared [19]. The overexploitation of fuelwood is at the origin of the widening circle of deforestation around the towns of Garoua and Maroua. According to a similar finding [20], the Moroccan urban sector consumes 1,273,801 tonnes of charcoal per year.

In addition to the deforestation and degradation of wood resources, the production of charcoal is at the origin of negative impacts such as the amplification of climate change triggered by the emissions of greenhouse gases, reduction of ecosystem bio-productivity, fragmentation of wildlife habitats and soil exposure to erosion [21]. With rapid urbanization, demand for charcoal is expected to continue to increase in the foreseeable future [8,12]. The challenge for many governments has been responding effectively to the many dimensions of charcoal as both a solution and a problem. In a surprising number of cases, charcoal is not considered in the energy policies and programs of many of the largest consuming nations [22-24].

Policies for addressing charcoal have for the most part have been insufficient at meeting their objectives [22,14]. Rising costs of fossil fuels, accelerating impacts of climate change, and significant shortfalls in meeting energy access goals in the developing world calls for a re-examination of the potential that charcoal holds as a modern, renewable fuel contributing to low carbon development. A definitive fuel switch from firewood to charcoal is occurring today in many developing countries driven, primarily, by rapid urbanization [25,22,12]. Improved cook stove programs and fuel switching to 'modern' and 'cleaner' fuels have been the dominant approach for addressing the charcoal 'problem'. Banning of production, trade, and use of charcoal has been enforced in several countries, but due to protests and the lack of viable alternatives, they tend to be lifted soon after they are implemented [25,26, 24].

Despite the above-mentioned environmental consequences, people are motivated by the associated financial, social and cultural benefits and continue to destroy the natural environment [21,26]. This is due to the fact that it is an economic activity that fetches fast and easy income and does not require huge capital or prior skills [21]. Charcoal is often associated with poverty, i.e., with poor producers and poor

consumers. Zulu [27] reviewed the socio-economic implications of charcoal production, sale and use in sub-Saharan Africa, particularly in terms of its contribution to poverty alleviation. With high levels of poverty, the dependence on biomass energy sources continues to rise in sub-Saharan Africa [27,6].

The charcoal sector is a source of employment and income for producers, sellers and transporters [16,18,4]. Charcoal production provides employment to many rural poor suppliers of urban markets [15,2]. Growing urban charcoal demand and markets provide opportunities for income generation from the production of charcoal in rural areas where it is often the most commercialized resource, and from the sale of charcoal in urban areas [28,29,30]. It is estimated that 52.9% of the actors involved in Nasarawa State (Nigeria) earn 20,000 naira per month [21]. In Haut-Atlas Occidental (Morocco), a charcoal worker earns on average 85,000 dirham per year. Wholesalers earn 21,000 dirham per branch of wood [20]. The charcoal market also provides urban households with an affordable, convenient, and reliable source of energy and associated energy services at relatively stable prices [31-34]. Charcoal can be less expensive than electricity, both in terms of stove and fuel costs. A charcoal fire requires less maintenance than a wood fire. However, charcoal production can also have perverse effects on poverty. These include negative health impacts at the production and use sites generally associated with smoke inhalation and carbon monoxide poisoning [35,32,36].

Almost all of the major findings noted above are relevant for Cameroon. Indeed, Cameroon is not an exception to this general situation because 83% of Cameroon's populations depend on woody biomass as a source of energy, and in rural areas it is often the only available source of energy [36,4]. In 2008, estimates from the Energy Information System (EIS)-Cameroon revealed that, domestic energy consumption consisted of 82.3% of fuelwood, 30.6% of charcoal and 27% of gas throughout Cameroon. It is estimated that the quantity of fuelwood consumed in Cameroon increased from 7,500,000 m³ in 1980 to 12,000,000 m³ in 1998 [16]. According to the Ministry of Energy and Water [37], fuelwood consumption increased at an annual rate of 2.67% from 1981 to 2002.

The annual consumption of fuelwood in urban areas of Cameroon is estimated at 2,203,496 tonnes for firewood, and 356,530 tonnes for charcoal [38]. To meet this demand, the exploitation of peri-urban forests constitutes a source of proximity for many actors. In the current context of global changes, the relationship between cities and energy consumption patterns are major challenges for sustainable land use planning in many countries. Africa and in particular the sub-Saharan part, is one of the regions of the world where uncontrolled urbanization has experienced exponential growth for the past fifty years and has had enormous consequences on the environment. The sudden increase in urban populations and rapid urban expansion are accompanied by neither energy infrastructure, nor adapted consumption patterns [15].

The city of Yaounde, like many other cities in Cameroon and Africa, has experienced strong urbanization since the 1970s. The city had a population of more than 2,852,987 inhabitants in 2015, 12% of the total population and 22% of the urban population of Cameroon, Yaounde had an urban population growth rate of around 4.2% for the period 2010-2015 [39]. This rapid increase has significant effects on socio-economic development, a diversification of craft activities using wood energy (bakeries, embers, foundry and catering) and the increase in demand for firewood and charcoal. Deforestation in Cameroon linked to urbanization and the development of activities like the production of fuelwood (firewood and charcoal) has increased and constitutes a major concern [20,40,37].

The demand for wood energy in Yaounde metropolis is constantly increasing and likely to cause many problems for the sustainability of the sector. An important wood-energy sector has developed in neighboring districts of Soa, Bikok, Mfou, Obala, Awae, Mengang and Mbalmayo and plays a significant role in supplying Yaounde with charcoal. Such demands for firewood and charcoal can have numerous environmental, social and economic implications. In a context of rapid spatial expansion of the city, increased demand for charcoal and the concern for the preservation of ecosystem in Cameroon, peri-urban forests appear more than ever to be ambivalent spaces, between satisfactions of needs of the population in fuelwood and natural heritage to be protected [41]. In view of this scenario, it is useful to study the impacts of charcoal production on the woody resources that

surrounds the city. The objective of this study is therefore to identify and assess the main impacts of supplying Yaounde city with charcoal. This assessment is underpinned by the hypothesis according to which the exploitation of charcoal has significant negative environmental effects, with substantial contributions to monetary income and employment.

2 MATERIALS AND METHODS

2.1 Collection of Data

Investigations were carried out in one of the main supply circuits, Bikok sub-division, Center Region of Cameroon. This study collected data and information from both primary and secondary sources. Fieldwork took place between the last quarter of 2016 and the second quarter of 2017. The main tools used for data collections were; questionnaire survey, direct observations and interviews. The questionnaire survey was carried out with a sample population of 87 charcoal producers (a sampling rate of 61.26%) located in 12 villages in Bikok sub-division, 43 charcoal sellers (wholesalers and semi-wholesalers; a sampling rate of 52.43%) surveyed in 6 markets of Yaounde city (Mokolo,

Acacia, Mendong, Mvog-Bi, Byiem-assi, Nsam) and 12 charcoal transporters in both locations (Fig. 1).

Direct observations were carried out in all of the sites selected with the aim of assessing wood carbonization techniques as well as the extent of degradation of wood resources. Formal interviews were conducted with seven other resource persons which constituted; two staffs from the Ministry of Forestry and Wildlife (MINFOP), the head of the forestry post at Bikok, the mayor who controls the local development program of Bikok, the leaders of Nyomo and Meyila groups and one transporter. Informal interviews were carried out with many stakeholders of the activity mainly retailers in Yaounde city. In addition, plant surveys were carried out in two square plots of 50 meters each to better assess the impact of charcoal production on the degradation of biodiversity. The two plots were selected in an old fallow land and the secondary forest in Bikok. The quantification of charcoal production was done through the use of dendrometric indicators such as barrel height, average diameter, total wood volume and species.

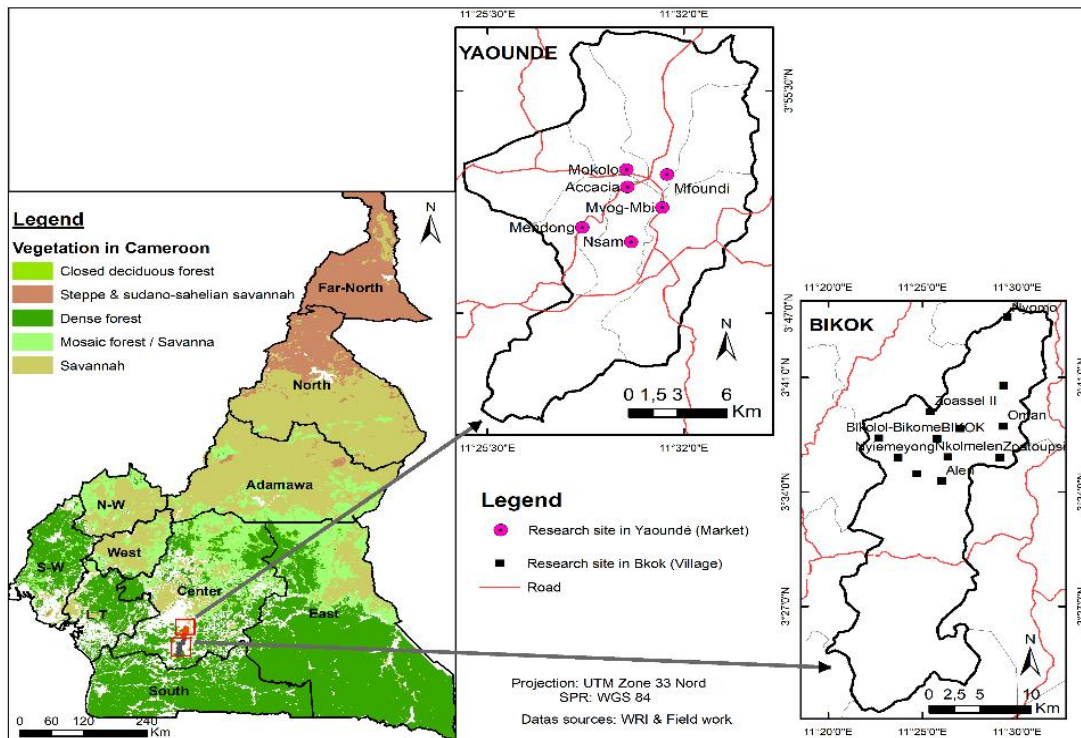


Fig. 1. Location of charcoal production sites and major markets

2.2 Data Processing and Analysis

The qualitative data obtained were analyzed according to a thematic approach of environmental dynamics, while the quantitative data were coded and analyzed using Microsoft Excel. The identification of the different impacts (biophysical, economic and social) was based on the matrices of Léopold [42]. The assessment of these impacts was based on their characterization. The criteria used were: nature, intensity, extent, duration and reversibility. This assessment was inspired by the work of Tchindjang [43]. The presentation of the results revolves around three points, the factors determining the demand of charcoal in Yaounde, the sector proper as well as its socio-economic and environmental impacts.

3. RESULTS

3.1 Factors Influencing the Demand for Charcoal in Yaounde City

3.1.1 Strong demographic growth

The city of Yaounde, like many capitals of developing countries, experienced a high rate of urbanization linked to rampant rural exodus. Indeed, with a growth rate of 6.8% between 1976 and 1987 and 5.7% in 1987 and 2005, its population increased from 180,000 in 1967 to

2,440,470 inhabitants in 2011 and to approximately 2,852,987 in 2015 [44,39]. Fig. 2 illustrates this growth.

Increased in population observed in the city of Yaounde has led to a considerable increase in the need for wood resources. Associated with insufficient access to fossil domestic energy as in many other cities in Cameroon, the increase in the urban population has led to an increase in demand for fuel wood; particularly charcoal.

3.1.2 Household energy needs and the evolution of oil and gas prices

The supply of domestic energy (gas and oil) in the city is considerable insufficiency due to the ever-growing population and the unsuitable energy policy. In addition to this insufficiency, the economic situation has favored the decline in the purchasing power of many households while the prices of fuels such as domestic gas and kerosene have also increased (Table 1). Household energy in the city is often rare and often experiencing an illegal increase in prices by certain unscrupulous sellers. Information gathered on the field shows that, rising prices for gas and kerosene is one of the major factors for the rise in the demand for charcoal. In fact, 52% of those surveyed confirmed that, the rise in fossil fuel prices have resulted to a rise in the use charcoal.

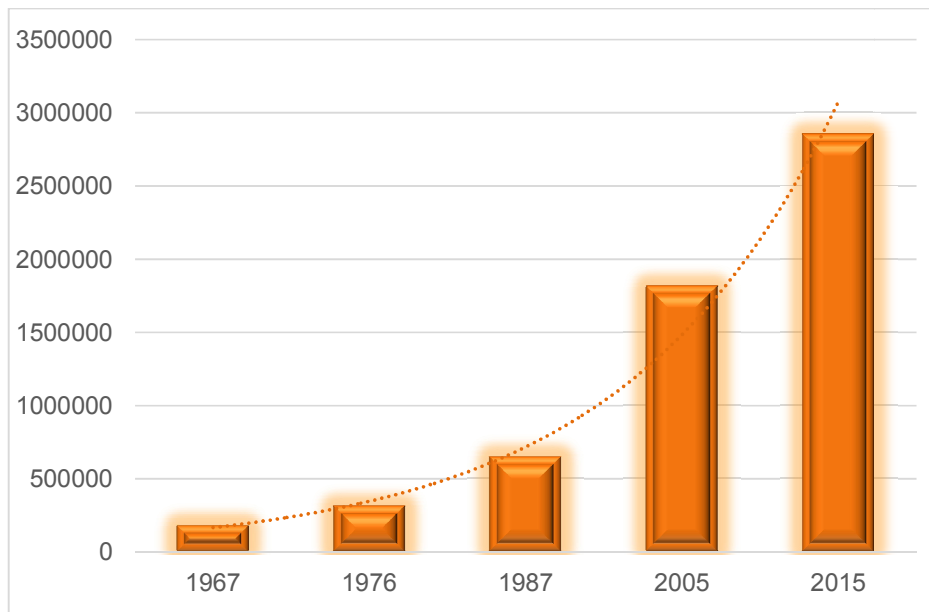


Fig. 2. Evolution of population in Yaounde between 1967 and 2015

The change in the prices of modern energy sources in the city associated with poverty of an increasingly large segment of households, has resulted to a rise in the demand for charcoal both for household consumption and for other income-generating commercial activities.

3.1.3 Proliferation of charcoal consuming activities

Unemployment and underemployment in the city of Yaounde have resulted to the proliferation of commercial activities and petty commerce on the streets. These activities occupy an important part in the consumption of charcoal. These petty commerce include among others; restaurants, local bakeries, rotisseries, fish smokers and black smiths. Surveys carried out in various markets in the city revealed that, the majority of consumers of charcoal are households, corn sellers, plums, braised fish commonly called "braisers", and blacksmiths (Fig. 3).

Fig. 3 shows that charcoal is used by both households and informal sector activities. Households are the largest consumers of charcoal (35%) in the city. Almost 70% of

households in the city use charcoal even if sometimes occasionally. In poor households, it is very often the main source of energy used. The emergence of iron wrought in metal welding shops is also an important source of charcoal consumption. Indeed, almost all metal carpentry workshops which a few years ago used only electricity as a source of energy are now engaged in the use of charcoal for the production of iron articles.

3.1.4 Conducive conditions for charcoal production in Peri-urban area

Several factors are behind the boom in charcoal production in the peri-urban areas of Yaounde. Located in the equatorial zone, Yaounde and its environs are characterized by a favorable climatic atmosphere for the development of the dense semi-deciduous forest. Even if human occupation has strongly affected this forest, profoundly modifying its physiognomy, there are many pockets of secondary forests in its peripheries with exploitable species (Table 2). These tree species are harvested for both charcoal production, fuelwood, non-timber forest products and timber by the local population.

Table 1. Evolution of gas and oil prices (1991-2017)

Year	Price of domestic energy		
	Gas price (12,5kg)	Kerozene price (1l)	Charcoal (5 liter buckets)
1991/92	2900 XAF	152 XAF	200 XAF
2006	6000 XAF	365 XAF	300 XAF
2009	6000 XAF	350 XAF	300 XAF
2014-2017	6500 XAF	350 XAF	400 XAF

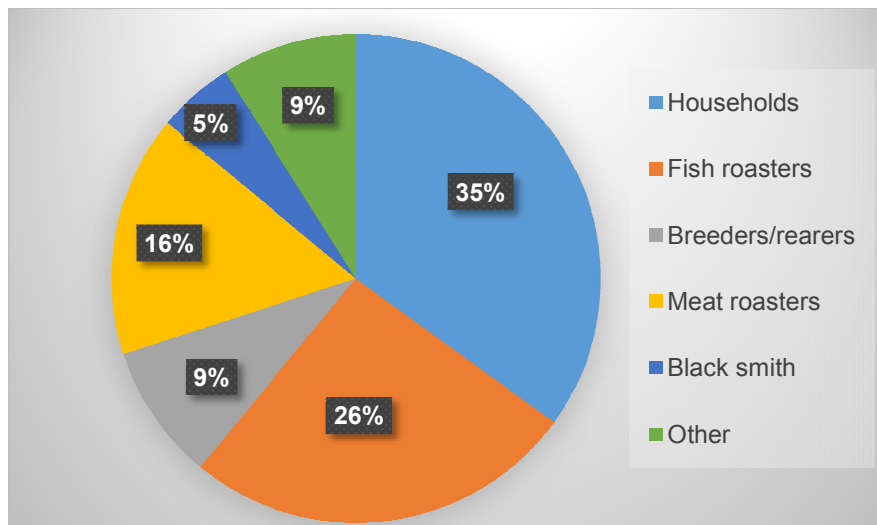


Fig. 3. Consumers of charcoal in Yaounde

Table 3 shows that, precarious living conditions favored the involvement of the populations in the production of charcoal. The survey also indicated that unemployment and poverty also influence the number of trees felled by the producer of charcoal per month. Charcoal production is therefore experiencing rapid development in several countryside near Yaounde, including the Municipality of Bikok. It has become a lucrative activity for many. The involvement in the charcoal industry is for many an effective means since access to trees is generally (89%) by inheritance or is relatively easy.

3.2 The Supply of Yaounde with Charcoal

3.2.1 Yaounde charcoal supply sites

The demand for charcoal has increased significantly in the city. This increase in demand has been accompanied by a rapid development of production sites in the outskirts of the city such as Soa, Nkoabang, Obala, Mengang, Mbalmayo, Mfou, Awa, Bikok (Fig. 4). The latter, by virtue of its production, constitutes one of the main charcoal supply basins in the city. The process consists of a multitude of actions ranging from production in the forests of Bikok to

commercialization in the various markets of Yaounde.

3.2.2 Actors in the charcoal sector

The charcoal sector involves a multitude of stakeholders who contributes to the development of this activity in production, transportation and marketing. These actors can be grouped into two; direct actors and indirect actors (Table 4).

3.2.3 Techniques, production process and quantities

The techniques of charcoal production around the city of Yaounde and particularly in Bikok subdivision are essentially artisanal. The tools (machete, axe and chainsaw) are archaic and the workforce is mostly family. There are four main stages in the charcoal production process, from tree felling and cutting, to charcoal bagging and storage. Pre-carbonization activities ranges from tree felling to grinding stone development. They consist of the development of the site, the cutting of wood to be charred into logs of varying length (0.4 and 0.6 meters), the grouping of pieces of wood and the constitution of the millstone (Plates 1a and 1b).

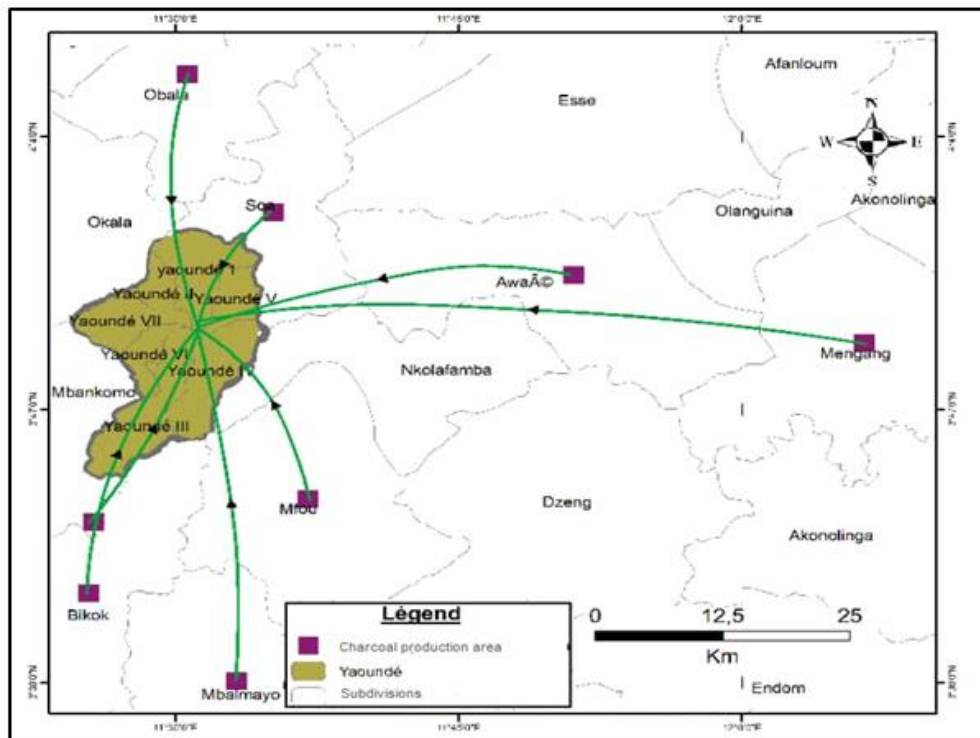


Fig. 4. Yaounde charcoal production and supply zones

Table 2. Main tree species in Yaounde peri-urban area and their calorific value

Calorific value of species	Local name of species	Scientific name of species	Commercial name of species
Species producing good quality charcoal	Adum	<i>Cylicodiscus gabonensis</i>	Okan
	Adjap	<i>Baillonella toxisperma</i>	Moabi
	Atui	<i>Piptadeniastum africanum</i>	Debenna
	Abang	<i>Milicia excelsa</i>	Iroko
	Akom	<i>Terminalia superba</i>	Frake
	Abing	<i>Petersiantus macrocarpus</i>	Abale
	Ebé	<i>Cordia platythyrsa</i>	Mukumari
	Elon	<i>Erythroleum ivorense</i>	Tali
	Okoga	<i>Lophira alata</i>	Azobe
	Sikong	<i>Pteleopsis hylodendron</i>	Osanga
Species producing low quality charcoal	Assié	<i>Entandrophragma cylindricum</i>	Sapelli
	Ayous	<i>Triplochyton scleroxylon</i>	Ayous
	Ebebang	<i>Phyllanthus discoides</i>	Ebebang
Species producing poor quality charcoal	Eyen	<i>Distemonanthus benthamianus</i>	Movingui
	Akolé	<i>Ficus exasperata</i>	Akol
	Angossa	<i>Markhanmia tomentosa</i>	Angossa
	Asseng	<i>Musanga cecropoides</i>	cecropoides
	Fia	<i>Persea americana</i>	Avocado

Table 3. The reasons for the involvement of population in charcoal production

		Reasons or reasons which led to the practice of this activity				Total
		Unemployment	Poverty	Leisure	Satisfaction of basic needs	
Main source of income of the stakeholder	Agriculture	8	18	1	15	42
	Trade	1	5	0	0	6
	Breeders	0	1	0	0	1
	Charcoal production	6	16	0	12	34
	Others	0	3	0	1	4
Total		15	43	1	28	87

Table 4. Actors in the charcoal sector

Stakeholders /Categories	Main activities
Direct actors	
Producers (Sawyers and charcoal makers)	Cut wood in forests or at rivers sides. Almost all of them are men ranging from 20 to 40 years (they represents 85% of charcoal producers)
Carriers (Loaders and drivers)	Act as a link between charcoal producers, buyers (wholesale/ retailers) and consumers
Traders (Wholesalers, semi-wholesalers and retailers)	Wholesale or retail charcoal to retailers and other consumers
Consumers(Households, bakeries, poultry farmers Blacksmiths)	Use charcoal in their various activities
Indirect actors	
Ministry (Staffs)	Responsible for supervising activities related to wood management, energy and particularly charcoal; compliance with regulations on the exploitation of these resources, environmental protection and reforestation
Councils (Council workers)	Organize commercial spaces, collect taxes relating to the exploitation and transportation of charcoal
NGOs (CIFOR, WWF, GIZ)	Intervene in sensitization, capacity building and promotion of improved stoves and reforestation as well as for the sustainable management of the wood energy sector
Local traditional authorities (Chiefs)	Deal with the regulation of customary law and the settlement of minor disputes.

The wood charring phase begins with the introduction of fire into the grindstone through the ignition hole as shown on Plate 2a (A). During carbonization (Plate 2b), the charcoal maker constantly monitors the grinding wheel.

The amount of charcoal produced depends on the number of cubic meters of wood in the stack and the charring monitoring process. The quantification of charcoal production in Bikok was done at the millstone level and at the production site level. Productivity per wheel depends on several factors, with the main ones being, the quality of the woody resource, the respect of the carbonization stages and the physical strength of the producer. Field surveys indicated that, producers ranging between 20 and 44 years of age have productions per wheel of more than 40 bags. On the other hand, older charcoal burners who no longer have physical strength will have relatively low productivity (Fig. 6).

The activities in the post-carbonization phase include, destroying the grinding wheel, cooling the charcoal with water, drying and bagging. Once the charcoal is loaded into the bags, they are transported overhead from the production site to storage locations. These drop-off locations can either be at homes or along the road side. The duration of the charcoal production cycle is on average 14 days (Fig. 5).



Plate 1a. Felled tree



Plate 1b. Layout of the first layer of logs in the millstone



Plate 2a. Grinding wheel ignition port (A)



Plate 2b. Carbonization of wood

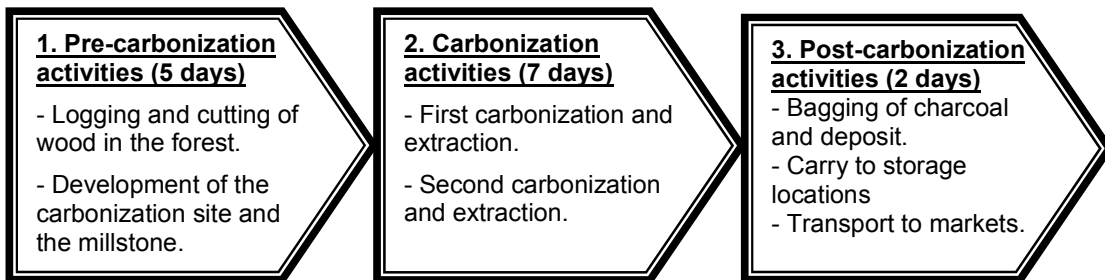


Fig. 5. Activities and duration of carbonization in the municipality of Bikok



Plate 3a. Overhead transport



Plate 3b. Car transport

Plate 3. Charcoal transport. The charcoal produced in the forest is overhead transported from the production site to the storage site (home or along the road). From the storage location to Yaoundé, transport is done by cars

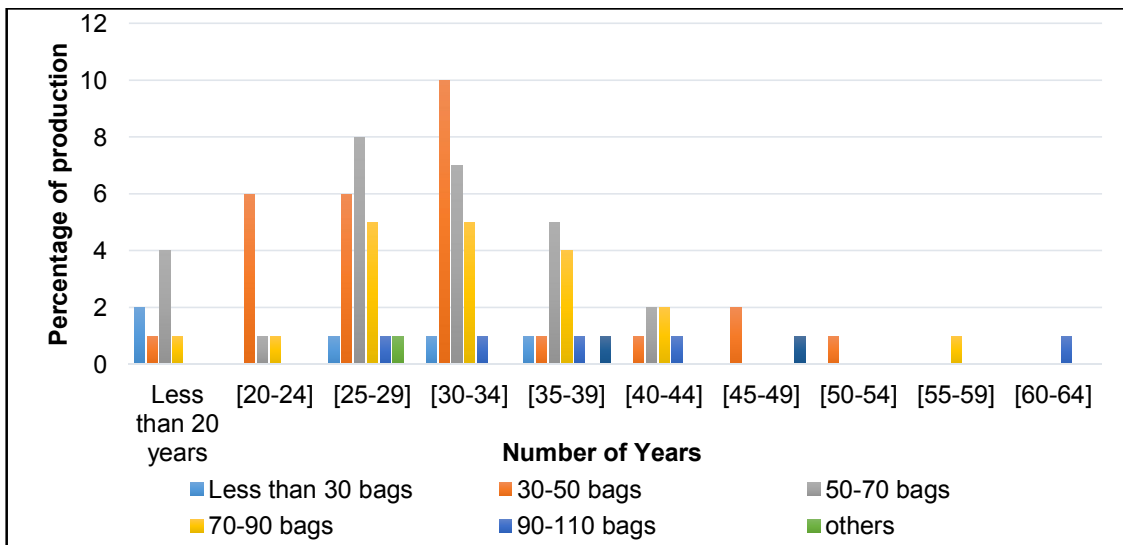


Fig. 6. Productivity (per wheel) according to the age of the producer

The 87 charcoal producers surveyed in Bikok had an average monthly production estimated at 6,000 bags of charcoal equivalent to about 119 trees per month. This production is mainly sold in the urban markets of Yaounde.

3.2.4 Organization of the sector

The charcoal industry in Yaounde and its environs is not really organized and takes place illegally. Wood energy is not the subject of any real public policy in Cameroon for the moment and this situation fuels illegal practices of all kinds on the part of producers and government

agents. Producers are developing many strategies to bypass the controls of government agents. The charcoal market operates thanks to the major stakeholders in the value chain, such as transporters, wholesalers-retailers and retailers. To this effect, there are two types of circuits in the charcoal value chain, namely the direct circuit (short) and the indirect circuit (long). The first is made up of producers and consumers. In this circuit, the producer will sell his product directly to the final consumer without passing through a middlemen. The long indirect circuit is made up of producers, wholesalers-retailers, retailers and consumers.

3.3 Socio-economic and Environmental Impacts of Charcoal Production

3.3.1 Densification and assessment of impacts of charcoal production

The demand for charcoal creates lucrative opportunities for direct actors (producers, traders and transporters) and increasingly generates a number of environmental concerns. Several environmental and socio-economic impacts are noted during the different phases of charcoal production from wood cutting, carbonization, transportation and marketing (Table 5).

Table 6 reveals the identification and assessment of various impacts. The allocation of evaluation parameter relates to the valuation by the populations of the affected component, the level of concern on the society and the protection of the component by laws and regulations as indicated by the results. The absolute assessment of the impacts was done by calculating the weighted average of the various impact indicators.

3.3.2 Description of the impacts of charcoal production

3.3.2.1 Environmental impacts

The exploitation of charcoal is an environmental concern in the area. It has resulted to the destruction of the forest cover, the decrease in

floristic diversity especially NTFPs, soil erosion, and the significant decline in the services rendered by peri-urban forests. The removal of trees for the production of charcoal is at the origin of the disappearance of plant biodiversity in production sites. Indeed, the survey conducted among charcoal producers in the research site in Bikok sites shows that, nearly 2,331 trees are cut per year to produce charcoal. During felling, some smaller trees are pulled down by the main tree thereby causing a considerable degradation of the vegetation cover. The felling of trees to produce charcoal creates clearings that can go beyond half a hectare when the sites concerned have a high concentration of sought-after species. Measurements in the field have shown that on average, for a felled tree and carbonization work, a clearing or hole of 13.5 square meters on average is created. This area essentially represents the space for clearing trees and the installation of the carbonization wheel. By cumulating, when we consider on average, the 2,331 trees felled per year on the survey sites, we have a total area of 3.14 hectares deprived of trees each year. Some of the large clearings created are colonized by agricultural activities.

The survey indicated an intensive harvesting of trees from the various sites for charcoal production (Fig. 7). The number varies depending on the sample sites. The proportion of trees felled in the secondary forests is high.

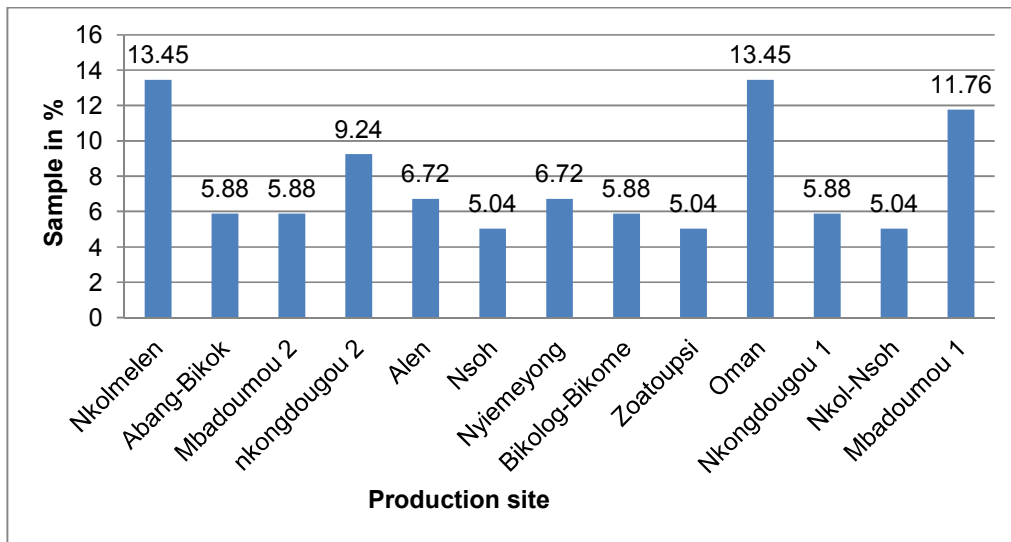


Fig. 7. Average monthly proportion of trees felled in production sites in Bikok

Table 5. Identification of the impacts from the Léopold matrix (1971)

X = The activity has an impact on the component of the environment		Components of the Environment													
		Biophysical environment							Human environment						
		Air	Soil	Surface water	Flora	Fauna	NTFPs*	Employment	Conflict	Local economy	Quality of life	Health	Safety	Governance	Cultural heritage
Phase of production of charcoal	Activities/ Sources of impacts														
Pre-carbonization phase	A1. Inheritance / Production quota / Purchase and fell	Xn	Xn	Xn	Xn	Xn	Xn	Xp	Xn	Xp	Xp	Xn	Xn	Xn	Xn
	A2. Development of the carbonization site	Xn	Xn	Xn	Xn	Xn	Xn						Xn		
	A3. Transport of wood from the cutting site to the kiln		Xn		Xn			Xp		Xp		Xn	Xn		
Carbonization phase	B1. Carbonization / maintenance of furnaces	Xn	Xn	Xn	Xn			Xp				Xn	Xn		
Post carbonization phase	C1. Charcoal drawing / extraction	Xn										Xn	Xn		
	C2. bagging and depositing							Xp		Xp			Xn		
	C3. Transport / Road checks /collection of taxes/ frequency of supply	Xn						Xp	Xn	Xp			Xn	Xn	
	C4. Marketing in markets and neighborhoods	Xn						Xp	Xn	Xp	Xp	Xn	Xn	Xn	
	C5. Charcoal consumption	Xn								Xp	Xp	Xn	Xn		

*NTFPs=Non-timber Forest Products, Xn = negative impact; Xp = positive impact

Table 6. Evaluation of the impacts of charcoal production

Component of the affected environment	Impact activities	Impacts	Evaluation parameters					Evaluation
			Nature	Intensity	Extent	Duration	Reversibility	
Air	Cut trees; Create carbonization site; Consumption,	Degradation of air quality	-	1	2	1	2	1,5
Soil	Cut trees; Transport; Carbonization	Soil degradation process	-	4	2	5	4	3,7
Surface water	Cutting of trees; Carbonization;	Degradation of surface water	-	2	3	2	3	2,5
Flora	Tree cut Carbonization	Disappearance of plant species	-	5	4	5	5	4,7
Fauna	Cut trees/create carbonization sites	Loss of wildlife and habitat	-	3	3	5	5	4
Non-timber forest products (NTFPs)	Cut trees/create carbonization sites; Carbonization	Reduction in NTFPs, loss of medicinal species	-	2	2	5	5	3,5
Employment	Cut trees; Bagging/ deposit/Transportation to markets	Job creation	+	3	3	4	3	3,2
Conflict	Road checks and tax collection	Sources of conflict	-	4	2	4	2	3
Local economy	Cut trees; Furnace construction	Employment and increase in income	+	3	3	5	4	3,7
Quality of life	Cut trees / carbonization Sale of charcoal	Improved quality of life	+	3	3	5	4	3,7
Safety / Accidents	Cut trees; Transport Carbonization/bagging	Source of accidents (injuries and burns)	-	3	2	3	3	2,7
Health	Carbonization; Sale; Consumption	Source of disease on the population	-	3	3	4	2	3
Governance	Cut trees; Road checks and tax collection	Bad governance	-	3	4	3	2	3
Cultural Heritage	Cutting of trees	loss of culture	-	4	5	4	5	4,5

*Legend: (1- 2) = very low or negligible impact; (2.1 - 2.9) = low impact; (3- 4) = significant impact; (4.1 - 5) = very significant impact
- = negative impact + = positive impact*

Fig. 8 reveals that, in the sites of Oman, Nkolmelen, Mbadoumou 1 and Nkongdougou 2, located in secondary forests, monthly averages of felled trees is 13.45%, 11.76% and 9.24% respectively. This is explained by the fact that, the woody resource used essential for the production of charcoal is still in abundance in these villages, unlike sites like Nsoh, Zoatoupsi and Nkol-Nsoh where, the most prized species are rare.

With increase pressure on the desired plant species, degradation of plant biodiversity is eminent. Some of the species used for charcoal production in the secondary forests and in old fallows, are already rare or are endangered (Figs. 8 and 9).

The situation is alarming in the old fallow land of Alen village where *Elon* species has become absent and the *Adum* species is becoming very rare (6.67%). The rarity of these species in the Municipality of Bikok is due to overexploitation.

The diameter of trees species felled for charcoal production has witnessed a mutation. There is a decrease in the diameter harvestable trees both in secondary forests and in old fallow land. The exploitable diameter is currently between 10 and 30cm. It is obvious that the level of tree removal for charcoal exceeds the capacity for renewal of the resource and inevitably leads to the degradation of the environment. One of the consequences of the intensification of cuts is the increase in the distance covered from the

inhabited areas to the charcoal production sites (Fig. 10).

Fig. 10, reveals the increase in the distance traveled by producers from homes to production sites. On average, the distance has increased from less than 1km in 2006 to more than 5 km in 2016. This increase was accompanied by strong pressure on certain species. Indeed, the species used for the production of charcoal are also used by the population for food and health. In terms of food, species such as *Elon* and *Djansang* are useful for the production of caterpillars consumed locally and also for seasoning foods (condiment). In terms of health, the bark of plants such as *Ebe*, *Elon*, *Adum* and *Atui* are used in traditional pharmacopoeia to cure a number of diseases (chronic cough, swollen foot, mystical disease and poison). According to charcoal producers, the cutting of these trees has resulted to scarcity or disappearance of certain NTFPs like caterpillars in Bikok.

The production of charcoal is also a source of fragmentation of animal habitat and loss of wildlife biodiversity, the decline in soil stability and the degradation of ambient air quality through carbonization activity. Cutting down trees decreases the carbon sequestration capacity of the forest. The carbonization and use of charcoal releases carbon dioxide (CO₂) into the atmosphere. In addition to the trees used for the production of charcoal, the other carbon pools of the forest like the undergrowth and litter are degraded during charcoal production

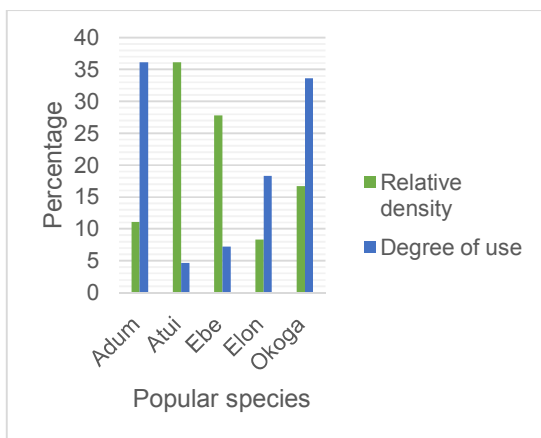


Fig. 8. Rarity of species according to their degree of use in Nkolmelen secondary forest

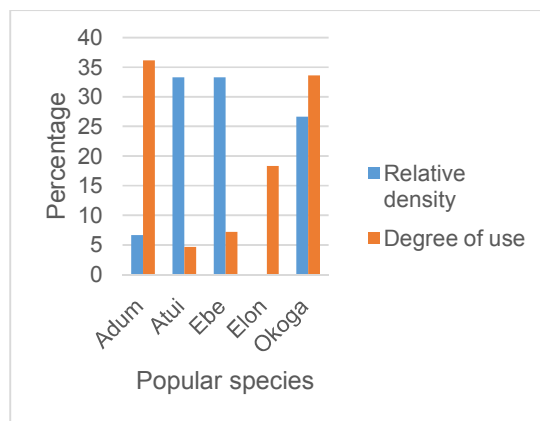


Fig. 9. Rarity of species according to their degree of use in the old fallow land of Alen village



Plate 4a. Anthropogenic clearing due to charcoal production



Plate 4b. Physiognomy of the site after carbonization

Plate 4. The production of charcoal leads to excessive cutting of trees and the creation of clearings (4a and 4b) which can lead to deforestation. Plate 4b shows bare soil that has suffered the consequences of carbonization. Plate 4b also shows an abandoned producers' camp testifying to the remoteness of the site from the inhabited areas

activities and their carbon stock also released in the atmosphere. These activities deprive the soils of their plant cover, thus exposing it to erosion and leaching. Soil erosion, wastewater and debris from logging and carbonization sites affect water quality in rivers. This alteration undoubtedly has a negative impact on aquatic fauna. Some villagers believe that, the production of charcoal has led to a decrease in fishing yields in Bikok. Indeed, 76.6% of charcoal producers believe that, some animal species are increasingly rare in the locality. This scarcity is due to the destruction of habitat by charcoal producers. Majority of charcoal producers also engage in hunting (trapping, hunting with dogs) when they are in the forest.

The assessment of the impacts of charcoal production on the forest and the biophysical environment in general using the chi-square test revealed a significant relationship (Table 7). The more the activity develops, the greater the negative impacts on the biophysical environment.

3.3.2.2 Socio-economic impacts

The charcoal sector is an activity that generates many jobs in the various stages of the value chain from exploitation, transportation to marketing. These different actors find in this activity a source of income which permits them to meet up with their basic needs. Indeed, 75% of the charcoal producers consider their activity to be a profession and work regularly with about 3 to 6 people. In effect, the production of charcoal in Bikok provides employment for more than 300

people. Many people are involved in the sale and use of charcoal for commercial purposes in Yaounde city. This is evidenced by the impressive presence of charcoal sellers (wholesale and retail) in all the markets of the city, the omnipresence brayers of fish, maize, macabo and plantain at almost every crossroads and along popular streets of the city.

In terms of revenue, producers have an estimated daily income of between 3000 and 6000 XAF. 70.1% of producers estimated their monthly profit margin between 50,000 XAF and more than 150,000 XAF (Fig. 11).

Fig. 9, reveals that, the profits made from this activity are not negligible in the Cameroonian context (in Cameroon, the monthly minimum wage set by the government is 36,270 XAF). They cut down trees in an abusive manner, to maximize their monetary income, irrespective of the sustainability of the resource and the protection of the environment. However, it is important to note that, for many producers, charcoal is not the only source of income. In Bikok, all the producers are farmers or are engaged in other small lucrative activities. Similarly, in Yaounde, apart from a few wholesalers, almost all charcoal sellers sell other resources (firewood, foodstuffs, manufactured products of first necessity, etc.). Charcoal sellers also have sizable profit margins. In fact, 51.2% of sellers estimated their monthly profit margin between 50,000 XAF and more than 150,000 XAF (Fig. 11).

Table 7. Chi-square result on the impact of charcoal production on the biophysical environment

	Value	ddl	Asymptotic significance (bilateral)
Pearson chi-square	17,280 ^a	3	,001
Likelihood ratio	10,440	3	,015
Linear by linear association	,009	1	,923
Number of valid observations	87		



Fig. 10. Evolution of average distance of charcoal production sites in Bikok (2006-2016)

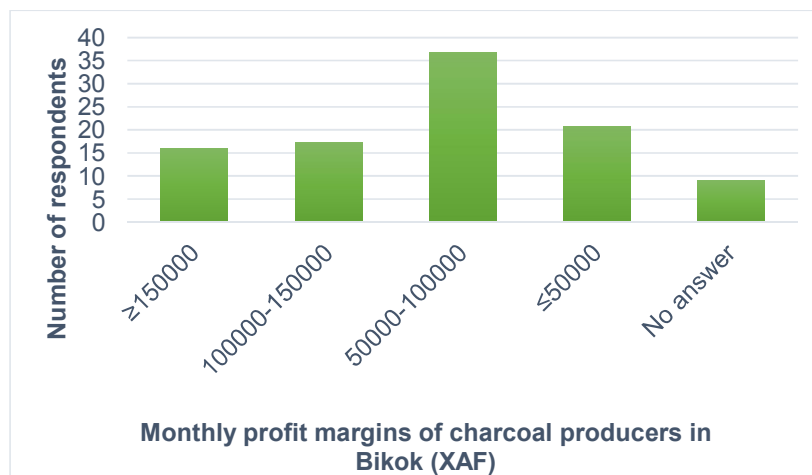


Fig. 11. Evaluation of the monthly profit margin of producers in Bikok

The production of charcoal is an activity likely to stimulate the development of economic activities such as the manufacture of materials used for the combustion of charcoal commonly called "kiln".

However, these positive aspects cannot make us forget that the production and use of charcoal has significant negative impacts on the health of producers and consumers (exposure to high heat, exposure to charcoal dust, exposure to

toxic fumes, accidents linked to the absence of protective measures ...). 23.3% of charcoal workers claim to have been victims of lung disease. The overexploitation of trees that provide traditional pharmacopoeia products and the scarcity of these resources also have a negative impact on the health of the people who depend solely on them. The scarcity of *Erythroleum ivorense* is likely to affect the cultural practices, heritage or knowledge of the people.

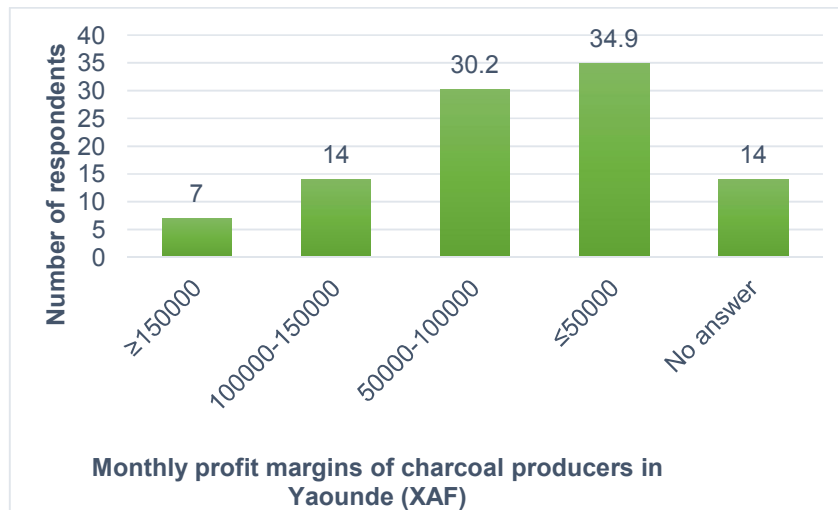


Fig. 12. Evaluation of the monthly profit margin of charcoal sellers

In terms of governance, the exploitation of trees to produce charcoal is done illegally. For this reason, during transportation to Yaounde, charcoal feeds a well-oiled corruption system involving government agents on the one hand and charcoal producers or buyers on the other. The refusal of producers or buyers give in to corruption or the attempt by government agents to exaggerate the amount of these costs often leads to open conflicts between the protagonists.

4. DISCUSSION

This study focuses on the implications of supplying charcoal in the city of Yaounde. It underlines the importance of this sector in terms of the quantity of charcoal sold and the related socio-economic and environmental issues. It shows demand for charcoal in the city is at the origin of many environmental externalities in the places of production and socio-economic for the populations involved in the sector. As such, this study is important for the impacts and benefits of the wood energy sector in the Congo Basin remain largely unknown, the data being rare and unreliable [15,2]. The same observation was made for Tanzania [41]. In this regard, particularly concerning Cameroon, fuelwood has not been the subject of intense scientific research and related scientific articles are scarce [4]. However, there is almost no public policy on wood energy in Cameroon (the forest policy and law of Cameroon mention wood energy in just a few words) and if we really want to regulate this sub-sector or give it the place it deserves in the context of the promotion of renewable energies,

it will be necessary to have decision-making support data. Having reliable decision-making support data before taking any action in the wood energy exploitation sub-sector is fundamental as it is, an activity which touches several centers of potentially conflicting interests such as poverty, sustainable forest management, energy security, land tenure and health.

The hypothesis which guided the investigations was confirmed. Indeed, the study showed that Bikok is an important charcoal supply basin for Yaounde thanks to its proximity (20km) and the availability of species sought by charcoal producers. The Bikok area alone supplies nearly 6,000 bags of charcoal per month to the city of Yaounde. Ecologically, the demographic dynamics combined with poverty give energy needs significant and negative impacts on peri-urban forests. The poverty rate of the population is a factor that pushes them to get involved in the charcoal sector, and significantly, in the process of forest degradation. Harvesting of wood to meet charcoal needs is at the origin of forest degradation, reduction of forest areas, decrease in flora diversity, and fragmentation of wildlife habitats in the outskirts of the city. There are also significant effects on soils and watercourses in the extraction sites. The resulting effect is forest degradation and deforestation directly linked to charcoal production in line with the work published by other authors [45,2,21,12]. The impact on floristic diversity is reflected in the scarcity of the species required and the more increasing distances required to travel before having a valuable tree species. A consensus

among researchers is emerging about the devastating effects of fuelwood exploitation on woody resources and peri-urban forests [45,20, 18].

The problems of wood energy and sustainability can be considered from two opposite angles: wood energy as a cause of deforestation and degradation, or on the contrary, as a promising source of renewable energy [20]. The results of our work also allow us to have this dualistic perception of charcoal related activities. In this dualistic perception, the environmental aspects of logging for the production of charcoal seem to have received more attention as evidenced by the long discussions on the extent to which charcoal can cause environmental degradation. In connection with this debate and concerning Cameroon, Eba'a Atyi et al. [4] stated that "In forest regions including Douala and Yaounde, fuelwood remains a by-product of agriculture or wood processing in sawmills". "As concerns sustainability of the sub-sector, apart from the Far North and probably the North Regions whose fuelwood resource management must be given special attention for fear of an impending crisis due to overexploitation of the resource, sustainability concerns are not justified in the case of Cameroon. Resources are considerable and fuelwood remains in many cases a by-product of agriculture or the logging of timber or poles"¹. Our results show that charcoal is not always a by-product of agriculture or timber harvesting. In Bikok, trees are felled specifically and only to produce charcoal. The removal of trees for charcoal exceeds reproduction capacity and results in a scarcity of the species concerned. The signs of environmental degradation are obvious, and we cannot say that sustainability concerns are not justified. Contrary to claims that charcoal production only leads to forest degradation, this activity is at the origin of deforestation in Bikok, i.e. the reduction in the area of the forest, the conversion of forest to other land uses including to obtain wood for fuel, for agriculture, animal grazing or urbanization purposes. The felling of trees to produce charcoal creates clearings that can go beyond half a hectare when the sites concerned have a high concentration of sought-after species or when due to the architecture of the forest, felling the targeted tree causes significant damage on trees and shrubs surrounding the target trees.

¹ Eba'a Atyi, R., Ngouhouo Poufoun, J., Mvondo Awono, J.P. Ngoungoure Manjeli, A. and Sufo Kankeu, R. 2016. Economic and social importance of fuelwood in Cameroon. *International Forestry Review* vol.18 (S1), P 63-64.

On the other hand, charcoal production has significant positive impacts. The charcoal sector contributes significantly to informal employment and to improving the income of the households involved in the value chain in Yaounde and environs. Several income generating opportunities exist at different levels of the value chain, including production, transport and marketing. These activities substantially enable those involved to improve their income and meet their needs. Indeed, 70.1% of producers estimate their monthly profit margin between 50,000 and more than 150,000 XAF. This contribution to employment and to the improvement of incomes was also noted by many authors who have worked on the wood energy sector [46,4,31,12].

5. CONCLUSION

Over the past decades, rapid population growth, poverty, unemployment, the proliferation of charcoal-consuming activities, the rise in the price of fossil fuel and the availability of wood resources have led to the development of a real charcoal "industry" around the Cameroonian political metropolis. As has been noted, this activity has positive impacts with some negative effects, on the physical and human environments. This study has shown that supplying the city of Yaounde with charcoal constitutes a source of degradation of peri-urban forests and other environmental negative impacts. This sector also contributes substantially to the improvement of household incomes and provide jobs and energy security to city dwellers and villagers. Faced with the continued increase in fossil fuels, the hydropower deficit and poverty, wood energy will continue to be the primary source of energy for households and for certain economic actors in the informal sector.

The avenues of solutions that have generally been proposed over the past decades still seem relevant to us. These include the improvement of energy efficiency at the level of charcoal producers (improved carbonization) and consumers (extension of improved charcoal stoves), large-scale production of charcoal from agricultural residues and residues or by-products of logging and wood processing industries, agroforestry, reforestation, peri-urban forest plantations for fuelwood (for example with fast growing species of appreciable calorific value) and the sustainable management of peri-urban forest areas. Agroforestry, reforestation, or plantations in peri-urban areas should be part of

sustainable development programs for peri-urban areas or sustainable landscape (urban and peri-urban) programs considering the needs for a sustainable supply of fuelwood to cities. All this presupposes effective and adequate consideration of wood energy in sectoral and cross-sectoral public policies (forest, energy, agriculture, land tenure, land use planning, etc.). This is very far from being a reality at present in Cameroon even if the national forest policy prescribes the promotion of the economic, ecological and social functions of the forest.

In a context of climate change, population growth and increased poverty, it would be useful to conduct a study on the resilience capacities of peri-urban forests, to guarantee sustainable development of the charcoal sector. It would be also essential to produce data allowing to plan charcoal production in an integrated manner, as a component of a complex and sustainable territorial system and to work for a true territorial or landscape approach at the crossroads of energy, agricultural, land tenure, environmental and social concerns. This is, in our opinion, one of the conditions for having sustainable cities.

CONSENT

As per international standard or university standard, respondents' written consent has been collected and preserved by the author(s).

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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