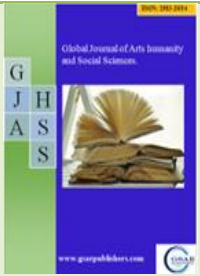
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An Assessment of Solid Biomass Consumption for Cooking and Heating Services and the Sustainability of Vegetation Resources of Northern Bauchi State, Nigeria

By

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Abstract

This study assessed the consumption of solid biomass for cooking and heating services and the sustainability of vegetation resources to meet the energy demand of Northern Bauchi State, Nigeria. This study adopted a mixed methods approach to address the research objectives. To achieve the objectives of the study mixed methods approach was adopted, integrating both the quantitative, qualitative and spatial analysis. Data obtained were analyzed using SPSS Version 26 and Arch-GIS 10.3 in form of table and Maps. The study revealed that majority of the respondents (78.1%) were relying on wood fuel and charcoal for cooking and heating. The study further revealed that forest based resources were the major sources of the solid biomass and this has been one of the determinants of deforestation, degradation and fragmentation in the study area resulting to generally low vegetation index of 0.067-0.141 in the study area. In conclusion the study discovered enormous consumption of solid biomass for cooking and heating services is which being sourced from remnant of forest based resources which resulted to a high pressure and threat to the sustainability of the existing vegetation resources. The study recommends for the need to replace the traditional way of cooking with advanced and high efficiency biomass cook stove. The study also shows the urgent need to protect and conserve the stressed vegetation and exploit alternative and sustainable energy sources cooking and heating.

Keywords: Assessment, Consumption, Solid Biomass, Cooking and Heating Services, Sustainability, Vegetation Resources, Energy Demand

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INTRODUCTION

Biomass is regarded as any plant species which can be directly used as fuel or be transformed into- any other forms for the purpose of combustion. These Included wood fuel, charcoal and other vegetal and animal waste (UN-ESCWA, 2022).The solid biomass such as wood fuel and charcoal has simplicity for domestic utilization especially for cooking and heating services. Solid biomass can be used directly for heating and cooking, making it one of the energy sources which provides high-temperature as quickly as possible (Ibitoye *et al.*, 2023).

Globally, the use of biomass is the pronounced and dominant energy for cooking services in developing countries. In Nigeria, biomass energy consumption dominates the country energy need for cooking and heating services. It is obvious in the rural areas

that traditional biomass is still most widely used for cooking and home heating based industries. This inefficient and unsustainable habit of using traditional fuels not only increases fuel consumption but also have socioeconomic problems and increases health hazards for women and children as well as causes environmental degradation including air pollution and deforestation (Sa'adand Bugaje 2016).

The utilization of solid biomass in Nigeria is something of great concern, Sa'adand Bugaje(2016) argued that biomass remains the most dominant energy for both household sector and small scale rural industries and commercial outlets in Nigeria; over the years its use continues to increase even in the 21st century. It is widely observed that the biomass resources available in Nigeria and study area include wood fuel, charcoal, agricultural waste and crop residue, sawdust and wood shavings, animal dung/poultry



droppings, industrial effluents/municipal solid waste among others. The woodfuel, charcoal and agricultural by products is the dominant solid biomass that dominated the large rung of the country energy ladder especially for residential uses sector. According to Sa'ad and Bugaje (2016), the pattern and magnitude of consumption across all the six geo-political zones of Nigeria, particularly for household uses varies greatly.

Globally, on the other vegetation is known to be one of the tangible and non tangible resources that provide timber and non timber forest products. According to Hula (2010) in the rural areas of developing countries like Nigeria, increasing in the number of poor was identified as one of the push factor for destroying their own resource base including vegetation and this results in exploitation of resources for food, fuel and fodder faster than it is being grown. According to Sa'ad and Bugaje (2016), high rate of consumption of biomass in the country energy composition can be link to many factors such as socio-economic like poverty and lack accessibility and high cost of clean and modern fuels as well as socio-cultural factors like culture and the household size of individuals.

It was observed in the study area, that the vegetation resources are under serious pressure due to the increased demand to meet the energy need for cooking and other productive services. This can be physical seen by decline in the density of trees even in the forest reserves. Interestingly, production of solid biomass especially wood fuel and charcoal result in deforestation, forest degradation and fragmentation, FAO (2007) argued that deforestation, degradation and fragmentation usually results to complex socio-economic problems as well as ecological challenges such as loss of biodiversity, the destruction of forest-based societies and climatic disruption, flooding and the temperature rises, soil nutrients loses among others. In this regard, Hula (2010) argued that increasing pressure vegetation resources to meet the population demand may likely lead to the encroachment and threaten their sustainability. This highlights the need to establish the nexus between the continued solid biomass consumption for cooking and other productive services and the potentials of vegetation resources to meet the demand. There is no doubt that research of this kind is less documented in the study area and Bauchi State at large, the study in this context will provide empirical evidence in this regard.

STUDY AREA AND RESEARCH METHOD

Location of the Study Area

The area is approximately located within Latitudes 11⁰12'N to 12⁰45'N and Longitudes 9⁰37'E and 10⁰58'E. The area has a total landmass of about 12508 square kilometers; and shares a border with Yobe state to the north and north-east, Jigawa to the north-west part, and Darazo Local Government of Bauchi State to the south. The area has three (3) emirates (Katagum, Misau, and Jama'are) and nine (9) Local Government Areas (Katagum, Shira, Gamawa, Itas-Gadua, Giade, Zaki, Misau, Dambam, and Jama'are) and three hundred and seventy village areas (370) as shown in Table 1 and Figure 1.

Table 1: Distribution of Village Areas and Households in the Study

LGAs	Land Area in Km ²	No. of Village Areas	Population in 2019 as projected	Population Density/ Km ²	No. of Households
Gamawa	2, 857	48	439, 600	159.4	54,575
Katagum	1, 395	46	452, 911	336.4	56,614
Zaki	2, 042	43	293, 177	148.8	36,647
Itas/Gadua	1, 622	29	353, 242	225.7	44,155
Shira	1, 303	39	361, 713	287.7	45,214
Jama'are	341.6	29	181,627	551.0	22,703
Giade	781.4	24	240,922	319.5	30,115
Misau	989.0	67	404,067	423.4	50,508
Dambam	1, 177	46	231, 981	204.4	28,998
Total	12058	370	2,959,379	295/km ²	369,529

Source: National population Commission (2010) and Author's Compilation (2019)

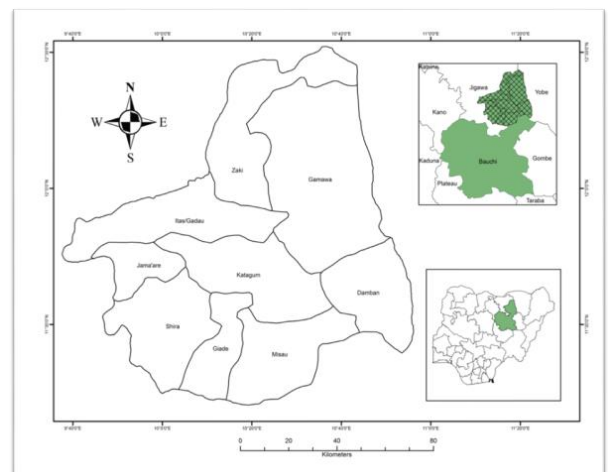


Figure 1: The Study Area

Source: Geographical Information System Unit FUDMA

Climate of the Study Area

The climate of the study area is tropical wet and dry characterized by two main seasons i.e. rainy or wet season starting from June-October and a dry season which occupies the rest of the year which caused by the movement of Inter Tropical Convergence Zone (ITCZ) or Inter Tropical Discontinuity (ITD) which separates the two major air masses. The rainy season begins late in the Northern part of the State, usually around June or July, and records the highest amount of 800mm per annum. While it is humidly hot

during the early part of the rainy season in the south, the hot, dry, and dusty weather lingers up north. The area has a mean daily maximum temperature of 23.4°C with a mean daily minimum being 13.5°C. Maximum temperature occurs between March and August with extreme values of 24.3°C in April (Bauchi State Diary 2008; Chadi, 2018). The climatic data from the study area indicated relatively high solar irradiation and a low annual average of wind speed. This indicates the potential of off-grid electrification using solar photovoltaic panels in rural communities in this geopolitical zone. The study area is an area with an average annual solar irradiation of 5.96kWh/m²/day with mean daily wind speeds of between 2.0 to 4.0 m/s at 10 m height (Ajayi, 2008; Akpan and Ishak, 2012).

Vegetation of the Study Area

The study area lies mainly in the Sudano-Sahelian Savannah region. The Sahel type of savannah, also known as semi-desert vegetation, becomes manifest from the middle of the State as one moves to the north. The study area is mainly characterized by scattered trees, shrubs and grasses. This type of vegetation comprises of encroached forest and grazing reserves, plantation and parklands as well as riparian vegetation. The vegetation types as described above are conditioned by the climatic factors, which in turn determine the amount of rainfall received in the area of about 500-800 mm per annum in the northern part of the State (Bauchi State Diary 2008; Chadi, 2018). The most widely tree species found in the study area include *Parkia biglobosa*, *Adansonia digitata*, *Khayasenegalensis*, *Fadherbia albida*, *Tamarindus indica*, *Ceiba pentandra*, *Diospyros mespiliformis*, *Propolis africana*, *Balanites aegyptiaca*, *Acacia nilotica*, *Acacia seyal*, *Acacia Senegal*, *Combretum glutinosum*, *Combretum micranthum*, etc. there also found some exotic plant species such as *Azadirachta indica* and *Eucalyptus cameldulensis*. In addition, fruit trees are grown on the farm lands such as *Magnifera indica*, *Moringa oleifera*, and *Cajanus cajan* among others.

Population and Socio-Economy of the Study Area

The study area has an estimated population of 2,093,537 people in the 9 L.G.As based on the 2018 population projection as shown in Table 1. The ethno-linguistic groups include Hausa, Fulani, Karekare, and Kanuri (Sule, 2017). This accounts for the differences in dialects, settlements, customs, festivals, historical backgrounds, and occupational patterns in the study area. There are cultural similarities in the people's languages, occupational practices, festivals, and mode of dressing with a high degree of ethnic interaction especially in marriage and economic livelihood (Bauchi State Diary 2008). The area has a population density of 1-199 persons per square kilometer (Sule, 2017; Sule 2017b). The study area is predominantly rural with few towns like Azare, Misau, Jama'are, and Gamawa. Agriculture is the main economic activity in the rural areas with millet, guinea corn, groundnut, beans, and sesame seed being the predominant crops cultivated. Furthermore, about 97.0% of the household energy needs for cooking in the study area mainly is obtained from traditional biomass such as wood fuel (NBS, 2009 in Akpan and Ishak, 2009).

Biomass such as trees, shrubs and other woody plants remain one of the important energy sources for cooking and heating services, it also play an important role to the socio-economy and livelihood as wood fuel extraction offers many benefits such as jobs opportunities in the study area. This study observed that in the study area various fuels and technologies were used for lighting services such as electricity from the national grid, disposable batteries flashlight and solar home systems, etc. Other fuels used cooking and heating are crop residues, animal dung, wood fuel, charcoal, other woody biomass and Liquefied Petroleum Gas.

RESEARCH METHODS

Research Design

This study adopted a mixed methods approach to address the research objectives. To achieve the objectives of the study mixed methods approach was adopted, integrating both the quantitative, qualitative and spatial analysis. A reconnaissance survey of nine LGAs and two selected villages was done to get quick overview of data collection processes and data were collected through field surveys or questionnaire administration, and documentary sources.

Data Sources and Types

The data used for this study include the satellite imagery of the study area obtained from United State Geological Survey (USGS). Other types of data collected include the household socio-economic and demographic data and types of energy used by household etc. Furthermore, documented records obtained from Directorates Forestry and Range Management in the present Bauchi State Ministry of Agriculture and Natural Resources.

Sampling Procedure

Sampling Frame and Size

The sampling frame for the study was determined using the arithmetic population projection method. The population of the study area was projected up to 2016, using the NPC (2016) 3.5% annual growth for the State (city population 2021). Additionally, the sampling frame was obtained using the total projected population and average rural household size of Bauchi State which was reported as 8.0 (NPC and NBS 2016) and later projected 2020. The technique was mathematically expressed as follows:

$$N = \frac{\sum p - 9 p}{n} \dots \dots \dots (i)$$

Where

N= is the total number of households.

∑p= is the total population

n = is the average household size of the rural areas

This implies that N= (3066714/ 8) = 383340. Therefore the total number of households was 383340; this made up the sampling frame of the study.

The sample size for this study was determined using Krejcie and Morgan (1970) sample size determination technique. Dillman (2011) in Kimutai, Kiprop, and Snelder (2019) describes Krejcie and Morgan (1970) formula as a good technique for determining an adequate representative sample size. According to Danlami and Islam (2020), this formula has been widely adopted in micro-level studies of household characteristics. The formula was expressed as



follows:

$$S = X^2 NP (1 - P) \div d^2 (N - 1) + X^2 P(1 - P) \dots \dots \dots (ii)$$

Where

S= required sample size.

X² = the table value of chi-square for 1 degree of freedom at the desired confidence level

(3.841).

N = the population size.

P = the population proportion (assumed to be .50 since this would provide the maximum sample size).

d = the degree of accuracy expressed as a proportion (.05).

$$\text{This implies that } s = 3.841 \times 369529 \times 0.50 (1 - 0.50) / (0.05)^2 \times (369529 - 1) + 3.841 \times 0.50 (1 - 0.50) = 384 \dots \dots \dots (iii)$$

In this regard, Krejcie and Morgan (1970) argued that for a population of more than 75,000 to 1000000 elements, a sample size of 384 to 400 elements is adequate for the survey research. However, for the purpose of data collection, a total of 396 questionnaires were administered instead of the initial number of 384 samples, this is to enable achieve uniformity in the distribution of the questionnaires to the sampled communities.

Sampling Technique

The sampling technique adopted for this study was the multi-stage sampling method. In the first stage, a multi-stage cluster sampling technique was used classifying all the nine LGAs of the study area as a sampling unit. In the second stage, two groups of clusters (villages) were statistically selected from each of the nine LGAs using simple random sampling. This is to have wider geographical coverage between the LGAs irrespective of the number of population and households. This gives a total of 18 selected village areas as the sampling clusters (Appendix I). In the third stage, twenty-two households were purposively selected from each of the selected communities based on 2 obvious reasons (i) lack of total number of households in the selected communities and (ii) to give an equal geographical coverage to the selected villages. The household selection was done systematically at an interval of two households continuously until the required samples were obtained through this process a total of number of 396 households were selected for the study. Households returned their filled copies of questionnaire, and nine copies questionnaire were not returned. Finally, a total of 387 filled copies of questionnaire were returned, this accounted for more than 90% of the total number of the administered questionnaires. This goes in line with the suggestion of Danlami and Islam (2020), that at least 50% of the response rate is required for an effective reporting and analysis of any survey research.

$$\begin{aligned} \text{Adequacy} &= 387/396 \times 100 = 97.7\% \\ &= 9/396 \times 100 = 2.3\% \end{aligned}$$

Data Collection Technique

The study collected both field and documented data. The field survey data were generated through field observation, checklist and household surveys using semi-structured questionnaire which were conducted in 2019 and 2020. The semi-structured questionnaire was designed and administered to the households who were the target

respondents of the study. Mean while key informant interview was conducted with head of forestry units of the LGAs. In addition field observations and check listing were carried out to assess the available renewable energy systems in the study area. Furthermore, Landsat 8 operational land imagery (OLI) of 20th May, 2019 with a resolution of 30 meters was downloaded through USGS Global Visualization Viewer Website.

Data Collection Instruments

Both field survey and documentary data were acquired in this study. The field survey data were acquired through questionnaire administration and key informant interview in addition to the GPS survey and field observation. While documentary data were acquired through the records of the State Ministry of Agriculture.

Household Surveys

Questionnaire surveys were used in this research to collect quantitative data from the households within relatively short time. The survey was conducted with the head of household, who where the target respondent of this study. The questionnaire consist of household variables such as household socioeconomic and demographic variable, available energy option use, types fuels used, sources of traditional biomass to households among others.

Method of Data Analysis

Both geospatial, quantitative and qualitative were used for the study. ArcGIS 10.3 was used to perform the geospatial analysis. These spatial datasets used for the mapping of available renewable energy potentials include climate data which were generated for 20-year period from 2000-2019, in addition to Landsat 8 NDVI and elevation map of the study area. These datasets were generated from various sources such as SWAT, NASA and USGS and processed using Arc GIS 10.3 software. Furthermore, Landsat 8 OLI image of 2019 with a resolution of 30 meters were downloaded through USGS Global Visualization Viewer Website. The satellite imageries were pre-processed to correct the geometric and radiometric error to enhance the imageries visualization using Arc GIS 10.3. The result was subjected to normalized difference vegetation index (NDVI) to have an understanding of the vegetation density of the study area.

$$NDVI = (NIR - RED) / (NIR + RED) \dots \dots \dots (iii)$$

Where RED is visible red reflectance and NIR is near infrared reflectance, using equation (iii)

Landsat 8 NDVI = (Band 5 - Band 4) / (Band 5 + Band 4). The NDVI was analysed to understand the spatial density of vegetation in the study area.

The quantitative data were analyzed with Microsoft excel and statistical package for social sciences (SPSS 26). Descriptive and inferential statistics was used to analyse the data. Moreover, for descriptive statistics, the result was presented in form of percentages and frequencies, using tables and charts. The Chi-square (x²) and Cramer’s V symmetrical measure and Binomial statistic were used to analyze the relationship and association between variables used in the study. The qualitative data collected which were largely in unstructured format was organized in textual



form and incorporated where necessary under the research objectives and inferences.

RESULT AND DISCUSSION

Survey of the Household Energy Consumption for Cooking and Heating Services

It is important to understand the pattern of the household energy consumption in order to arrive at the meaningful conclusion. In the study area, the household sector especially cooking and heating accounts for the lion share of energy usage. It is expected that the choice of energy options will be determined by the availability and accessibility of the fuel. In respect to this, the available energy options for cooking and heating were examined and the distribution of the available energy options between LGAs of the study area is presented in Table 2. The result shows cumulatively that 69.8% of the households use wood fuel as a primary energy option for cooking. This implies that traditional biomass dominated the energy use for cooking in the study area. Hence the high dependence on wood fuel in the study area can be attributed to the availability, affordability, and accessibility of woody biomass resources in the area. This study strongly agrees with Danlami and Islam (2020) who reported that 70% of the households in Bauchi State use wood fuel as a main cooking fuel option and disagrees with FAO (2016d) in FAO (2017) that reported 3 percent of wood fuel used for cooking in Europe and less than 1 percent in North America.

	13.7%	69.8%	8.3%	1.3%	7.0%	100.0%
					%	%

Source: Field Survey 2020

Na'ibbi (2013) and Tukur (2021) further confirm that the high dependence on wood fuel is more pronounced in northern Nigeria, compared to the other energy options. Elsewhere in Nigeria and the African continent, this study further agrees with several studies that argued that wood fuel or woody biomass is the primary energy option for Nigeria and much of the rural households (Barau, n.d; Masekoamenget al., 2005; Shaad and Wilson, 2009; UNDP and WHO, 2009; Maconachie, Tanko and Zakariyya, 2009; Global Alliance for the clean cookstove, 2011; Abdulkarim et al., 2013; Na'ibbi, 2013; Na'ibbi and Healey, 2013; Charles, 2014; Lambe et al., 2015; Muhammed et al., 2017 and Tukur, 2021). IEA, IRENA, UNSD, WB, and WHO (2019) further reported that traditional uses of biomass dominated renewable energy consumption in four developing countries (India, Indonesia, Nigeria, and Pakistan). Na'ibbi (2013) further argued that traditional biomass especially wood fuel remains the most important and vital renewable energy option for cooking in developing countries.

The result further shows that about 13.7% of the household used crop residue like cornstalk (Kara) and animal dung (Kandilo), the use of these fuels is more concentrated in the villages. The use of animal dung (Kandilo) was also observed by Na'ibbi (2013) in Nangere community and Goldemberg (2000) in Adamu, Ade, and; Akeh, (2020) described dung as perhaps the least preferred form of biomass and its usage indicates the extreme energy poverty of a household. However, the combine use of charcoal and other woody bio-fuels as primary fuel account for 8.3% of the surveyed households. The use of charcoal is usually more confined to the larger settlements and small size households. Thus, cumulatively the use of traditional biomass accounts for 91.3% in the area, this implies that nearly all the households are using polluting fuels as primary energy option for cooking and heating services. This figure (91.3%) revealed in this study is higher than 81.3% and 88.7% as reported in SE4ALL-AA (2016) and Nigeria Demographic and Health Survey (2019) respectively. Furthermore, Adamu et al., (2020) pointed out that the use of traditional biomass in Nigeria account for over 70% of household energy supply for cooking and the use is more pronounced in the rural households. Their findings further revealed that the National Bureau of Statistics had in 2007 found that North-east geopolitical zone of Nigeria where the study falls in consumed 95.9% of traditional fuels. This agrees with finding of this study which shows that 91.3% of the households rely on traditional biomass to meet their energy demands for cooking and heating services. This study further agrees with the assertions of Goldemberg (2004), Toole (2015) and Adamu et al., (2020) that the high use and dependence on traditional biomass leads to deforestation and indoor air pollution. The study further agrees with Akther, Miah and Koike

Table 2: Available Primary Energy Options for Cooking and Heating Services

LGAs	Available Cooking Energy Options					Total
	Crop residue & Dung	Firewood	Charcoal	Kerosene	L.P.G	
Dambam	1.6%	9.3%	.3%		.3%	11.4%
Gama wa	2.6%	7.2%	.5%		.8%	11.1%
Giade Itas/Gadau	1.8%	8.0%	.8%		.5%	11.1%
Jama'are	1.6%	9.3%	.3%			11.1%
Katagum	.5%	5.9%	2.6%	.3%	1.6%	10.9%
Misa u	1.3%	7.5%	1.0%		1.3%	11.1%
Shira Zaki	1.0%	7.8%	.5%	.8%	1.0%	11.1%
Total	2.8%	6.7%	1.6%			11.1%
	.5%	8.0%	.8%	.3%	1.6%	11.1%



(2010) and WHO (2016) argued that traditional biomass as renewable fuels are not considered an environmentally friendly.

The finding of this study shows that the use of kerosene (which is a transition fuel) accounts for 1.3% in the study area (Table 2). This is fossil fuel associated with significant health and environmental risks. Perhaps this is the reason why the WHO (2016) discourages households from the use of solid biofuels and kerosene in the homes. The result further shows that the use liquefied petroleum gas which is among the clean fuel for cooking services among the surveyed households accounts for about 7.0% in the study area. The use of clean fuel among the surveyed households of 7.0% is lower than 11.3% of the national average as reported in NDHS 2018.

None of the surveyed households have reported the use of an advanced biomass cookstove (ACS). Nevertheless, since it is difficult to switch from solid biomass to clean and modern fuels due to so many reasons especially in the rural areas of developing countries. This study emphasized the need for replacing our traditional way of cooking with advanced biomass cookstove (ACS). These are high efficiency and wood saving stoves. Yahaya and Ali (2008) classified advanced biomass cook stoves into "Save80" and "Wonderbox". These stoves as the name implies, saves 80% of the wood fuel consumption compared to the three stone stove with high efficiency at higher temperatures with low emission of carbon and air pollution.

Furthermore, considering the cumulative share of a household that uses kerosene and LPG of 7.0% in the study area, this study disagrees with what has been reported by Eleriet *al.*, (2012) of 4.2% of the households in Bauchi State that use kerosene and LPG as cooking fuel options. Although the use of charcoal, kerosene and LPG for cooking was reported by small size households, the use of these fuels was particularly more pronounced in the major settlements where charcoal, kerosene and LPG business outlets could be located. This study observed the increase cooking fuels outlets especially in the headquarters of the Local Governments and other major settlements in the area.

Considering the findings of Eleriet *al.*, (2012), this study revealed a mudslide increase in the use of clean cooking fuels in the study area. However, it is important to note that clean energy access was limited to small family size than high economic class in the area. If the trend of clean fuels access (such as BLEN) would be expanded to every household irrespective of size, this would reduce pressure on the existing trees on farmlands and forest reserves. This study opined that there is a need for the Nigerian Government to come up with a plan of replacing traditional biomass consumption with smart options such as biogas, given the availability waste and also the need to involve local communities and use sustainable fuel wood and charcoal production from *Acacia auriculiformis*, *Ziziphusspina-christi* plantations and by using nitrogen fixing trees such as *parkiabiglibosa*, *Gliricidiasepium*, *Leucaenaspp*, *Tephrosiaspp*. and some *Acacia spp* which can help to double maize yields and aid the local production of bio-fuel and this will eventually lead to the job creation and also reduced cost of households energy in the study area. Moreover, this shows need of

implementing policies and programs which aimed promoting the domestic fuel ethanol through the utilization of agricultural products, in this regard the Nigerian Bio-fuel Policy and Incentives (NBPI) and Automotive Biomass Programme (ABP) of Nigerian government needs to be fully implemented to allow more access to sustainable energy to the poor and rural populace.

Additionally the Chi-square result ($\chi^2 = 614.12$, degree of freedom of 4 and p-value less than 0.05) shows that households in the nine (9) LGAs of northern Bauchi State significantly differ in the use of available energy options for cooking and heating services. This shows that different types of energy options are being adopted for cooking and heating services in the study area.

Mapping of the Sources of Solid Biomass for Cooking and Heating Services

Furthermore, the biomass based resource analysis of the study area reveals that solid biomass resources from forest and grazing reserves, farmlands (horticultural lands), woodlots orchard, residential shades and animal dung constitute the major sources of cooking fuels in the study area. The result in Figure 2 shows that 45.25% biomass used in the households was sourced from the patches of forest reserves. Moreover, the finding further indicated that 18.36% of the biomass used for cooking are mainly collected from farmlands; this includes wood fuel, stalk and dung whereas fallowed land supplies 8.04% of traditional biomass of the total biomass used for cooking. It is revealed that 28.34% of the biomass used for cooking was obtained from the other sources; this includes encroached grazing reserves, riparian vegetation, privately owned woodlands, orchards, residential shade trees, and cow dung. Similar sources of wood fuel were also observed in Kano close settled zone (Cline-Cole, Falola, Main, Mortimore, Nichol, and O'Reilly, 1988).

This implies consumption of thousand tones of solid biomass daily in the study. This is portraying the extent of pressure on vegetation resources and perhaps the reason why biomasses are becoming more scarce energy resources (Figure 2). This study agrees with Akintola and Alamu (2010) who claimed that daily consumption of wood fuel in the rural communities of Nigeria is estimated to be 27.5 million kg/day which is a clear indication of high rate of deforestation and forest degradation resulting from wood fuel consumption. This study further strongly agrees with the findings of Na'ibbi (2013) and Tukur (2021) who observed that the density and size of vegetation resources have drastically reduced in the Northern Nigeria especially in neighboring LGAs of Nangere and Potiskumin Yobe and around Katsina metropolis in Katsina state respectively. Thus this study observed a consensus among forestry officers in the LGAs, pointing out the low sustainable biomass index of the protected areas such as forest and grazing reserves, plantations as well woodlots in the study area. They expressed concern on regeneration and density of the floristic compositions of the protected areas. They further attributed the unfortunate situation to lack of accessible and affordable alternative cooking fuels, poor implementation of renewable energy policies, poor enforcement of laws and regulations etc. This study therefore, calls for utilization of biomass energy in efficient, sustainable,

economical and environmental friendly ways as suggested by World Biomass Association (WBA).

Considering the reduction of vegetation resources and compared with consumption rate, there is urgent need to protect and conserve the stressed vegetation and exploit alternative sustainable energy sources in the study area. This study observed that agriculture remains the major economic activity, mainly cultivation of rice, corn, millet, groundnut, beans, sugar cane and the waste from these crops, wood chips and animal dung can be used to generate clean energy as biomass modular power plants of 100-1500kw. Furthermore, this study observed that plants such as jatropha, maize, cassava, soya beans, and sugar cane grow well and can be utilized for the production of bio-fuel in the area. This shows the importance of producing bio-fuel crops to boost the chances of alternative to solid bio-fuels. This corroborates with Mshelia (n.d), Dayo (2008), and Charles (2014) who reported the potentials of Jatropha, Cassava, sugar cane, maize and corn in northern Nigeria for the of bio-fuels. On the other hand, the study also observed that livestock production was the second significant socio-economic activity after crop cultivation in the study area. Many studies have shown that animal dung and waste are good sources of biogas production. It is a significant advantage to the area considering the study of Charles (2014) which confirmed that 1kg of fresh animal dung produces about 0.03m³ of biogas and stressed millions of m³ of biogas would be produced every day. This would reduce the extent of pressure on degraded protected areas such as forest and grazing reserves.

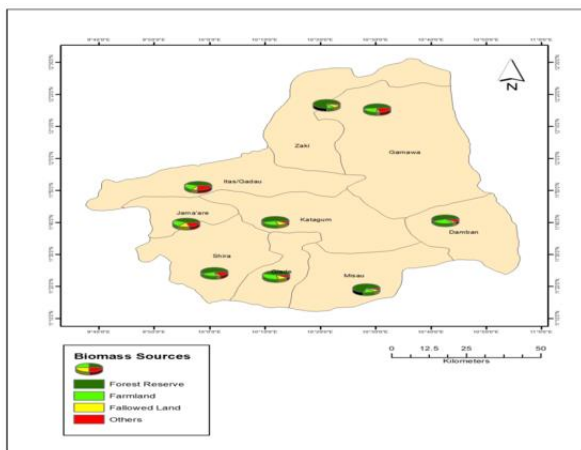


Figure 2: Spatial Distribution of the Sources of Biomass in Northern Bauchi State

Source: Data Analysis (2021)

Assessing the Sustainability of Vegetation Resources for Meeting the Energy Needs

The study area lies within Sudano-Sahelian Savannah Zone of northern Nigeria (Sule, 2017). The study area is blessed with diverse tree species, shrubs, herbs, grasses and other forms of vegetation resources, which can be used to meet the household energy need. The record obtained from directorates of forestry and range management in the than State Ministry of Agriculture and Natural of Resources (MANR) revealed about twenty four (24) forest reserves and twelve (12) grazing reserves in the study area.

The forest reserves were established for conservation and protection of environment, as well as production forestry based resources where as the grazing reserves were provided for provision of pastures to the nomads. Nonetheless, these natural resources are reported to be over exploited for wood fuel collection. Records made available to this research from MANR revealed that all the forest and grazing reserves are heavily degraded, largely due deforestation resulting from wood fuel extraction as shown in Figure 2.

The Normalized Difference Vegetation Index (NDVI) image of the study area obtained in May, 2019, evidences from ground truthing and documented records indicated that the vegetation of the area has drastically reduced with majority of the land is becoming barren land. Figure 3 reveals 0.37 as the highest normalized difference vegetation index value (NDVI) in the area, and this implies a low vegetation cover. It is further established that deforestation and forest degradation resulting from wood fuel collection is a main factor of the observed vegetation change in the study area. This study agreed with Na'ibbi (2013) who argued that demand for agricultural land and wood fuel was assumed to be responsible for the observed vegetation change in Nangere and Potiskum LGAs of Yobe State Northern Nigeria.

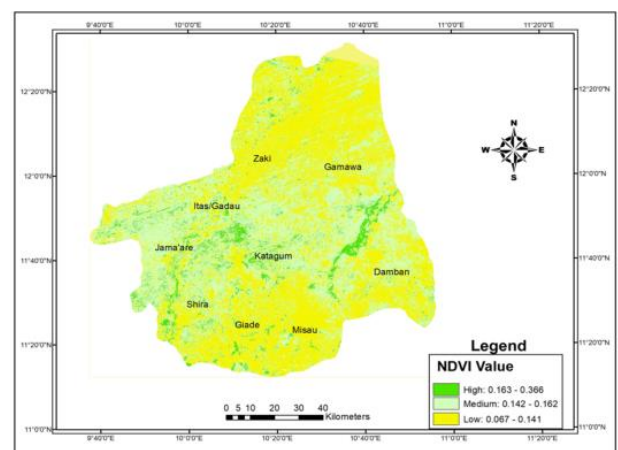


Figure 3: Pattern of Vegetation Density in Northern Bauchi State Source: Data analysis (2021)

Figure 3 shows the evidence and pattern of vegetation condition in the area, and it is worthy to observe the few patches of forest reserves across the study area which have become severely stressed at NDVI value of 0.37, despite a gazette (law) protecting and restricting people from cutting down live trees in the study area. An evidence of high vegetation index of 0.37 can be found around the rivers and forest reserves, where majority of the cooking fuel is coming from. This study further identifies the gazette forest reserves which are still serving as pool of wood fuel to the study area and beyond, they are Dagauda, Danfisa, Bayawo, Damban A and B (Damban LGA) Dugunde, Chinade, Dagaro, Yayu, Kujuru, RigiyarAlhaji and Madara forest reserves (Katagum LGA), Gamawa and Jarwa forest reserves as well asUdubo Grazing reserve (Gamawa LGA), Buzuzu forest reserve (Jama'are LGA), Gadau, Lizai and Baushe forest reserves (Itas/Gadau LGA),Dalli

and Zigau forest reserves (Shira LGA), Kurba and Jawo forest reserves (Giade LGA), Maladumba, Bagam, Umala, Yandabayo and Gambara forest reserves (Misau LGA) where as Sakwa and Katagummaikaba forest reserves made the list in Zaki LGA. Most of these reserves are experiencing high rate of deforestation resulting from wood fuel collection, most of the households and wood fuel sellers in the study area relied and over-exploit these reserves without due consideration of their sustainability. An official in the directorate of forestry in the state reported that continued dependence on the degraded forest and grazing reserves for wood fuel extraction has been a potential threat to the management objectives of the reserves (protection and production of natural vegetation and plantation) in the state.

CONCLUSION

The study concluded enormous consumption of solid biomass for cooking and heating services is which being sourced from remnant trees and patches of forest reserves and the high reliance on solid biomass poses a lot pressure and threat to the vegetation resources and put the sustainability of fragile ecosystem at stake. It was established that the vegetation cover become severely stressed, indicating how vulnerable the vegetation resources are due to overexploitation and collection of woody biomass.

RECOMMENDATIONS

- i. This study emphasized the need for replacing our traditional way of cooking with advanced and high efficiency biomass cookstove (ACS).
- ii. The study recommended that bio-fuel can be produce from plants such as jatropha, maize, cassava, soya beans, and sugar cane which grow very well in the area.
- iii. Considering the level of daily production fresh animal dung, the study emphasize that millions of m³ of biogas would be produced every day as biogas
- iv. There is urgent need to protect and conserve the stressed vegetation and exploit alternative sustainable energy sources

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