An Empirical Analysis of the Impact of Household Fuel Wood Consumption on the Environment in Nigeria

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Abstract

We analysed the impact of household fuelwood consumption on the environment in Nigeria using survey and Landsat remote sensing data. The study employed descriptive statistics and Chi-Squared tests as well as image classification techniques. The results revealed that majority of the households are headed by males whose age fall within the category 44-56 years with a household size of five to six persons, earning an income between ₦10,000 to ₦15,000 monthly with 74% of them being married. With regards to the types of cooking fuels available to the households, the 2010/11 result showed that fuelwood fetched was the most common and widely used source. This is followed by fuelwood purchased, then kerosene, Liquidities Petroleum Gas (LPG), charcoal and grass by both rural and urban households in that order. However, a declining pattern was observed over the years for fetched fuelwood while an increasing pattern for fuelwood purchased and LPG was observed. On fuelwood exploitation and their sources, the results revealed that fuelwood fetched from the unfarmed area and the community were declining. In contrast, own woodlots and the proportion of fuelwood fetched from the forest showed signs of increase for both rural and urban areas over the years. The Chi-square results for change in fuelwood sourced areas showed a high chi^2 value of 4078.913a with a probability of 1%, indicating that the changes in the wood fetching areas were not by chance. Also, chi^2 test value of 4219.527 and a significant P value of 1% further revealed that fuelwood exploitation through distance trekked over the years for both rural and urban areas has been increasing. The results of the image analysis corroborated with LULC change that has indicated a decline in vegetal cover between 2011 and 2019. Urbanization and population growth accompanied by the demand for fuel among others might have the expansion at the expense of natural vegetation. The study recommends that government and Non-Governmental Organization (NGOs) should improve LPG use and encourage afforestation based on the United Nation's policy of Reducing Emissions from Deforestation and Forest Degradation (REDD).

Keywords: Empirical Analysis, Impact Household Fuelwood Consumption, LULC Change

INTRODUCTION

Wood fuel is the most useful forest resources utilized by households. It encompasses of wood obtained from trunks, branches and other parts of trees and shrubs used as fuels for cooking, heating or generating energy through direct combustion. Although, there are other sources which include dungs and agricultural residues such as straws, however, it has been noted that among all the tree products, fuelwood is the most used energy source (Onoja and Emodi (2012).

In developing countries, despite being in the 21st century, there are still about 2.7 billion people who rely on a wood tree and leaves for cooking. Through the use of inefficient devices like 3-stone fire, mud stoves, brick stoves with no operating chimney or hoods (The International Energy Agency, IEA). Similarly, over 70 per cent of rural and some proportion of the urban households of Nigeria rely on solid fuels as their major source of energy for agriculture and other domestic food processing activities (Maina & Kyari, 2020).

Some of the factors that increase fuelwood consumption in Nigeria relate to a rapid urbanization due to rural-urban migration whereby these migrants rely still on firewood because they cannot afford Liquidities Petroleum Gas (LPG). Other reasons relate to the influence of socio-economic characteristics of the household head such as household's age, educational level, household size, wealth status, income and price of alternative sources of energy (Ujih *et al*, 2016).

The over-dependence on fuelwood in Nigeria contributes greatly to drought and desertification, destruction of aesthetic nature, flood etc. The rate of fuelwood exploitation affects the vegetative coverage of the area, and if this acts go unabated, that could lead to deliberate cutting of trees at a large scale basis. In fact, this indiscriminate cutting down of trees without replacement makes the country to be losing about 350,000 to 400,000 hectares of forest land per year. Hence, out of the 909,890 km^2 of the country's land area, about 580,841 km^2 accounting for 63.83% of the total land is impinged on by desertification (FAO, 2016). Towards this end, it has become very important for the pattern of fuelwood consumption and its impact on the environment to be assessed in Nigeria for efficient resource utilization and sustained environment.

There are many literature on household's fuelwood utilization and the factors responsible for such pattern e.g. Onoja & Emodi (2012) and Ujih et al. (2016). However, these studies dwelt on a particular region, state or local government. Therefore, this paper bridges a gap based on three objectives: I) examine the socio-economic factors of the household heads in Nigeria and the pattern of household energy sources used, II) examine sources of primary cooking fuels and the major places of sourcing fuelwood while objective III) assess the impact of fuelwood exploitation based on the changes in the distance trekked over the years as well as spatio-temporal changes of vegetation cover.

MATERIALS AND METHODS

2.1 Study Area

The study area is Nigeria which lies between latitudes 4º 12′ 40.37″ N to 13º51′ 36.50 ″ N of the equator and longitudes 2º 45′ 47.735″ E to 14º42′ 55.123″ E of the Greenwich meridian. Located at the extreme inner corner of the Gulf of Guinea on the west coast of Africa, Nigeria occupies an area of 923,768 sq. km (356,669 sq mi), extending 1,127 km (700 mi) East to West and 1,046 km (650 mi) North to South. The country has 36 states and a projected population of 214, 312, 387at the end of 2019 (National Population Commission [NPC], 2006).

The country has a tropical climate with variable rainy and dry seasons, depending on location. It is hot and wet most of the year in the southeast but dry in the southwest and farther inland. A savanna climate, with marked wet and dry seasons, prevails in the north and west, while a steppe climate with little precipitation is found in the far north. In general, the length of the rainy season decreases from south to north. In the south, the rainy season lasts from March to November, whereas in the far north it lasts only from mid-May to September. A marked interruption in the rains occurs during August in the south, resulting in a short dry season often referred to as the

August break. Precipitation is heavier in the south, especially in the southeast, which receives more than 120 inches (3,000 mm) of rain a year, compared with about 70 inches (1,800 mm) in the southwest. Rainfall decreases progressively away from the coast; the far north receives no more than 20 inches (500 mm) a year. Temperature and humidity remain relatively constant throughout the year in the south, while the seasons vary considerably in the north; during the northern dry season, the daily temperature range becomes large as well (Eludoyin & Adelekan, 2013).

Nigeria is grouped into Forest (rain forest, freshwater swamp, and mangrove) and Savannah (marginal, short, woodland/tall grasses) vegetation belts. They reflect the tight link between the vegetation and the country's climate (Figure 1). The household sector in the study area is characterized by various energy; the most used sources include Electricity, Fuelwood, Kerosene and petrol (NBS, 2015).

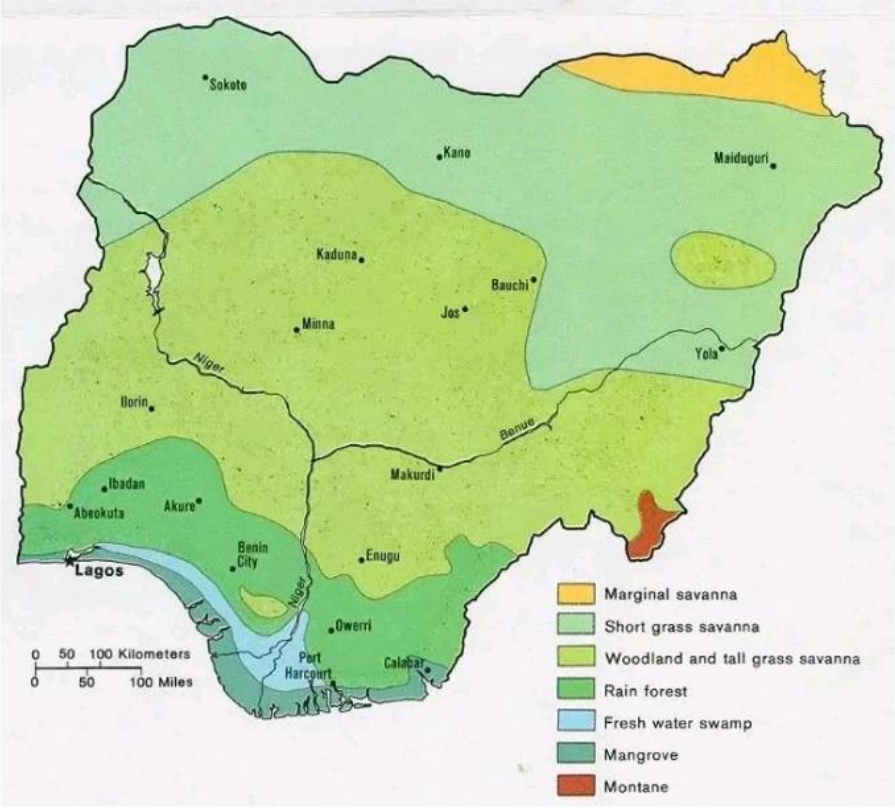


Figure 1: Vegetation Belt of Nigeria

Data Source

Two different sources of data sets are employed which include questioannaire survey and landsat satellite data. Landsat used are Landsat 7 ETM+ (2011) and Landsat 8 (2019) satellite imageries were covering the selected areas interest respectively. The imageries are obtained from the United States Geographical Survey's website. Whereas the later contained data from the database of the National Bureau of Statistics (NBS) on General Household Survey, Panel 2010-11, 2012-2013, 2015-2016 and 2018-2019. The data sets were based on various surveys conducted over these periods on the same households, which gives a total of 5000 across the country. The relevant information collected in the survey includes household socio-economic characteristics, information on the farm, non-farm enterprise, income-generating activities, food consumption, expenditure, and other non-food expenditure.

Sampling Technique
The vegetation map of Nigeria was integrated into ArcGIS 10.3 and overlaid on the administrative map of Nigeria. One district was selected at random from the three major vegetation belts of Nigeria. These are Osogbo (woodland and tall grass savanna), Ikpoba-okha (rain forest) and Fagge (short grass savanna) districts of Nigeria.

METHODOLOGY

Descriptive Statistics
Descriptive statistics were used to describe the characteristics of the data sets through the use of frequencies and graphs. Thus, it was used to examine the socio-economic factors of the household heads, the pattern of household energy sources used and also examined the major places of sourcing fuelwood in Nigeria.

Chi-Squared test X^2
Chi-square is a method used in statistics to calculate the difference between observed (o) and expected data values (e) and divide it by the expected value. It is used to determine how closely actual data fit expected data. A small chi-square value tells us that any differences in actual and expected data are due to chance, so the data is not statistically significant. A large value tells us the data is statistically significant, and there is something causing the differences in data. Thus, the test was used to assess the impact of fuelwood exploitation and the changes in the distance trekked over the years. The X^2 formula is given as:

$$X^2 = \frac{\sum (0\text{-}e)^2}{e}$$

Image Classification
The Landsat acquired were prepared and integrated into "Erdas Imagine" Software, and classified (via supervised classification) through a variable combination of spectral bands for change detection. This is based on the Landsat pathfinder classification scheme of the United States Geological Survey (Anderson *et al.*, 1976). The imageries were adjusted over space and time to be applied to each study location (Osogbo, Ikpoba-okha, Fage and Sabongari). Common features identified include water body, vegetation, built-up areas, and bare-land etc. assessment. The output of the classified imageries was then imported into ArcGIS 10.3 to generate thematic maps. The algorithm also generated statistics, used to estimate predominantly, the change in vegetation cover between 2011 and 2019. Other studies (Jesuleye *et al.*, 2013; Adzandeh *et al.*, 2014) have also used a similar method.

The extent of urban expansion (change) was obtained by computing:
Where: PC is the percentage change,
X is the observed change, and Y is the sum of change.

$$PC = \frac{X}{Y} \times 100$$

$$RC = \frac{PC}{100} \times n$$

While the annual rate of such change was obtained by computing:
Where: RC is Rate of change, n is the study year intervals = 8 (2011 – 2019)

RESULTS AND DISCUSSION

The Socio-economic Characteristics of the Respondents

These include the respondent's characteristics examined such as sex, educational level, age distribution and rural urban based on rural-urban sectors. Figure 2 shows an estimated population based on the rural and urban sectors. Sex of household heads: The distribution of the respondents by sex revealed that the male was the dominant household heads in Nigeria as shown in figure 2, with 83% and 70% of the population representing male in rural and urban sectors respectively.

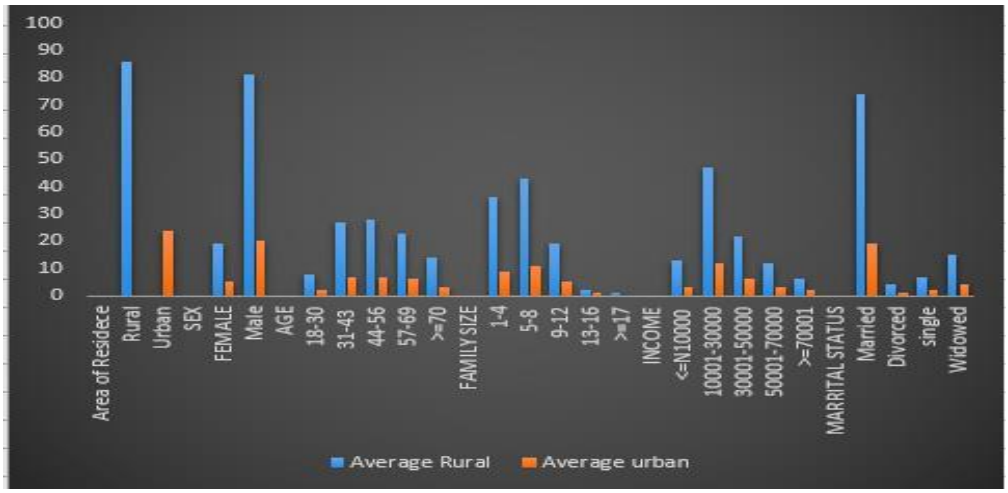


Figure 2: Socio-economic factors of household heads

An estimated population based on the rural and urban sectors is shown in figure 2. Male was the dominant household heads in Nigeria as shown in figure 2, with 83% and 70% of the population representing male in rural and urban sectors respectively. The low percentage of female respondents could be attributed to the fact in Nigeria, the pattern that is consistent with the norm, tradition and culture of the area is the one where a household is headed by the man based on his role and economic importance (FAO, 2010).

The age distribution of the respondents is an important attribute in determining the productive potential of a society. Hence, the result revealed that those in the age category 44-56 years have the highest percentage in both rural and urban sectors. This falls within the range of active age identified by the Food and Agricultural Organization (FAO, 2010). The implication could be the more active a household head is, the more he can support his household expenses.

Household size with the highest frequency was between five to six persons constituting a total of 43% and 11% for rural and urban sectors respectively. A similar range was reported by Maina et al (2019) this could mean that with all things being equal the higher the household size, the more the use of fuelwood because the more the financial burden on a household head the more he opts for cheaper or no cost at all fuel that has more negative implications on the environment.

The finding in figure 2 revealed that about 47% of the households in the study earned between ₦10,000 and ₦15,000 monthly, which is low. The implication of this is that there is income inequality in Nigeria with most of such households been classified between poorest to the poor based on the wealth classification index by (Demographic Health Survey [DHS], 2018). Thus, this high proportion of low income among respondents implies that the use of fuelwood through fetching could be high to save cost.

The distribution of the results showed that the majority of the households were married which constitute a total of 74%. Marital status and family size are linked, hence the more the household is living under a legal marriage union, the more the tendency of an increase in family size. These two socio-economic factors play a significant role in the economic situation of the household. Thus, the higher the household size, the more the financial burden and *vice versa* (Anyanwu, 2014).

Types of Cooking Fuels

The results of the study revealed that there was the prevalence of other fuel sources other than fuelwood in the study area. It also showed some rise and fall pattern over the years. For a virtual explanation of these figures, 3A and 3B are presented. The result showed that the proportion of households fetching fuelwood was the highest, as the most common and widely used source. This could be attributed to the low-income level of the majority of the households, as shown in figure 2. As opined by Odihi (2003), poverty is linked to environmental degradation in the form of deforestation. Thus it is difficult for the poor to survive on the expensive source of fuels. The next was kerosene, fuelwood purchased, charcoal, gas then grass in both rural and urban households as can be observed from figure 3a-b.

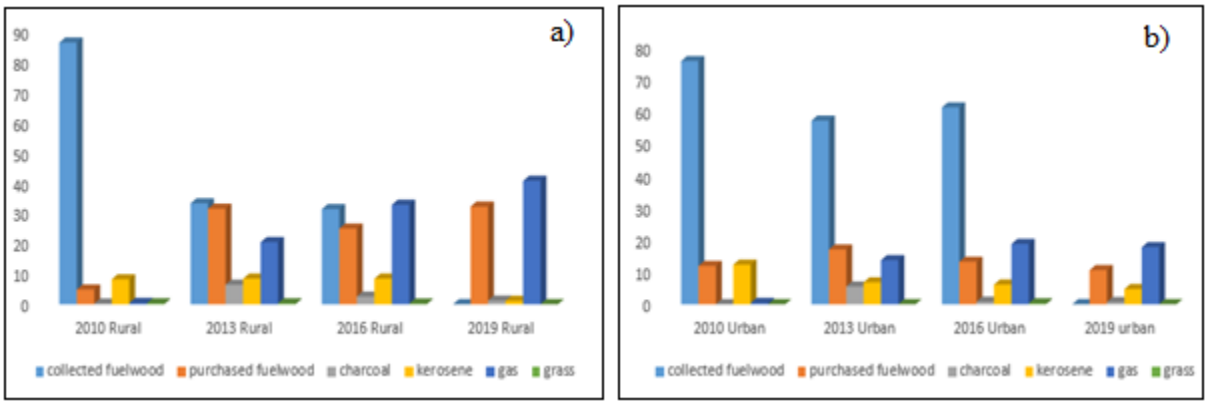


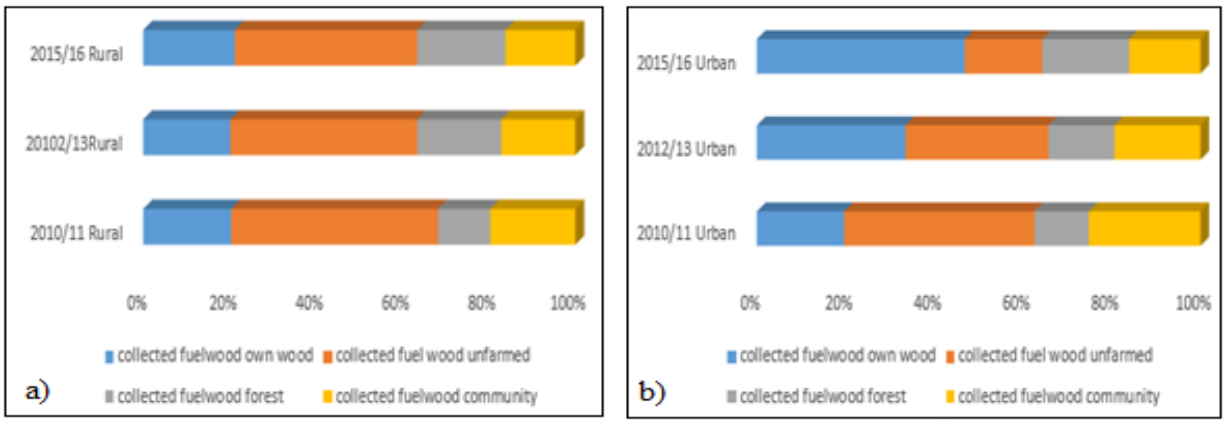
Figure 3: Source of primary fuel for cooking a) Rural, b) Urban

However, a declining pattern is observed over the years with fuelwood fetched declining while the purchased ones and other fuel sources increase with a significant rise in the use of Liquefied Petroleum Gas (LPG). Although, there was no data on fuelwood fetched by the 2018/19 GHS data, never the less the results show some interesting presentation. The fact that fuelwood fetched kept declining and the purchased ones increasing could imply a negative implication on the environment. It could be due to widening of the tree areas due to deforestation and desertification resulting from an indiscriminate cutting down of trees. This result agrees with the findings of (Abdulrashid & Ibrahim, 2018).

Source of Fuel Wood

In order to find out where the households fetched their fuelwood, the data that provided such responses were considered, however out of the four data sets used this information was missing in 2018/19 GHS. Hence, only three data sets were utilized. The results revealed that both the rural and urban households fetched their fuelwood from four sources own wood, unfarmed areas, forest and from around the community area. The patterns are shown in figures 4a and 4b. Both rural and urban households can be observed, that both fuelwoods fetched from the unfarmed area and the community are declining while own wood and the proportion fuelwood fetched from the forest

showed signs of increase. To further justify this result an (X^2) test was conducted and the results are presented in Table 1.



Figures 4: Source of wood for fuel, a) Rural, b) Urban

The Chi-square result in Table 1 shows a high chi^2 value of 4078.913a with a probability of 1%, indicating that the changes in the wood fetching area are not by chance. The results revealed that the count for community area and unfarmed were declining from 2010/11 to 2015/16 while the proportion of count for own woodlot and forest kept increasing over the years of the survey. This further indicates a sign of environmental deterioration from an indiscriminate cutting of the vegetation and the further widening of tree areas. It could still be deduced from the results that over the years the trees around the community and the unfarmed area seemed to be going extinct thereby forcing the households to fetch from their own woodlot or go further into the forest reserve.

Table: 1 Source of Fuelwood.

	Count 2010/11	2010/11%	Count 2012/13	2012/13%	Count 2015/16	2015/16%
Community	687	26%	600	22%	300	15.80%
Forest	195	9.10%	735	26.90%	996	37.00%
Woodlot	335	27.90%	600	12.30%	951	2.30%
Unfarmed	651	47.20%	332	38.90%	234	35.30%
Chi2 Value	*4078.913[a],*	*P-value*	*.000*			

The Impact of fuelwood exploitation through the time spent in trekking.

Fuel Wood Exploitation Through Distance Trekked. The distance is usually covered on foot to collect the wood by forming head load of various sizes. Moreover, sometimes in rural areas, animals such as donkeys are used to convey the wood fetched from the bush. For further assessment of the impact of fuelwood exploitation over the years through the time spent in trekking still a Chi-Squared test (X^2) was conducted, and the results are presented in Table 2.

The (X^2) test value for the changes in the time used to fetch fuelwood was also found to be very high 4219.527 and a significant P value of 1%. These show that the distanced trekked to fetch fuel wood for both rural and urban household has been increasing over the years. Most households trekked for 30 minutes or less in 2010/11; however, the distance kept increasing over the years. It can also be seen that the count for those that trekked for 30mins or less in 2010/11 was 1263 at 58.70% but as the years go by the count as well as the percentages kept declining. Similarly, the

same patterns were observed for the remaining minutes. These indicate how further the tree areas kept widening, forcing the households to spend more time in search of fuel wood over the years.

Table 2: Time Spent in Fetching Fuelwood

Time	Count 2010/11	2010/11%	Count 2012/13	2012/13%	count 2015/16	2015/16%
<30 minutes	1263	58.70%	258	9%	77	3%
30-60 mins	834	38.80%	1325	48.50%	594	22.00%
60-90 mins	26	1.20%	577	21.10%	1327	49.20%
90-120 mins	18	0.80%	398	14.40%	372	13.80%
>=120 mins	9	0.40%	177	6.50%	325	12.10%
Chi2 Value	4219.527					
	P-value	.000				

Land Used Land Cover (LULC) Change Detection

The statistics obtained from the image classification is observed across time to describe the LULC changes between 2011 and 2019. When the observed statistics of the LULC classes were compared, there was a percentage of change that shows the extent of expansion or reduction. Likewise, when the percentage changes were computed, there was a percentage that shows the rate at which the changes occurred within the stipulated period of study. This is detailed in Table 3. Where **(+)** indicates expansion, and (-) stands for reduction**.** Land cover maps were produced to show spatial structure (Figure 5A, 5B and 5C).

In Ikpoba-Okha, a significant among the features in table 3. is the forest cover (dense vegetation). While in 2011 there was a total of 290.5646 km^2 of forest cover, it has dwindled to as low as 109.6309 km^2 by the year 2019. That is a decrease of 180.934 km^2 (49.99 %) of the total forest cover, at 3.9992 % annual rate. It is also observed that all the other land uses in Ikpoba-Okha (except for water which decreased) increased over time.

Table 3 also revealed that in Fagge district of Nigeria, vegetation has depleted from 18.457 km^2 to 9.587 Km^2 from 2011 to 2019. That is also a decrease of 8.87 km^2 (49.96 %) at an annual rate of 3.9968 %. Further analysis of Table 3 shows that, in 2011, natural vegetation (riparian zone and dense vegetation) were among the dominant land cover classes in Osogbo district, with 3 217.48 ha and 4 910.45 ha respectively. The proportion of riparian zone (gallery forest) and dense vegetation has reduced to 1 000.53 ha and 3 110.02 ha by the year 2019, given the compound change (reduction) of 2 216.95 ha (18.73 %) at an annual rate of 1.4984 % as well as 1800.43 ha (15.21 %) at an annual rate of 1.2168 % respectively.

From the above observations, two main driving forces were identified as the causes of these trends. The first is the population boom. The exponential increase in the population has caused for the use of the lands and forest resources to support and sustain life. Hence the increase in the use of the land for buildings and for agricultural purposes as well as cutting down trees for economic advantage (such as used as fuels for cooking, heating or generating energy). Secondly, Urbanization is the other main factor responsible for changing land use in Nigeria. Huge structures that come with metropolitan cities have sprung up, forcing the forest line backwards. In this note, Bello and Arowosegbe (2014) parroted that, Nigerian urban centres are faced with rapid growth and development, which contribute to land-use change. Hence, the demand for land food and fuel by the households and policy constraints that manage land use as well as the spatial interactions and deforestation accelerates expansion at the expense of ecological resources.

Table: 3: Extent and Annual Rate of Change between 2011 and 2019

Selected Areas	LULC Feature	Land Cover Statistics		Changes between 2011 and 2019		Annual Rate of Change from 2011-2019
		2011	2019			
Ikpoba-Okha		Km^2	Km^2	Km^2	%	%
	Farmland	209.7762	211.1762	+ 1.4	+ 0.39	+ 0.0312
	Dense Vegetation	290.5646	109.6309	- 180.934	- 49.99	- 3.9992
	Grass	337.6845	361.1815	+ 23.497	+ 6.49	+ 0.5192
	Buildup area	252.4694	347.3821	+ 94.913	+ 26.22	+ 2.0976
	Water body	0.3450	0.291	- 0.054	- 0.01	- 0.0008
	Wetland	118.4779	179.6559	+ 61.178	+ 16.90	+ 1.352
	Total	1209.318	1209.318		100	
Fagge		Km^2	Km^2	Km^2	%	%
	Bare land	7.732	11.931	+ 4.199	+ 23.65	+ 1.892
	Vegetation	18.457	9.587	- 8.87	- 49.96	- 3.9968
	Water body	0.0153	0.0081	- 0.0072	- 0.04	- 0.0032
	Buildup area	9.038	13.716	+ 4.678	+ 26.35	+ 2.108
	Total	35.2423	35.2423		100	
Osogbo		Ha	Ha	Ha	%	%
	Bare land	3 832.92	2036.07	-1 796.85	- 15.18	- 1.2
	Water body	319.864	358.83	+ 38.97	+ 0.33	+ 0.0264
	Roc-out crop	439.021	359.64	- 79.38	- 0.67	- 0.0536
	Buildup area	2 033.061	7 934.06	+ 5 900.9	+ 49.87	+ 3.9896
	Riparian zone	3 217.48	1 000.53	-2 216.95	- 18.73	- 1.4984
	Dense Vegetation	4 910.45	3 110.02	- 1800.43	- 15.21	- 1.2168
	Total	14 752.80	14 799.15		100	

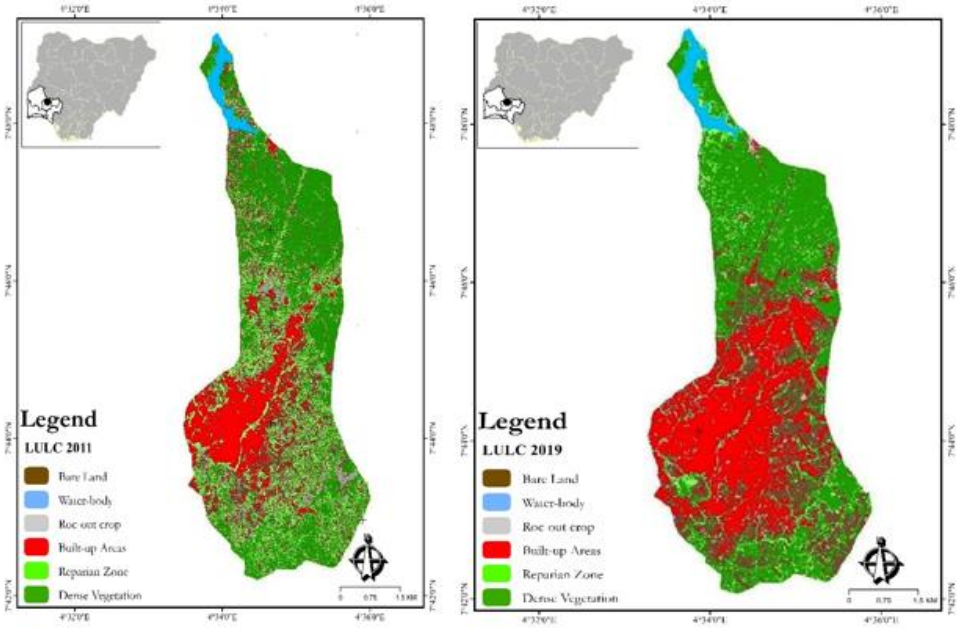


Figure 5: a) 2011, b) 2019 Pattern of LULC in Osogbo LGA, South-west of Nigeria

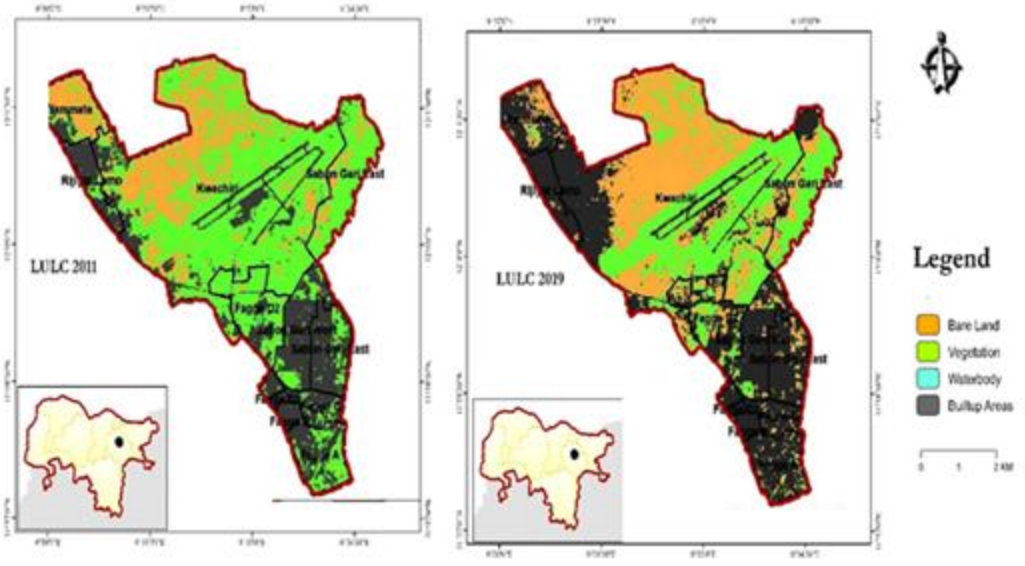


Figure 6: a) 2011, b) 2019 Pattern of LULC in Fagge LGA, North-west of Nigeria

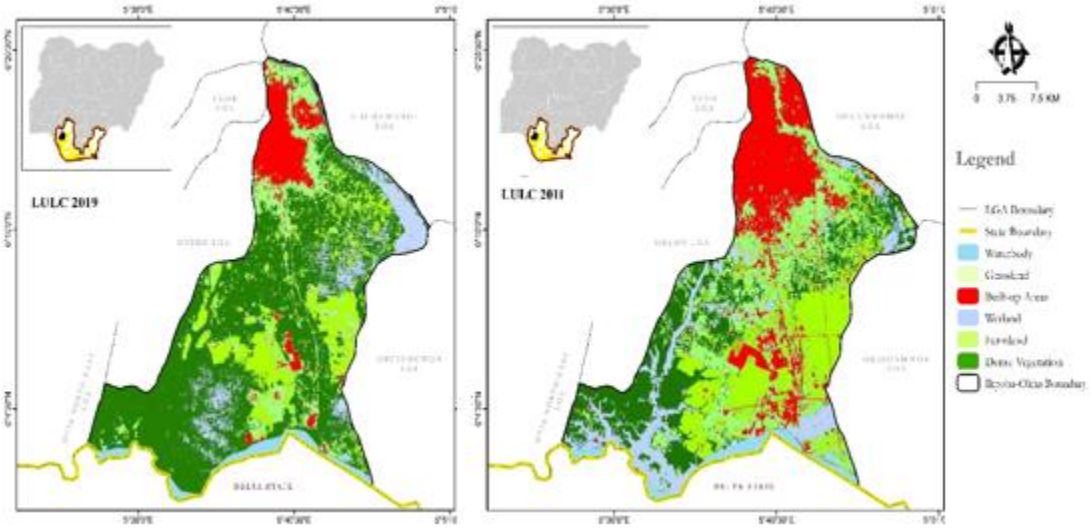


Figure 7: a) 2011, b) 2019 Pattern of LULC in Ikpoba-Okha LGA, South-south of Nigeria

A similarity can be drawn from some empirical researches in Nigeria. For instance, urban expansion and vegetation depletion in cities like Suleja LGA of Niger state (1982-2012); Kano metropolis of Kano state (1976 and 2015); Zaria urban area of Kaduna state (1985-2015); Katsina LGA (1996-2016) and so on have appeared to follow the same trend of changes (Sunday and Umar, 2013; Adzandeh *et al.*, 2014; Umar *et al.*, 2017; Umar *et al.*, 2019).

CONCLUSION

Majority of the households were headed by male gender whose age fell within the category 44-56 years with a household size of five to six persons having the highest frequency, earning low income between ₦10,000 to ₦15,000 monthly and majority were married. Furthermore, the majority of

these households were found to either fetch or purchase fuel wood, although the use of kerosene has also been observed and an increasing pattern for LPG use. Moreover, due to years of excessive fuelwood exploitation, the wood exploitation on the unfarmed area and the community have been observed to be declining while own woodlot and the proportion of fuel wood fetched from the forest showed signs of increase for both rural and urban areas. Another discovery is that the distance trekked over the years to fetch fuelwood show signs of increase for both rural and urban areas.

A gradual LULC change could, however, be observed due to the emergence and expansion of settlements and built-ups that were not in existence. The situation has led to the widespread conversion of forest and natural vegetation cover into farmlands, and other land uses. Forest exploitation might also play a role in accelerating deforestation rate, due to wood obtained from trunks, branches and other parts of trees and shrubs used as fuels for cooking, heating or generating energy. The mechanisms by which the observed expansion transpires, land fragmentation might have emerged as a side-effect.

Thus, this study recommends that governments and Non-Governmental Organizations (NGOs) should improve the welfare/income of the households since poverty is linked to environmental degradation so that they could substitute fuelwood usage with other efficient energy sources. Also, the use of LPG should be encouraged through lowering of installation cost or given some incentives to the households. Finally, afforestation should be encouraged so as to plant more trees. This can be done by adopting the United Nations policy of Reducing Emissions from Deforestation and Forest Degradation (REDD) which rewards people for conserving their trees instead of cutting them down and by also paying them to plant more trees.

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