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Potential Impact of Fish Smoking on Mangrove Resources in Southwest Cameroon

Joel Hans Dongmo Keumo Jiazet[1,2]

Abstract

The main objective of this study is to contribute to the sustainable management of mangrove forests in Cameroon through assessing the impact of fish smoking activities on mangrove resources. Mangrove wood is harvested by local communities for many purposes, but most notably as fuel for fish smoking. Population growth has greatly increased the pressure on these resources in recent years. Our study focused on fish smoking activities in Ndian and Fako, in the southwest region of Cameroon. Through structured and semistructured questionnaires, 243 fish smokers were interviewed in 9 local markets. Our study found that all the fish smokers were women from Cameroon, Ghana, Nigeria, and Benin. Ninety-three percent of our respondents purchase the wood they use, which is mainly red mangrove (*Rhizophora racemosa*). The quantity of wood consumed is governed not only by the amount of fish requiring smoking but also by the type of oven used. Per fish smoking session, a traditional oven takes 53 hr to smoke 528 kg of fish and consume 1,205 kg of wood at a cost of 50€. A modern cinderblock oven, on the other hand, requires only 5 hr to smoke 160 kg of fish and consumes 122 kg of wood at a cost of 10€. Cinderblock ovens are preferable both ecologically and economically and could be one of multiple solutions for the sustainable management of mangrove wood resources. However, interventions are necessary in order for fish smokers to become aware of the benefits of these improved cinderblock ovens.

Keywords

fish smoking, forest, mangrove, sustainable management, ovens, wood

Introduction

In Cameroon, mangrove forests cover approximately 250,000 hectares and are among the most extensive stands in Africa (Angoni et al., 2015). Fishing camps have been widely established throughout them, and mangrove wood is harvested for many purposes, but most notably as fuel for fish smoking. As most rural areas do not have electricity, local people use smoking as a way to preserve fish. This has been a common method for preserving meat and fish for millennia in many parts of the world (Kone, 2001). Because of population pressure, this artisanal technique of preservation consumes greater quantities of mangrove wood each year and is having a progressively detrimental impact on mangrove forest sustainability. The conservation of mangrove ecosystems is thus becoming an increasingly urgent topic (Tiéga & Ouédraogo, 2012). Mangroves are important not only for the needs of local population, but because they have a significant influence on climate change as they sequester 5 to 6 times more carbon than conventional forests (Bilé, 2012).

Globally, mangrove forests are the most threatened tropical ecosystem and are being degraded and depleted at alarming rates (Polidoro et al., 2010). In just 10 years, national territory mangrove forests in Cameroon have decreased from 250,000 hectares to 134,400 hectares (Food and Agriculture Organization, 2007; Hamilton & Casey, 2016). This is more than 11,000 hectares lost per year, which equals 4.4% of the total area of

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mangrove forests every year. Population pressure also causes mangrove destruction in unprotected areas, especially around settlements, villages, and towns where poverty and land issues force people to move onto any open land they can (ENVI-REP Cameroun, 2010). Other accelerating factors in mangrove destruction have been the modernization of wood cutting equipment, particularly the introduction of chainsaws, and the greater availability of large pirogues, powered by outboard engines, which enable easier access to the mangroves stands (Din & Blasco, 2003). Resource renewal is also threatened, as long-term conservation plans are not in operation in most areas, and little or nothing is being done to address the overconsumption of this resource. The overexploitation of mangroves also threatens the sustainability of fish smoking activities. This happens on two levels: one is that the long-term supply of firewood is compromised and the other is that mangroves are an important habitat for the breeding of halieutic resources, and its loss is resulting in decreasing fish stocks (Food and Agriculture Organization, 2007). Effective mangrove conservation measures thus need urgently to be employed to avoid both socioeconomic and ecological disasters.

Despite their evident ecological value, and the fact that they constitute an important source of income for surrounding coastal communities, there is a lack of mangrove protection measures in many tropical regions (Spaninks & Beukering, 1997). It is now widely recognized, however, that conservation legislation is of fundamental importance to successful mangrove management systems (Van Lavieren et al., 2012 cited in Z. N. Feka, 2015).

In Cameroon, while there are mangrove protection laws, their implementation has not been effective (Din et al., 2017). The result is that mangrove forests continue to be depleted at an uncontrolled rate. In the south-west region of the country, pressure on woody resources such as mangrove is particularly extreme. The purpose of this study was to address issues around fish smoking in the region through answering the following questions: Who are the fish smokers? What is the main type of wood used as fuel, what does it cost, and where does it come from? What factors impact on the amount of wood used for fish smoking? Our overarching aim is to contribute to the sustainable management of mangroves through an assessment of the impact of fish smoking activities on them. More specifically, we

- describe the socioeconomic lives of those involved in fish smoking;
- identify the sources of energy, wood species, wood cost, and alternative fuels used;
- determine the yields of different oven types and the amount of fuel they require.

Methods

Study Site Description

The study was conducted in Ndian and Fako department, in the south-west region of Cameroon. The geographical coordinates of the locality are 4° 20′ to 4° 50′ N latitude and 8° 30′ to 9° 00′ E longitude (Din, 2001). The site is bordered to the north by Korup National Park, to the east by the city of Kumba, to the south by the Mungo river, and to the west by the Akwafe river, which forms the border between Cameroon and Nigeria (the Bakassi Peninsula).

The study site is a coastal area, where there are many elongated banks of dry land. The hydrography is characterized by the Andokat and Rio Del Rey rivers, which converge in an estuary (Olivry, cited in Tadjoung & Effala, 2008). Soils are essentially gray or black vases, with silty textures, sandy, or clayey. They are formed of river alluvium which is relatively rich in organic matter (Tadjoung & Effala, 2008).

The climate is characterized by a brief dry season and a rainy season that last over nine months. The flora consists essentially of tree species with a dominance of *Rhizophora racemosa*. *Rhizophora mangle* and *Rhizophora harrisonii* are also present. The wildlife is dominated by vertebrate such as fish, birds, and reptiles, but there are also invertebrates such as crabs and molluscs (Ngo-Massou, Essomè-Koum, Kottè-Mapoko, & Din, 2014). The indigenous people at the study sites belong to the Kory, Isangele, Oroko, and Balong tributes (Fomete & Tchanou, 1998). There is still virtually no infrastructure and access is by canoe. Fishing and hunting are the main human activities.

The Survey

Before beginning fieldwork, interviews were held with staff at the Institute of Agricultural Research for Development (IRAD), who had a good knowledge of the study site, and were able to advise us on locations. Our first field trip was conducted with personnel from the IRAD and the Ministry of Livestock, Fisheries and Animal Industries' (MINEPIA) team, who introduced us to the fishing communities and explained the purpose and importance of our work. Our choice of fieldwork sites was thus partly determined by the relationship that the IRAD and MINEPIA had with fishing communities. During this first trip, nine fishing communities were identified (Figure 1) and invited to take part in the study. They were Eyengue, Idenau, Esobe, Njonji, Debundsha, Bakingili, Batoke, Down beach, and Tiko.

Our research was authorized by the head of the IRAD, Limbe Batoke, and by the Fako Divisional Delegate of the MINEPIA. All interviews were

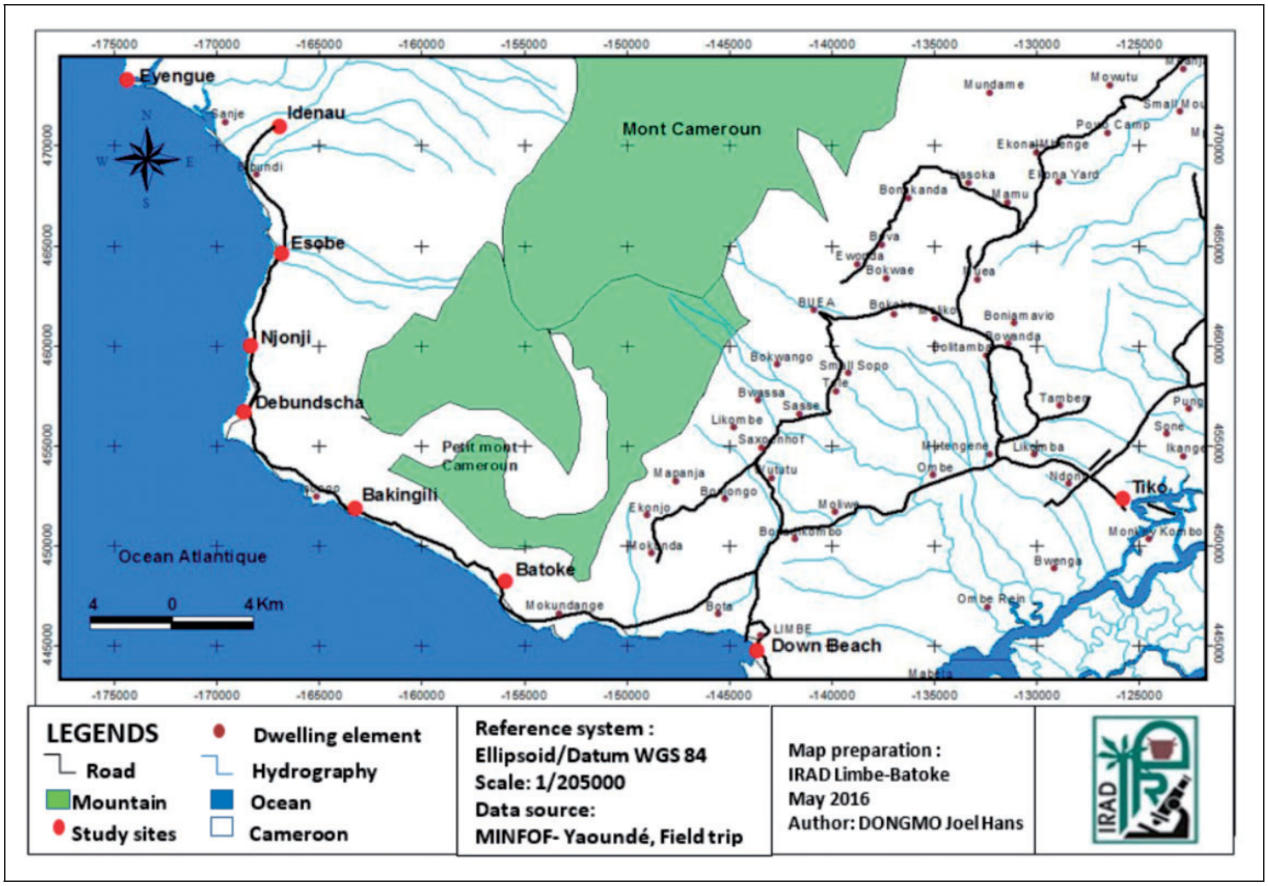

Figure 1. Communities surveyed location.

conducted with the consent of respondents, and confidentiality was assured. A total of 243 fish smokers were surveyed. Table 1 gives a summary of data obtained from each site.

The surveys comprised semistructured interviews based on a questionnaire which were designed with help of the IRAD team. This questionnaire had several components.

Socioeconomic life of those involved in fish smoking

Data were collected through the interviews which focused on respondents' socioeconomic, demographic, and professional characteristics as well as their daily activities. Questions were designed to elicit gender, marital status, age, study level, number of family members, nationality, and main professional activity (fishing, fish smoker, or fish seller).

Wood Provision, Wood Species, Wood Cost, and Alternative Fuels Used

Interviews were conducted in the fish smoker's kitchens. This allowed us to directly observe the fish species, any alternative fuels used, the type of oven used, and the wood species used for smoking. The questionnaire elicited detailed data about the wood fuel used, such as how, where, and how often wood is collected or purchased, and at what cost. Fish smokers were asked how far they had to travel for their wood supply and the impact that distance had on their lives. They were also asked to quantify their oven capacity (the maximum number of kilograms of fish it could hold at one go) and the amount of wood needed to smoke this quantity. In each community, GPS coordinates were recorded using the GPS receiver (GPS GARMIN MAP 64).

The Yield of Different Oven Types

We asked some respondents to monitor their wood consumption. These were selected according to their location (proximity to the IRAD)—as we needed to visit them 4 times a week. When there was a smoking session, the weight of the fish and of the wood used for smoking was measured and recorded. Fish and wood species, smoking time, wood purchase, and sales costs were also recorded. Direct observations were made of the conditions to which fish smokers were exposed (smoke, heat, flames).

Table 1. Data Description.

Sites		Eyengue	Idenau	Esobe	Njonji	Debundscha	Bakingili	Batoke	Down beach	Tiko
Interviewers		45	50	20	13	12	6	10	82	5
Fish quantity (kg/week)	min	68	136	34	34	68	34	68	68	68
	mean	673.2	910.5	71.4	198.77	107.67	167.17	129.2	487.74	185
	max	1700	2380	136	408	170	408	204	1632	357
Wood quantity (kg/week)	min	225	270	42	90	120	30	126	90	168
	mean	1681.156	2176.38	92.1	336.92	173.75	208	246.6	818.9	315.2
	max	2400	3360	180	540	270	504	378	2650	608
Wood cost (€/month)	min	35	80	20	25	15	8	15	35	35
	mean	223.32	273	42	33.15	43.33	22.13	83.27	198.73	65.02
	max	400	420	75	112	63	50	160	400	82
Smoking time (hours)	min	6	48	24	4	24	4	6	6	24
	mean	61.95	72	28.2	25.77	36	15.83	19.4	55.16	62.4
	max	96	96	48	72	48	48	48	96	72
Fish smokers experience (years)	min	2	1	1	4	6	0.5	6	2	15
	mean	13	10	5	12	15	8.58	14.9	17	21
	max	30	22	11	25	28	25	30	37	25
Smoking frequencies (number of time/week)	min	1	1	1	1	1	2	1	1	2
	mean	2.28	2.3	2	1.54	2	2.5	2.1	2.62	2.8
	max	3	4	3	2	4	3	3	8	3

Data Analysis

Qualitative data from the interviewers and questionnaires, and quantitative data from respondents' consumption monitoring sheets, were analyzed for each site with Excel 2010 software. Maps were made using ArcView 3.2 software. Three statistical tests were performed using R software. *T* tests were used in order to compare ovens yields and to compare the amount of wood consumed and the quantity of fish smoked. The Pearson *r* linear correlation test was performed to determine the degree of correlation between the amount of wood used and the quantity of fish smoked. The one-way analysis of variance was performed in order to compare wood consumption between different communities, compare different oven yields, and determine if there was any correlation between the amount of wood used and the experience of fish smokers.

NB: Because the observation numbers of each variable were not equal, we used the harmonic mean of the group sizes. Thus, type 1 error levels (i.e., reject the null hypothesis when true) are not guaranteed. All statistical tests were performed at the significance level of $\alpha = 5\%$.

Results

Description of Fish Smokers' Socioeconomic Live

In our sample, all the fish smokers were women. The main activity for men was fishing. Most women surveyed were married (88%) and many (especially foreigners) had a husband who was a fisherman and who supplied them with fish. Fish smokers' ages ranged from 20 to over 60.

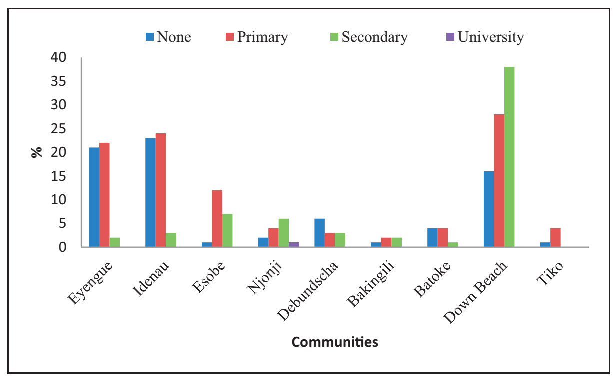

Figure 2. Levels of education of fish smokers according to respondents.

Primary school was the highest education level for most respondents (42.4%), 26% had secondary level. Assuming that a person who has not had any schooling is illiterate, the illiteracy rate among respondents was 31.6%. Figure 2 shows that the illiteracy rate is very low in all communities except Debundscha. In addition to the sale of smoked fish, 8.6% of fish smokers also sell fresh fish. Fishing and fish smoking allows entire families to subsist; nearly 1,018 people were supported by the 243 fish smokers studied. On average, each supports a family of 3 to 6 people.

The majority of fish smokers were from Cameroon (47.3%), followed by Ghana (23.45%), Nigeria (22.63%), and Benin (6.6%). Ghanaians were more represented in Idenau than in all other areas. Most respondents said they had been smoking fish since they were young and that they had inherited work spaces, equipment, and necessary skills from their mothers. The study found that 60.5% of fish smokers had at least 10 years of experience in smoking.

Wood Provision, Wood Species, Wood Cost, and Alternative Fuels

Wood species used for fish smoking. Wood quality is important in fish smoking. Several wood species were used as firewood. We have grouped them in first choice species (the main ones used for fish smoking), second choice species (averagely used) and third choice species (least used). Among the first choice, 71% used mangrove wood (*Rhizophora racemosa*) and 20% Azobe (*Lophira alata*). Rubber tree wood was the most used second choice species. Eight percent of fish smokers did not mention any second choice species because they used only one species for their activities. Mango was the most used third choice species (used by 15% of all respondents), and fruit trees were occasionally used. Most fish smokers used only two species: 64.6% did not use a third choice species. Timber species such as Ilomba, Paduk, Zingana, and Tali were less commonly used as firewood. When they were used, it was usually only branches which were harvested. Figure 3 shows wood utilization intensity in our study sites.

Respondents gave several reasons to explain their choices concerning firewood. The main reason was the capacity of the species to provide heat energy, followed by the ability of the species to color the fish attractively (Figure 4) and also to be in constant supply without any shortages. Distance to the collection site and the cost of the wood were less important.

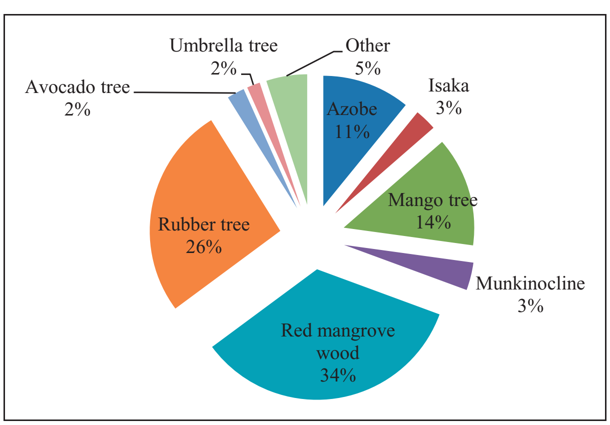

Figure 3. Wood utilization intensity in study site according to respondents. NB: *Other* refers to wood species very rarely used (species that have been cited less than 5 times in total). They are Orange trees, Palm trees, Ilomba, Paduk, Taiga wood, Tali, plum trees, apple trees, Kolumba, and Zingana.

Alternative fuel. Although wood smoking contributes to the physicochemical properties of fish, it does not always achieve fish smokers' goals. Thus, some fish smokers used alternative energy sources (Figure 5), as well as firewood, in order to improve physical aspects of the fish, most usually the color. The most used alternative source of fuel was waste collected from the beach (Figure 5(a)). Cassava peelings (Figure 5(b)) were the second most used. The least used alternative energy source were coconut shells (Figure 5(c)) and palm kernel waste (Figure 5(d)). Fifteen percent of respondents did not use any alternative sources of energy saying that wood was sufficient for their physicochemical requirements. Table 2 shows the different alternative sources of energy used.

Wood price. Fish smokers acquired firewood in several ways. Some only purchased it, and others, in addition to purchasing it, also collected their own wood. The restocking frequency varied from one fish smoker to another and was also affected by the season and the availability of fish. Wood purchases occurred weekly, monthly, and sometimes even annually, as sometimes the peak smoking period is only 1 or 2 months. On average and for fish smoking session, fish smokers use 50€ for wood.

During the peak smoking period, large-scale fish smokers spend an average of 200€ per month on purchasing wood. We have classified large-scale fish smokers as those who spend a sum greater than or equal to 150€ per month. Fifty-two percent of respondents are large-scale smokers and are mainly located in Eyengue, Idenau, and Down Beach. They sometimes spend up to 400€ per month on wood and are mainly Ghanaian (47%) and Nigerian (30%). A few (17%) are Cameroonian. Small-scale fish smokers (47.7%), who we classify as having wood expenses less than or equal to 70€, were mostly located in Batoke, Esobe, Njonji, and Bakingili.

Wood was sold in variety of ways. In Down Beach, red mangrove wood was sold by *line* (15 pieces of

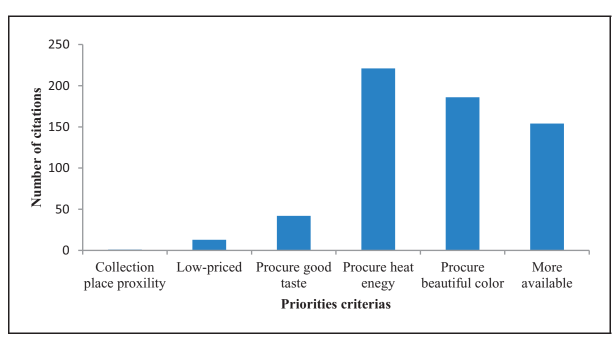

Figure 4. Reasons for firewood preference according to respondents.

Figure 5. Alternative energy. (a) Plantain and cassava peel. (b) Waste from beach. (c) Coconut shell. (d) Palm nuts waste.

Table 2. Alternative Energy Sources Used by Fish Smokers.

Alternative energy source	Utilization percentage
Cassava peel	33.4
Plantain peel	31.3
Coconut shell	31.3
Bunch of palm nuts waste	22.6
Waste taken on beach	49.8

wood—see Figure 6) at a cost of 16€, or by car load (a *Dyna* truck), which comprises 12 lines and a costs 192€. In Eyengue, it was sold in lots (see Figure 7), which comprise 120 pieces (see Figure 7) and cost 46€. Wood is transported either by tricycle motorcycles, or by rickshaw or, mainly in the case of fruit tree species, by a person carrying it balanced on their head.

Wood purchased by fish smokers usually came from mangrove forests, continental forests (Bomanas forest), agricultural fields, and home gardens (see Figure 8). It was usually cut by chainsaws (99.17%) and then transported mainly by canoes (97%).

Figure 6. Red mangrove wood piece.

Seventy-four percent of respondents said that the mangrove forests were depleted, 20% said they did not know and 6% said this was not the case. Those who said the forests were becoming depleted supported their opinion

Figure 7. Two lots of wood (120 pieces/lot). NB: It takes 15 pieces like the one in Figure 6 to form a *line*.

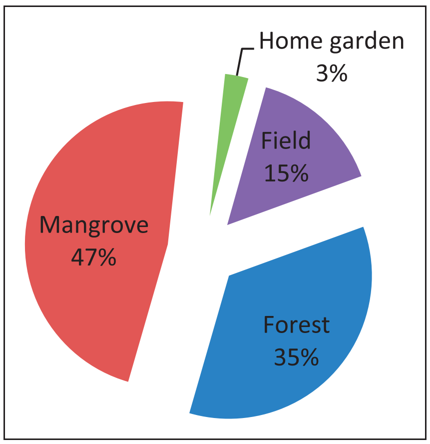

Figure 8. Firewood origin according to respondents.

by saying that the distance between where the wood is cut and where it is sold is increasing all the time. This increase in distance also increases the price of the wood.

Wood consumption. More wood is used in Down Beach, and Eyengue, and particularly in Idenau, than in other communities. Indeed, there is a significant difference ($F = 17.348$, $df = 243$, $p = .00012$) between wood consumption in the nine communities.

The largest scale fish smokers in the study area were Ghanaian, the majority of whom (62%) were located in Idenau. Some could even be classified as industries since they consumed 400€ to 420€ in wood per month (this is during the peak smoking period of 1 or 2 months). They are closely followed by smokers from Cameroon and Nigeria. Those from Benin did less fish smoking and therefore consumed less wood than others. The amount of wood used in smoking by all respondents was twice the amount of fish smoked. Indeed, there was a significant difference ($t = 11.559$, $df = 242$, $p = .00035$) between wood quantities and fish quantities. The Pearson Correlation Test ($r = .952$) showed a strong correlation between the amount of wood consumed and the number of fish smoked.

The amount of wood used was not significantly affected by a fish smoker's experience ($F = .728$, $df = 242$, $p = .865$) in any community. Indeed, there was no significant difference ($F = 1.761$, $df = 242$, $p = .138$) between wood quantities used and respondents' age groups.

Oven Yields

Different Type of Ovens Used

The amount of wood and fish that can be used at any one time depends on oven size. Several oven types were used in the study sites, but 99.6% of fish smokers used a traditional oven (*banda*). These were suspended iron *bandas* (Figure 9(a)), suspended wooden *bandas* (Figure 9(b)), or circular ovens (Figure 9(c)). Suspended iron *bandas* were the most common, used by 75.3% of our respondents. These fish smokers were mainly located in Down Beach, Idenau, Njonji, and Batoke. Suspended wooden *bandas* were used by 13.2% of respondents, mainly located in Tiko (100%) and Eyengue (60%). Only one respondent used a modern cinderblock oven (Figure 9(d)). However, fish smokers are not always able to use the oven of their preference. Figure 10 shows oven preferences.

The majority of fish smokers (68%) preferred traditional ovens to the new cinderblock oven because they have a large capacity and are known to be durable. Some respondents had not come across cinderblock ovens.

Oven Yields

Oven performance varied significantly within the study area (Table 3). Some were better than others and each, according to our respondents, had its advantages and disadvantages.

On average, a traditional oven has a capacity of 528.5 kg of fish and consumes 1,204.5 kg of wood with a smoking time of 53 hr. For the same smoking time, the cinderblock oven which has a capacity of 160 kg of fish per smoking session can smoke approximately 2,750 kg of fish with 780 kg of wood. Thus, although the traditional ovens have a larger capacity per smoking session, the amount smoked per kg of wood is far less compared to the cinderblock oven, the smoking time is longer and the cost of wood is far higher. For the same amount (160 kg) and species of fish, a cinderblock oven consumes 122 kg of wood at a cost of 4€, with a smoking time of 5 and a traditional oven consumes 365 kg of wood

Figure 9. Oven types in study site. (a) Suspended iron *banda*. (b) Suspended wooden *banda*. (c) Circular oven. (d) Cinderblock oven.

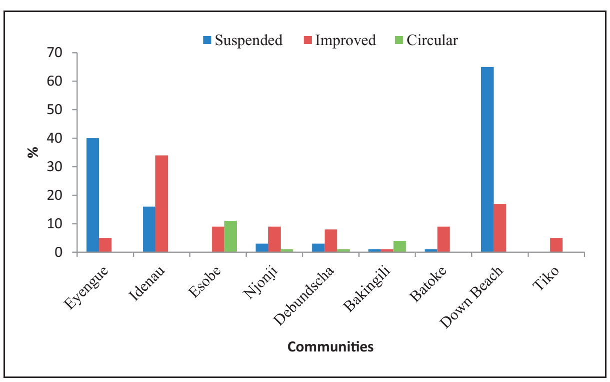

Figure 10. Oven preference by zone according to respondents.

costing 9€ with a smoking time of around 21 hr. Whether in quantity and cost of wood, or in smoking time, a traditional oven uses twice as much as a cinderblock oven. However, the cost of buying a cinderblock oven is almost double that of a traditional oven (165€ compared to 89€—see Ndiaye & Diei-Ouadi, 2009). On the other hand, a traditional oven has a shorter life span. A suspended wooden *banda* may last only 5 months, although, on average, traditional oven lasts about 6 years compared to 13 years for a cinderblock oven.

It is clear that cinderblock ovens are more economical. They are also safer to use, in that they do not generate as much heat and smoke as traditional ovens, and they smoke fish more cleanly (so that the fish are less carcinogenic). Despite the better performance of cinderblock ovens, they are not widely used, either because smokers are unwilling to try to the new ovens or because they do not know about them. A project aimed at introducing one type of cinderblock ovens (chokor ovens) in the region failed mainly because of insufficient training and monitoring by project managers.

Discussion

Fish Smokers' Socioeconomic and Demographic Characteristics

Fish smoking is a very important activity in the south west region of Cameroon and the demand for smoked fish continues to grow. Chabi et al. (2014) suggest that

Table 3. Different Oven Type Performance.

Oven	Fish quantity (kg)	Wood quantity (kg)	Smoking time (H)	Oven durability (month)	Ratio (wood/fish) (kg)
Traditional					
Suspended iron	585	1235	56	240	2.11
Suspended wood	472	1174	59	2	2.49
Circular	77	97	26	24	1.26
Improved					
Cinderblock	160	122	5	96	0.76

this demand is because of taste of smoked fish. Studies in Benin, Togo, and Ivory coast (Abotchi, 2010; Chabi et al., 2014; Oulaï et al., 2007) have found, like us, that all fish smokers are women. However, Baryeh et al., cited in Oulaï et al. (2007), found that only 11.2% of producers were women.

Many fish smokers in Cameroon, particularly those in the south west region, have at least primary school education. This is not the case in all countries. According to Degnon et al. (2013), Djessouho (2015), and Chabi et al. (2014) the sector is characterized by high levels of illiteracy 85%, 89%, and 95%, respectively. This may be due to the Muslim culture in these countries, which may prevent women from going to school. Our study marks an exception to Le Bigot & Ribier's (2004) findings that west African tradeswomen do not receive as much schooling as their male counterparts.

Our study also found that 52.7% of fish smokers were foreigners, which is contrary to the finding of Fall, Tounkara, Diop, Thiaw, and Thonart (2014), who worked on a socioeconomic and technological study of the production of fermented and dried fish (Guedj) in Senegal, and who found that only 10% of fish smokers were foreigners. This difference could be due to the fact that the majority of fishermen in Cameroon are foreigners, unlike in Senegal, where the locals dominate the sector.

We also found that fish smoking processes are not random. Fish smokers have well-defined requirements for their activities. We found that 98% of respondents have a preference for wood for smoking because it allow them not only to quickly reach and maintain the required temperature for fish smoking, but also to solve issues linked to physicochemical properties such as color because as Knockaert (1999) explains, fish color depends on the type of wood used during smoking. Pouokam (2011) found that only 75% of fish smokers have preference for wood. This discrepancy with our study may be due to the fact that our sample was governed by the relationship between government (IRAD, MINEPIA) and the fish smokers who participated in our study.

Wood Species

A large percentage (76%) of wood used by fish smokers is red mangrove wood. In their study on fish smoking in the same region as ours, N. Z. Feka and Manzano (2008) found that 62% of wood used for fish smoking is mangrove wood. Thus, smoking is highly dependent on mangrove forests (Ajonina, 2008; Ajonina, 2001). Indeed, this study found that red mangrove is the favored wood for fish smokers. However, Pouokam (2011), who worked on the firewood sector in the Kribi fisheries, found that smokers used Sambi (*Uapaca guineensis*). This difference is due to the scarcity of Kribi mangroves relative to other species (Angoni et al., 2015). Angoni et al. (2015) also found that second wood choice by fish smoker was Azobe (25%), which is also the second choice found in our study (although at just 13%). This gap is due to the fact that Azobe is not as widespread in the south-west region of Cameroon as it is in the southern region and also that red mangrove wood is still available, unlike in Kribi. Indeed, Pouokam (2011) reports that according to the fish smokers at his study site "the red mangroves are finished and all gone." Njifonjou (2009) cited in Pouokam (2011) argues that no more than half of mangrove wood consumption is related to fish smoking activities.

Mangrove wood is still the main resource used for fish smoking in areas of Cameroon other than Kribi (Angoni et al., 2015). This dependence on red mangrove wood is due to its capacity to produce a great amount of heat energy (Ajonina & Usongo, 2001). This study also showed that 47% of wood used by fish smokers comes from mangrove forests. Mulo and Ngueguim (2014), who worked on an assessment of the utilization of modern fish smoking ovens and their impact on forest conservation in the coastal communities of the south west region Cameroon, also found that over 40% of the firewood used for smoking was mangrove species. Besides mangrove forests, this study revealed that 35% of wood comes from continental forests and 3% from home gardens. Pouokam (2011) found that 55% of wood came from continental forests, 23% from home gardens, and 5% from mangrove forests. These differences are due to the fact that in Pouokam's (2011) study site, the mangrove forest stocks are almost exhausted, and this is putting pressure on other species such as forest trees and fruit trees. Forests are clearly under great pressure. Several wood species are cut for activities such as cooking food, baking bread, house construction, or building canoes, but fish smoking remains the main drive behind tree felling. How to reduce wood consumption is now a central challenge for many governments, and one solution could be the use of more economical ovens.

Oven Yields

This study found that 99.59% of respondents use traditional ovens. In their study of five communities in the same area, Mulo and Ngueguim (2014), found that 83% of fish smokers used traditional ovens and 11% used metal ovens. Our study found that with traditional ovens, smoking approximately 20 kg of fish cost 7€, about 3.7 times higher than the 2€ cited by Djessouho (2015) in his socioeconomic analysis of fish smoking in Benin. This difference is likely due to different wood species being used, as well as to varying costs. However, and perhaps most significantly, it is also due to the fact that the fish smokers surveyed by Djessouho (2015) used very small circular ovens, unlike the fish smokers in our study, the majority of whom used big suspended ovens.

Suspended ovens have a large capacity (can take 1,500 kg) for fish and consume 500 kg to 3,360 kg of wood with a smoking time ranging from 48 to 96 hr (2–4 days). These figures are supported by Chesnes (2009) in his study on the implementation of a Clean Development Mechanism project for the improvement of fish smoking ovens in the Douala-Edea reserve, who found it takes 3 to 4 days to smoke fish in a traditional oven. Our study found that suspended ovens have a ratio (wood quantity in kg/fish quantity in kg) of 2.3 over 53 hr of smoking. Thus, approximately 3 kg of wood is necessary to smoke 1.5 kg of fish, this is similar to Ngoma's (2005) finding in his study on improving fish smoking in Brazzaville. Ekomy, Bruneau, Mbega, and Aregba (2013), in their study of new concepts in the artisanal drying and smoking of food in Gabon, found that traditional longitudinal ovens have a ratio of 4.17 with a smoking time of 72 hr. This ratio is more than twice what we found in our study, which is probably due to differences in size and species of the fish (Ngoma, 2005).

We found that cinderblock ovens have a smoking time of 5 hr. This is supported by Ngoma (2005) who found that the smoking time of a cinderblock oven is 5 to 12 hr. We also found that the smoking time is almost 90% less than that of a traditional oven. N. Z. Feka, Chuyong, and Ajonina (2009) found that the smoking time of a cinderblock oven is 30% less than a traditional oven. This large gap could be explained by the fact that there were not many cinderblock ovens in our study site which prevented us being able to make a thorough estimate of cinderblock oven performance. Nevertheless, the study shows that cinderblock ovens are categorically more economical than traditional ovens. The FAO studies in 2008 showed that cinderblock ovens reduced wood consumption by 50% over traditional ovens. In their study, Mulo and Ngueguim (2014) found that for every 100 kg of fish smoked, the fuel cost was 2.5€ for a cinderblock oven and approximately 5€ for a traditional *banda* oven. This result is also supported by Ndiaye and Diei-Ouadi (2009) who report a result of 2€ of fuel per 100 kg of fish for a cinderblock oven compared to 5€ for a traditional oven.

Implications for Conservation

This study took place in nine communities, all located in the Fako department in the south west region of Cameroon. It has shown that wood plays a major role in the energy supply of the rural population. Wood is generally the preferred fuel for rural people because it is easily available, dispersed throughout the rural habitat, and can usually be obtained without major costs. Because there is no electricity in some villages in southwest Cameroon, and also because of population growth, there is considerable pressure on forest resources, which results in increasing deforestation.

Several species of mangroves, particularly Red Mangrove (*Rhizophora racemosa*), are used for fish smoking. Alternative fuels that could reduce wood consumption are rarely used as fuel; they are used to improve the physicochemical properties of fish for better sales. Women who live in villages in the mangrove forests also use red mangrove for their own domestic needs. Villages located far from mangrove forests, or in areas where mangrove supplies have been exhausted, have collection teams to transport firewood on canoes, which they then sell. The ever-increasing distance needed to be traveled to collect wood underscores how mangrove forests have become severely depleted. If nothing is done to conserve or sustainably manage the remaining stands, then the *Rhizophora* species will disappear, as is already the case in Kribi and in many other regions (Ngo-Massou et al., 2014; Pouokam, 2011).

This study found that there is a strong correlation between the amount of wood burnt and the type of oven used. Introducing cinderblock ovens could be key to reducing the consumption of wood; they require half the amount of wood used by a traditional oven. The smoking time is also shorter than with a traditional oven, and working conditions (smoke, heat, and fumes) are better. Furthermore, the resulting product is better and less carcinogenic, and therefore could be more valuable. The cinderblock ovens use over 50% less wood than the traditional ovens, reduce workloads, improve the product's value, and thus increase fish smokers' income. However, fish smokers have been slow to change to cinderblock ovens, which could be due to a variety of social, economic, and cultural factors.

Mangroves are known to sequester much more carbon than continental forests (Cordonnier, 2011). Thus, the loss of mangroves will affect the entire planet not only because it will lead to a loss of biodiversity but also because it will accelerate climate change (PFBC, 2006). As the population increases, coastal resources will continue to come under more and more pressure (Angoni et al., 2015). There is an urgent need to address the sustainable management of this vital coastal ecosystem.

Fish smoking is one of the key activities impacting on the disappearance of characteristic mangrove species. For many people, it is their sole livelihood. As it cannot be prohibited, strategies need urgently to be introduced to regulate mangrove wood consumption. To introduce regulations, it is first necessary for legislation to be passed to protect mangrove forests. At present, the implementation of law is an issue in Cameroon, and people are able to freely harvest as much wood as they want. We hope that this study will help underscore the alarming rate of mangrove depletion and thus encourage decision makers to implement conservation strategies for the sustainable management of mangrove forests through measures that also take into account the socioeconomic conditions of local populations. A balance needs to be found between consumption and preservation: This is the challenge for all parties involved in the fight for sustainable mangrove management in Cameroon.

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