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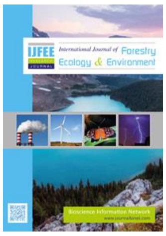

Assessment of fuelwood utilization and carbon emission on conservation of Mangrove (*Rhizophora racemosa*) forest in Koko, Delta State, Nigeria

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ABSTRACT

Fuel wood is the main energy source in rural and peri-urban areas where its utilization constitutes a significant index of carbon leakage from its renewable source due to over exploitation and production of its composite products. This study was carried out to ascertain the level of local deforestation and carbon emission from the use of Mangrove fuelwood as source of energy in Koko. The Five- point Likert scale questionnaires were administered in the community to verify the sources of mangrove fuelwood, preference for existing species of fuelwood and other alternative energy, impact on sustainable livelihood and environment. Twenty (20) randomly selected Households in Nana and New Koko quarters were assigned weighed bunches of mangrove fuel wood procured from the Fuelwood Market for use as energy burners. These were monitored daily for 14 days and collected data were analyzed using descriptive and chi-square (X^2) test statistics with mean score ≥ 3.00 as significant, while the carbon dioxide emitted from fuelwood by individual households was estimated by standard procedure. Results showed that mean of critically investigated indices were significant (mean score ≥ 3.00) in the order of existing booming market for mangrove fuelwood (3.04) < fuel wood consumption/cost of fuelwood (3.20) < 5-10 bunches required for fish-drying (3.25) < non-preference for other wood species than the mangrove fuelwood for kiln fish-drying (3.67). These perceptions corroborated the mean indigenous knowledge that fuelwood stoves released more fumes than kerosene stoves (3.91) with negative environmental health implications. High quantity of fuelwood used by households in Koko (3.67) accounted for approximately 411.15 - 734.67 kg and 333.54-694.15 kg of mangrove fuelwood consumed as well as the average 21.41-74.12 CO_2eq/kg and 16.47-70.82 CO_2eq/kg emission per day per household in Nana and New Koko quarters respectively. Furthermore, the high preference for mangrove fuelwood due to thermal capacity and presence of colour pigments for attractive commercial fish drying venture underpinned high fuelwood utilization along with carbon emission in Koko to impinge on conservation of the blue carbon Mangrove Forest. Therefore, pressure reduction by sustainable forest management by fuelwood efficiency and reduced emission profile to allow for other endowed ecological benefits of Mangrove Forest Conservation cannot be overemphasized as attempts at minimizing degradation and enhancing carbon de-capitalization in Koko Community.

Key Words: *Fuel wood, Deforestation, Carbon emission, Mangrove wood and Koko Community.*

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I. Introduction

Fuelwood extraction and carbon emission are critical utilitarian indices for evaluating pressure and sink capacities of forest ecosystems due to dynamic contributions to deforestation, habitat loss and greenhouse gas levels in the atmosphere (Mekonnen and Kohlin, 2009; UNEP, 2005). It is estimated that fuelwood constitutes over 70% of the primary source of energy among the rural populace of developing countries (Naughton, 2007), where population upsurge creates increasing demands for utilization of forest resources as leverage for economic empowerment as it is considered the cheapest and most readily available route out of poverty. The increasing harvest of fuelwood to drive other sectors of the economy often initiates a commensurate impact on the eco-service potential of standing forests and reduces the capacity to sink carbon at source. Domestic use of fuelwood and its composite products, such as charcoal as an energy source, has been reported as a significant carbon footprint in rural economies, especially where other forms of energy are absent to either augment or complement (Chidumayo and Gumbo, 2013; Gurmessa, 2010).

Consequently, the increasing extraction and use of firewood over time consistently lead to deforestation with resultant ecological imbalance that not only deprives the replenishment of atmospheric oxygen but initiates a chain of terrestrial pollution. The effect of fumes from fuelwood and its composites during cooking are critical contributors to acute respiratory infections in urban and peri-urban conurbations due to indoor air pollution with toxic and carcinogenic substances released into the atmosphere annually (Geissler et al., 2013). Furthermore, carbon emission has been reported as the main contributor to climate change, with the decline in forests estate as a result of deforestation through loss of stored carbon on earth (Boucher, 2011; UNFCC, 2005). Therefore, carbon emission, an index of increasing reliance on fuelwood in rural areas, reflects the deforestation trend that equates to habitat degradation and biodiversity loss. A good proportion of urban and rural dwellers rely on forest biomass as primary source of domestic fuel (Gurmessa, 2010). This wide range of dependence accounts for overconsumption of fuel wood, undermining the critical roles that each specialized forest type plays within forest ecological zone and supplying industrial materials (Angelsen and Kaimowitz, 1999). Consequently, forests and woodlands are reportedly lost annually with a commensurate massive loss of income to the rural poor that rely on the forest resources for sustainable livelihood (Berger, 2013).

Deforestation creates a set of multiple critical changes in the microclimatic environment that significantly influence biodiversity and bio-alterations of the edaphic system in various climatic regimes. The Mangrove Forest represents a specialized forest ecosystem that provides a wide array of ecological goods and services, sequestering carbon more than the conventional terrestrial forest (Bile´, 2012). Its wood plays a major role in fish drying and preservation, especially in border communities in the mangrove forest enclave. However, due to population pressure, greater quantity of mangrove wood is consumed annually, resulting in threat to the myriad ecological services, including its sustainability as breeding ground of halieutic resources, habitat for wide array of wildlife, primates, and fauna and its loss portend a decrease in fish stocks (Polidoro et al., 2010; Tiega and Ouedraogo, 2012). Delta State covers 17% of the total 10310.7sqkm of lower floodplain Mangrove ecological zone of the Niger Delta region, with *Rhizophora racemosa, R. harrisonii and R. mangle* as the endemic tree species. The mangrove belt runs parallel to the coast as barrier forest to protect the freshwater wetlands against the frequent tides of up to 1-3m amplitudes and provides habitat to various reptiles and mammals (SPWA, 2010). The prop roots act as substrates for attachment of Oysters other bivalves, while the bark is a sustainable source of tannin for dying, preservation of fishing nets and production of adjunct resin for wood-based panel products (Fuwape et al., 1999).

However, the extraction of fuelwood from the mangrove forest in Koko has become highly unsustainable in recent times, as it has endangered a lot of other life forms that create chain of ecological services within the swamp forest ecosystem for much greater sustainable services as livelihood options than the short term-use timber and energy sectors. Therefore, this work was conducted to ascertain the effect of extraction rates and use of mangrove fuelwood as a potential driver of other carbon footprints of fuelwood-induced carbon emission in Nana and New Koko quarters of Koko town, in the coastal swamp forest ecological zone of Delta State. This is to reduce the traffic for fuelwood as a way of soliciting and salvaging other critical ecological benefits in the mangrove forest ecosystem.

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II. Materials and Methods

Description of study area

The study was conducted in Koko, the Warri North Local Government Area headquarters of Delta State, Nigeria. The town is located along the Benin River, in the western Niger River delta on 5°59'40" North, 5°26'10" East and has an area of 1,841 km². Temperature is approximately 26°C. Koko town comprises two communities, namely Nana quarters and New Koko, which represent a rural and peri-urban area respectively (National Population Commission, 2006). Koko is situated in the fresh water swamp forest ecological zone with the largest vegetation of Mangrove Forest in Delta State. *Rhizophora racemosa* (red Mangrove) is the dominant tree species, exploited for fuel wood and timber by flitching at stump sites in the swamp forest. These economic activities have degraded the mangrove forest for over two decades, with resultant pressure over time as evidenced by the sea incursion on land, with the previous jetties now closer to the midst of the sea.

Delineation of study area

Koko town was divided into two (2) using the natural developmental segmentation – Nana quarters and New Koko (Industrial area of Koko). This was to assess the effect of emissions across the town properly. The industrial area of the town that spans from the entry Port does not have residential apartment with potential for fuel wood utilization but has a boundary area with significant residents clustered around the emerging mangrove forest. Hence, this area was completely employed as a representative of the New Koko in the study.

Data collection and analysis

Field investigations, personal interviews and questionnaire interviews were carried out to elicit respondents' bio-data; information on the economic usage of fuel wood and carbon emission; environmental factors of carbon emission from fuelwood utilization; and information on the ecological factors of fuel wood-carbon emission in Koko. The variables were based on five-point Likert scales-Strongly Agreed (SA), Agreed (A), Undecided (UD), Disagree (DA), and Strongly Disagreed (SD) - to gauge attitudes, values and opinions to which individuals either agreed or disagreed with test variables. Ninety-two (92) of the one hundred (100) copies of distributed questionnaires were evenly distributed in Koko community. Data gathered with the questionnaire were analyzed using the Chi square (X^2) test-statistics. First, an estimate of overall mean for each impact variable was computed from as the sum of mean score and the number of its impact statement. Then using the decision rule, impact statement was adjudged significant, positive and agreed decision (Mean ≥ 3.00) or not significant, negative and a disagreed decision (mean < 3.00).

Twenty (20) households were selected within each of the two (2) quarters demarcated for the study. The households were assigned bundles of Mangrove fuel wood from the fuelwood market in Nana town for use as energy burners with the tripod stoves. Each quantity of fuel wood for individual household was weighed with a sensitive spring balance every evening before cooking and then monitored the next morning and afternoon after cooking, by taking the weight of either the leftovers or the additional fuel wood at the end of each day.

Carbon emission was computed on the assumption that 1kg of fuelwood emits approximately 183kg of carbon dioxide upon combustion and 1cubic metre of fuelwood emits 61-73kg of carbon dioxide equivalent as well as other toxic and greenhouse gases over its lifecycle for open and closed fires in homes respectively (Tsietsi et al., 2013; WHO IAQ Guidelines for household fuel combustion). This was carried out for 20 households in two-quarters of Koko town daily for 14 days at the rate of 7 days per quarter.

III. Results

Demography of respondents

The demography of respondents revealed that majority were female (61%) while 39% of the respondents were male (Table 01). In addition, the percentage of married and single respondents was 67% and 33%, respectively. Twenty-five percent of the respondents had primary education, while 21% and 46% had secondary and tertiary education, respectively. The respondents in public and private sectors were 47% and 31%, respectively. Approximately 67% of the respondents live in New Koko, while 32% in Nana quarter. Then 57% of the respondent were natives of Koko, while 42% were

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non-indigenes. Furthermore, 45% of the respondents have relied on the mangrove forest for fuel wood for more than 15 years, while 36% for between 5-10 years.

Table 01. Demography of respondents

Characteristics		Frequency	Percentage (%)
Sex	Male	36	39.13
	Female	56	60.87
Age (years)	21 – 30	14	15
	31 – 40	18	20
	41 – 50	37	40
	51 – 60	16	17
	60 – 70	7	8
Marital Status	Married	62	67
	Single	30	32.6
Occupation	Student	21	22.83
	Civil Servant	42	45.65
	Farmer	12	13.04
	Others	17	18.48
Education	Primary	25	27.17
	Secondary	21	22.83
	Tertiary	46	50
Native to the town	Yes	53	57.60
	No	39	42.40
No of years relied on Mangrove fuelwood	1-5yrs	9	9.80
	5-10	33	35.86
	10-15	9	9.80
	Above 15	41	44.60

Economic Perception of Mangrove fuelwood and carbon emission in Koko

The results of perception and choice of mangrove fuelwood in Koko showed that respondents strongly agreed that fuel wood cooks better than kerosene stove (Table 02). The respondents also strongly agreed that the cost of using fuelwood tripod burner is less than kerosene stove in Koko. Furthermore, most respondents strongly agreed that there is a readily available market for fuel wood in Koko and that a bunch of fuel wood costs less than one hundred naira (₦100). Results also showed that respondents strongly agreed that a fish dryer used 5-10 bunches of fuelwood per week and that there are other alternatives to drying fish other than the use of mangrove fuel wood but still prefer the mangrove wood. Also, most respondents strongly agreed that there is an organized association of fuel wood marketers and the government collects taxes from fuel wood marketers.

Table 02. Assessment of Mangrove fuelwood utilization and choice in Koko

Variable	SA	A	UD	DA	SD	N	WS	MWS	Decision
Fuelwood is more expensive than kerosene.	13 (65)	13 (52)	7 (21)	32 (64)	27 (27)	92	229	2.48	NS
Cost of cooking with fuelwood is less than kerosene stove.	30 (150)	31 (124)	9 (27)	13 (26)	9 (9)	92	336	2.65	NS
Fuelwood market is a means of livelihood in Koko.	16 (80)	14 (56)	10 (30)	28 (56)	24 (24)	92	246	2.67	NS
A bunch of fuelwood costs less than N100 in Koko.	26 (130)	19 (76)	8 (24)	26 (52)	13 (13)	92	295	3.20	*
There is booming market for fuelwood in Koko.	18 (90)	22 (88)	14 (42)	22 (44)	16 (16)	92	280	3.04	*
There is high use of fuelwood by many households in Koko.	12 (60)	11 (44)	12 (36)	22 (44)	35 (35)	92	219	2.38	NS
A fish dryer uses 5-10 bunches of fuelwood per week in Koko.	22 (110)	26 (104)	12 (36)	17 (34)	5 (15)	92	299	3.25	*
There are other means for fish drying but prefers fuelwood in Koko.	18 (90)	22 (88)	14 (42)	22 (44)	16 (16)	92	280	3.67	**

Note: SA-Strongly agree; A-Agree; UD-Undecided; DA-Disagree; SD-Strongly disagree; N-Frequency; WS-Weighted score; MWS Mean weighted score. Figure outside the parenthesis is frequency of respondents while figures inside are product of Likert scale value and frequency of respondents. Mean score (MS)=3.00 Ns-Not significant; *Significant; ** highly significant

Perception of environmental implication of fuelwood and carbon emission in Koko

The result showed that respondents strongly agreed that fuel wood was obtained from mangrove forest in Koko and that mangrove wood is best for fuelwood and fish smoking (Table 03). In addition, majority of the respondents strongly agreed that the use of fuel wood was more than that of kerosene stove and that fuel wood stove releases more fumes than kerosene stove. The respondents also showed more charcoal production points than fuelwood depots in Koko.

Table 03. Evaluation of Mangrove fuelwood and composites characteristics in Koko

Variable	SA	A	UD	DA	SD	N	WS	MWS	Decision
Fuelwood is gotten from mangrove forest in Koko	33 (165)	27 (108)	9 (27)	13 (26)	10 (10)	92	336	3.65	**
Mangrove tree is good for fuelwood	34 (170)	27 (108)	13 (39)	11 (22)	7 (7)	92	346	3.76	**
There are other sources of fuelwood apart from mangrove forest in Koko.	22 (110)	32 (128)	8 (24)	13 (26)	17 (17)	92	305	3.29	*
Fuelwood stove release more fumes than kerosene stove	41 (205)	24 (100)	11 (33)	7 (14)	8 (8)	92	360	3.91	**
There are more charcoal production points than fuelwood depots in Koko.	11 (35)	13 (52)	10 (30)	31 (62)	27 (27)	92	226	2.46	NS
Charcoal is preferable to fuelwood for households in Koko.	13 (65)	15 (60)	11 (33)	30 (60)	23 (23)	92	241	2.63	NS
There are more households that use fuelwood than charcoal in Koko.	34 (170)	27 (108)	8 (24)	12 (24)	11 (11)	92	337	3.67	**
The use of fuelwood is less than kerosene stove in Koko.	18 (90)	19 (76)	12 (36)	20 (40)	23 (23)	92	265	2.89	NS

Note: SA-Strongly agree; A-Agree; UD-Undecided; DA-Disagree; SD-Strongly disagree; N-Frequency; WS-Weighted score; MWS Mean weighted score. Figure outside the parenthesis is frequency of respondents while figures inside are product of Likert scale value and frequency of respondents. Mean score (MS)=3.00; Ns-Not significant; *Significant; ** Highly significant

Comparative alternative attributes of Mangrove fuelwood in Koko

The result showed that respondents strongly disagreed that fuelwood market is better than fishing business (Table 04). It also showed that respondents agreed that fuel wood is used more for cooking than drying/smoking fish, with strong preference for mangrove fuelwood compared to rubber wood (*Hivea brasillienses*).

Table 04. Assessment of Mangrove fuel wood utilization and alternatives of in Koko

Variable	SA	A	UD	DA	SD	N	WS	MWS	Decision
Fuelwood market is better than fishing business in Koko	8 (40)	12 (48)	9 (27)	23 (46)	40 (40)	92	201	2.80	NS
Fuelwood is used more for cooking than fish drying in Koko	24 (120)	23 (92)	8 (24)	17 (34)	20 (20)	92	290	3.15	*
There are more firewood depots than kerosene/gas depots in Koko.	23 (115)	20 (80)	9 (27)	17 (34)	23 (23)	92	279	3.03	*
Mangrove firewood burns faster and better than rubber wood	30 (150)	21 (84)	14 (42)	15 (30)	12 (12)	92	318	3.44	*
Charcoal from mangrove tree is preferable to fuelwood for cooking and fish drying.	11 (35)	13 (52)	10 (30)	31 (62)	27 (27)	92	226	2.46	NS
Charcoal is preferable to fuelwood for households in Koko.	24 (120)	19 (76)	16 (48)	19 (38)	14 (14)	92	296	3.21	*

Note: SA-Strongly agree; A-Agree; UD-Undecided; DA-Disagree; SD-Strongly disagree; N-Frequency; WS-Weighted score; MWS Mean weighted score. Figure outside the parenthesis is frequency of respondents while figures inside are product of Likert scale value and frequency of respondents. Mean score (MS) =3.00; Ns-Not significant; *Significant; ** Highly significant

Carbon dioxide emission from the Mangrove fuel wood

The various daily emissions of carbon are shown in Figures 01 and Figure 02 for Nana and New Koko quarters, respectively. The highest and least daily emission of 74.12CO_2eq/kg and 21.41CO_2eq/kg was recorded in Nana, while for New Koko, it was 70.82 CO_2eq/kg and 24.71CO_2eq/kg in New Koko.

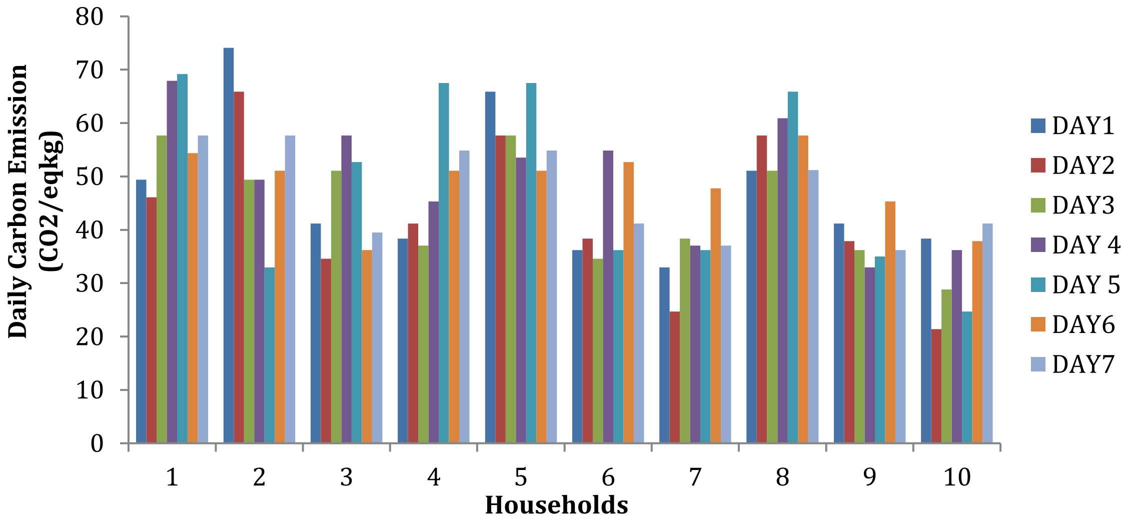

Figure 01. Daily carbon emission from Mangrove fuelwood in Nana quarters, Koko

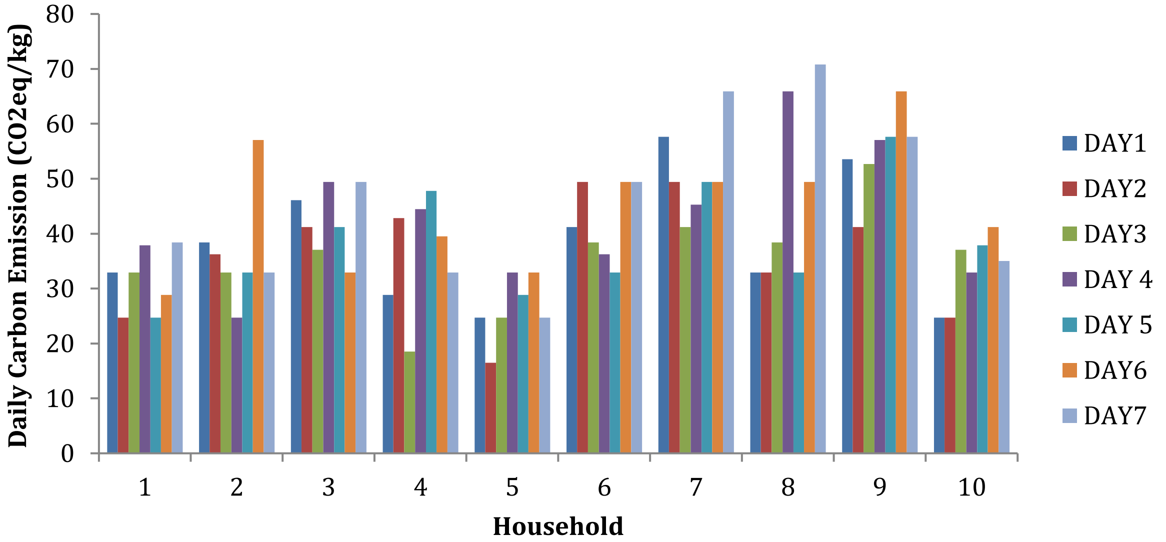

Figure 02. Estimated daily carbon emission from Mangrove Forest in New Koko

The comparative analysis of fuelwood utilization in Koko is shown (Figure 03). Sixty percent of households in Nana quarters used more fuelwood than New Koko. Nana quarter used the highest quantity of fuelwood of 734.67kg while the least of 333.54kg was in New Koko.

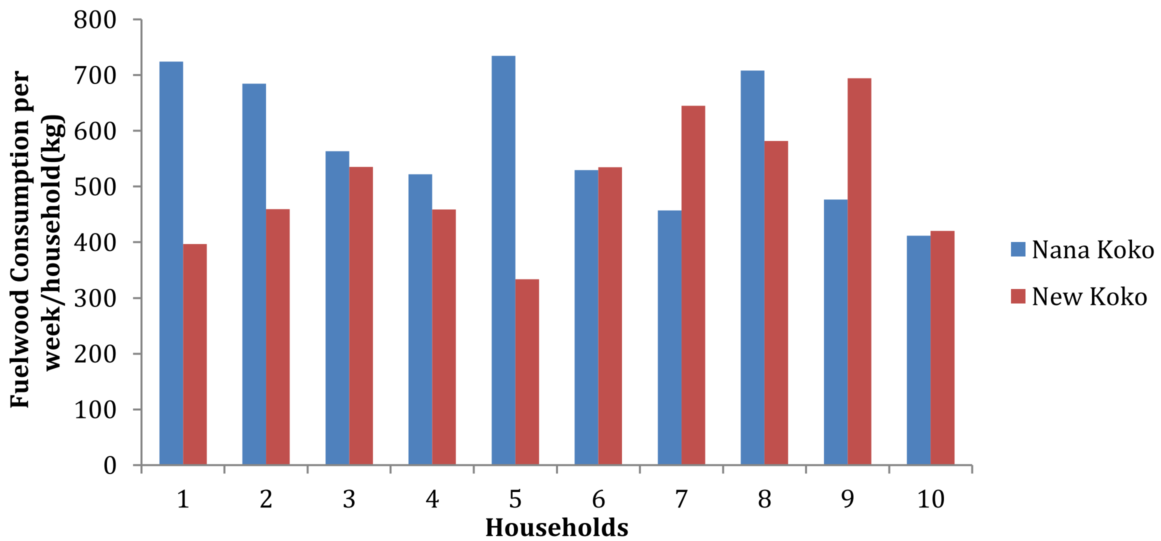

Figure 03. Comparative analysis of Mangrove fuelwood utilization by households in Koko town

IV. Discussion

Socio-economic characterization

Demographically, majority of the respondent are educated and could therefore be taken to have good knowledge of fuel wood utilization. Approximately 44.6% of respondents relied on mangrove forests for fuelwood over 15 years and are likely familiar with the environment to assert credible responses on the variables under investigation. The result showed that females consumed and supplied fuelwood more than males, probably due to the domestic responsibilities of running the home. The greater population of respondents (40%) were within the age bracket of 41-50 years which belongs to the active population group. The greater involvement of married people in fuelwood utilization and market may not be unconnected with the need to increase family income and minimize energy costs for cooking for the family.

Evaluation of fuelwood utilization

The study showed that the cost of a tripod burner that uses fuel wood from the mangrove forest is less than the kerosene stove in Koko. This may not be unrelated to the fact that fuel wood is cheap, available, and affordable in rural communities. Furthermore, this high reliance on fuelwood created a readily available market for fuelwood in Koko and constituted a livelihood for families in rural climes (Olugbire et al., 2016).

The respondents agreed that there is readily available market for fuel wood in Koko since majority of the household use fuel wood as means of cooking. The establishment of fuelwood market in Koko may not be unconnected with the fact that only small capital was required to step up the business (Larinde and Olasupo, 2011), with small income earners, both old and young people joining the business. The growing fuelwood market represents more significant visitors quickly with further detrimental traffic to the mangrove forest. Apart from the domestic implication of heavy fuel wood use without alternatives, respondents agreed that a local fish drying oven required a sizeable quantity of 5-10 (280kg) bunches of mangrove fuel wood per week. This finding was not different from Joel-Han (2019) that the quantity of fish fuelwood determined the quantity of fuel wood consumed during fish drying. Unfortunately, the Koko fish dryers consume more wood due to the traditional crude oven.

Furthermore, the respondents agreed that even though there are alternative means of fish drying, the larger population still prefers mangrove fuelwood. Ayuba et al. (2015) similarly reported that using fuel wood for fish drying could gradually become expensive over time and there is need to search for alternative drying sources. This may not be unconnected with fuelwood marketers' organized association and an anticipated increasing tax from fuelwood marketers (Kombat and Wätzold, 2019).

The respondents agreed that fuel wood from mangrove forests in Koko was best for fish drying compared with para rubber wood. This agreed with the findings of Joel-Hans (2019) that choice of fuelwood quality in fish drying was Mangrove (*Rhizophora racemosa*)> para rubber (*Hivea brasilensis*) > Azobe (*Lophira alata*). This was attributed to the specific heat capacity in addition to the ability of the Mangrove to release colour pigments that make the processed fish more attractive. Therefore may have accounted for the preference for mangrove fuelwood over para rubber (*Hevea brasiliensis*) wood from the secondary forest in Koko. This study further corroborated Ndayambaje and Mohren (2011) that fuelwood from natural forests was more preferred to plantations and woodlands sources probably due to the natural pigments related to formative ages of indigenous tree species known with longer gestation periods. Therefore, this will continue to be an underlying source of pressure on mangrove forests, which may constitute a significant pathway for its degradation and habitat destruction (Udo, 2016; Oluwabenga and Orimoogunje, 2015).

Assessment of carbon emission from mangrove fuelwood

The study revealed that fuel wood stoves released more fumes than kerosene stoves. This alludes to smoke and soot from wood-burning stoves as significant sources of air pollution and carbon emission that negatively impacts air pollution and carbon emission that negatively impacts public health and the environment. Furthermore, the respondents agreed that there were more charcoal production points than fuelwood sales depots in Koko. This finding is apt to the study as the volume of emission from the unrefined and local methods applicable in charcoal production contributes significantly to greenhouse gases (Emeodilichi, 2018).

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There was also higher fuelwood utilization in Nana quarter which may not be unrelated with the difference in socio-economic status of households in the two quarters within the Koko community. More peasants in Nana engaged more fuelwood for cooking compared to the more civil society of New Koko, which had a higher population of civil servants with perhaps kerosene stoves (Neufeldt et al., 2018).

Therefore carbon emission varied among the different households as it fluctuated among individuals and households. For example, the minimum carbon emission in New Koko was 16.47 CO_2eq/kg with a total emission of 185.30 CO_2eq/kg per week, while the highest carbon emission was 70.82CO_2eq/kg emitted by a household with a total emission of 323.31 CO_2eq/kg. However, in Nana the minimum carbon emission (21.41 CO_2eq/kg) was higher than in New Koko, while the highest emission (74.12 CO_2eq/kg) was from a household with a total emission of 380.47 CO_2eq/kg. This finding revealed that fuelwood not only constitutes the major source of energy for rural communities but also a major contributor to atmospheric pollution and greenhouse gases responsible for global warming (Sony Baral et al., 2019; Oluwagbenga and Orimoogunje, 2015). Nevertheless, the average daily carbon emission of 4.57-11.25 CO_2eq/kg and 5.13-10.68 CO_2eq/kg in New Koko and Nana quarters showed severe carbon leakage from the Mangrove forest in Koko, which detrimentally contributes to the global carbon emission.

V. Conclusion

The study revealed a significant threat to mangrove forest conservation by the utilitarian forces of fuelwood collection driven by domestic and commercial energy needs in Koko. High quantity of wood extracted from the forest amounted to commensurate high release of carbon in the two quarters. Furthermore, the organized fuel wood marketers represent additional linkage between the mangrove forest to other communities outside Koko and thus depict an over-reliance on the mangrove forest. This synergy further deepens the crisis of fuelwood extraction, which creates more degradation within the mangrove ecosystem while increasing carbon emissions from domestic use to huge volumes in fish drying and charcoal production in Koko. Even though there are alternatives, the choice of mangrove fuelwood due to its heating capacity and colour in commercial fish drying are forces to contend with in the conservation of Mangrove forest ecosystem. Therefore, there is a need to encourage and facilitate the use of alternative energy sources, especially for the conservation of Mangrove Forest in Koko to sustain its ecological service of preventing sea incursion on land while enhancing habitat for numerous endemic biodiversity of the Niger Delta region.

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