

BIOMASS BRIQUETTES AS A SUSTAINABLE ENERGY ALTERNATIVE: MITIGATING DEFORESTATION AND ENVIRONMENTAL DEGRADATION IN JIGAWA STATE, NIGERIA

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ABSTRACT

Deforestation is one of major global threats, it poses a serious challenge to human livelihood and nature in general. Extreme use of firewood as source of energy in Jigawa State, results in severe environmental issues including soil degradation, desertification, and heavy annual flooding. Using biomass briquettes could be a suitable and sustainable alternative to these environmental challenges. This study highlights the environmental implications of constant deforestation and presents an important benefit of biomass briquettes as a sustainable alternative to firewood. Additionally, a comprehensive survey was carried out about the level of awareness and perception of using biomass briquettes as a substitute to firewood. A study was conducted across 3 agro-ecological zones in Jigawa State involving 300 respondents. Data collected were analysed statistically using cross-tabulation procedure (degrees of freedom, Chi-square value, p-value, frequency, percent, and %mean). The results showed that most of the respondents were males (84%), aged between 26 to 45 years with tertiary (71%) level of education, and household size between 1 to 5 individuals (51%). Most of the respondents are farmers (52%). Moreover, the results revealed that 82.33% of the respondents were using firewood as the primary source of energy, and the majority (92.67%) believed there are environmental consequences of using firewood as a source of energy. 54.3% of the respondents spent >5000 Naira monthly on sources of fuel. Period to this survey, 76% of the respondents does not heard of biomass briquettes, 71% of the respondents believed biomass briquettes could be a suitable substitute to firewood, and 89% are willing to transition to biomass briquettes, whereas 92% of the respondents are eager to learn how to produce biomass briquettes, if training were given. It's absolutely recommended government should put more effort into an awareness campaign about the environmental consequences of deforestation, the harmful effects of using firewood as a source of energy, and present biomass briquettes as a sustainable substitute. Additionally, the government should propose a biomass briquette production training centre across the state.

Keywords: Deforestation, firewood, biomass briquettes, Jigawa state

1. INTRODUCTION

Deforestation is one of pressing issue globally, it posed a serious implication to human livelihood. Constant deforestation rate in search of fuel-wood is one of the major human activities that cause serious threats to environment [1]. Deforestation contributes to number of environmental challenges including a climate change which directly

influenced the rainfall patterns [2-4]. Deforestation has substantial environmental consequences that affect humans and animals ecosystems. The consequences of random removal of trees poses absolute threat not only forest but entirely socio-economic systems. Some of those environmental consequences are soil degradation; carbon emission, desertification, and biodiversity[5]. Soil degradation poses a significant threat to agricultural activities and livelihood. The act of deforestation disengages the soil which becomes prone to erosion and effect the soil fertility. Soil degradation, embodied by shrinking biological and economic of the region, is a widely significant issue that impact ecosystems, human, and animals livelihoods[6]. This adverse process is mostly due to human activity and other natural occurrence. Soil degradation is mostly profound in a rural areas where there are much dependence on land and its ecosystem[7]. For instance[8], Jigawa state is suffering from significant soil degradation due to massive tree cutting, overgrazing as well as intensive farming activities. These activities, have led to irrevocable soil degradation in the Jigawa State. Another environmental impact of deforestation is desertification. Desertification is the process whereby fertile land transformed into desert-like, this occurs usually in dry land, arid, and semi-arid areas[9]. Desertification is at alarming stage majorly in northern region of Nigeria, where farming and animals grazing are nonviable[10]. Dry-lands are majorly at risk of desertification due unfavorable variables such as water scarcity and lower vegetation cover. Globally, average area of desertification has surged to 9.2% of dry-lands, with 500 million people been affected[11]. Additionally, biodiversity extinction is another environmental implication of deforestation. Biodiversity impacts ecosystem services that contribute to human life and many organisms by providing means of living[12]. The holistic aim for the protection of biodiversity is to sustain nature of the ecosystem as much as possible. Many important species have been lost due environmental impact of deforestation and other human-caused impact such as overgrazing and intensive farming activities [13, 14]. Deforestation in Jigawa State has led to significant loss in biodiversity. This loss in biodiversity has led to extinction of various animal and plant species. These losses affect local communities that relies solely on these resources as sources of livelihood. Jigawa state with favorable weather conditions and vast arable land, has the potential to contribute significantly to meeting Nigeria's demands of food, but with current deforestation rate, the arable land will gradually be losing its fertility and transform into arid landscapes.

Jigawa state witnessed one of the most devastating flood disasters in its history. Out of 27 local government areas of the state, 19 were affected by the flood, destroying 80% of their farmland affecting over 120,000 victims and displacing about 57,661 persons. Moreover, the disaster washed away farm product such as rice, millet, sorghum, sesame, groundnut, vegetables and maize. It also destroyed bridges, thousands of houses, schools and live stocks such as goats, sheep, chickens and cattle [15, 16]. Recently, various initiatives were made for sustainable land management by the state government, amongst them was a successful afforestation campaign which recorded a significant increase in forest area coverage from 1,379.9 km² in 2020 to 1,757 km² in 2021 [17]. Despite this effort, Jigawa state is still faced with environment issues such as increased drought, climate change, and environmental degradation due to continued deforestation. Annually, Nigeria loses approximately 400,000 hectares of forest in which Jigawa state contributes significantly to the trend [18]. Therefore, it is necessary to look for an alternative clean energy source to address environmental sustainability comprehensively. In this study, comprehensive survey was conducted to assess the level of awareness and perception about environmental impact of deforestation within Jigawa state. Biomass briquettes made from agricultural residues were presented as an alternative source of energy.

2. BIOMASS BRIQUETTES

Biomass which ranks fourth in the world after coal, oil, and natural gas is an organic material from the environment such as residues from agricultural activities, remains of plants and animals, and non-fossil municipal wastes. The potential energy content of these biomass offer an eco-friendly solution which can help reduce the demand of fossil fuels and woods[19, 20].

Biomass briquettes are mostly made from agro-waste residues and industrial waste [21]. Biomass briquettes serves as sustainable source of energy, which met required fuel specifications such as lower carbon emission, and higher heating value [22, 23]. Biomass briquetting is process of compacting agricultural waste or residues and other industrial waste using binders (such as cassava binder) to enhanced energy density and usability [24, 25]. Briquettes produce less smoke than firewood. The carbon dioxide content is also very less compared to that of firewood. Biomass briquette produced with agricultural waste/or residues offer a cleaner substitute to traditional fuel (firewood) with lower ash content and high heating capacity[26]. Calorific value is the measure of energy content per kilogram in a fuel[27]. Production of biomass briquettes is a controlled process having a desired amount of energy per kilogram which is the most important characteristic of a fuel. Hence, biomass briquettes has higher calorific value than firewood. Blending various biomass with appropriate binders could strength the combustion performance of the briquettes to meet the standard for commercial purpose, these showed that choice of binders affect the overall performance of biomass

briquettes [20]. Adopting biomass briquettes could be a viable option to sustain environment as well as providing economic advantages as a sources of income to individuals [28]. Through biomass briquettes adoption as an alternative source of energy, there will be significant reduction in deforestation. This will equally support the government's effort of increasing the forest coverage in Jigawa state and reduce environmental challenges. Moreover, Jigawa state produce agricultural residues in metric tons but are poorly used or left to decompose or burns which directly lead to environmental pollution. By converting the residues into briquettes, the challenges will be minimized and environment will be protected.

3. METHODOLOGY

3.1 Description of the Study Area

The study was carried out in the Jigawa state, Nigeria. Jigawa State has three main ecological zones, namely Sudan Savannah, Sahel Savannah, and Northern Guinea Savannah. The state experiences a semi-arid condition with mean annual rainfall from 600 to 1,200 millimeters between month of May to September and temperature range between 12°C to 40°C. The zones are known for their intensive agricultural activities and animal rearing. The geographical location of the study areas are shown in Figure 1, and their ecological zones descriptions are presented in Table 1.

Table 1. Description of the survey locations.

Zones	Local Area	Government	Ecological zones	Latitude (°N)	Longitude (°E)	Altitude (m)
North-East	Hadejia			12.451	10.040	
	Malam Madori		Sudan Savannah	12.550	9.883	337
	Auyo			12.337	10.240	
North-Central	Dutse			11.744	9.341	
	BirninKudu		Northern-Guinea Savannah	11.456	9.496	430
	Gwaram			11.300	9.883	
North-West	Gumel			12.627	9.392	
	Maigatari		Sahel Savannah	12.804	9.448	337
	Babura			12.757	8.517	

3.2 Sampling Procedure

A multi-stage sampling technique was used. The study was conducted in three zones of the Jigawa State; namely North-Central (Northern Guinea Savannah), North-East (Sudan Savannah), and North-West (Sahel Savannah). In each zone three local government areas were sampled. In North-Central, Birnin Kudu (50 respondents), Dutse (25 respondents) and Gwaram (25 respondents) were sampled, in North-East, Hadejia (50 respondents), Auyo (25 respondents) and Malam Madori (25 respondents) while in North-West, Gumel (50 respondents), Maigatari (respondents) and Babura (25 respondents) were sampled. The target local government areas were choose based on their agricultural activities and input. Overall, the survey was carried-out in 9 local government areas selected in Jigawa State. Each zone were allocated with 100 questionnaires, and a total of 300 respondents participated in the survey.

3.3 Data Collection

Data were collected through structured questionnaire interview. Demographic information, socio-economic characteristic, current energy used, and awareness and perception about biomass briquettes were recorded.

3.4 Data Analysis

The data recorded were analyzed statistically using the cross-tabulation method to determine the correlation among the study areas and assessed the variables. Kruskal-Wallis test (H-test), Chi-square values, percentages were carried-out to investigate the present of significant differences in the socio-economic attributes of the responders across the zones. Moreover, the respondent's current energy used, perception and awareness about biomass briquettes were also subjected to statistical analysis using the same method.

4. RESULT AND DISCUSSION

4.1 Socio-Economic Description of Respondents

The result in Table 2 presented the H-test for the socio-economic characteristics of the responders in the study zones. The results displayed a significant difference of $p < 0.05$ among study areas for all variables with exceptions of number of house-size and their occupations. From the gender variable, the means percentage result across the three study zones showed that 84% of the responders were males and 16% were females, this implied the dominance of men as house-hold head in the study areas. North-west had lower number of female with 11% while North-east had highest number of female responders with 24%, North-central had 14% of females' responders. Among the participants, 78% are between 26 and 45 years of age, showed that the responders are mostly middle-aged adults. Only 7% are between the ages of 18 to 25 years, implied that young adult have least percentage of responders, while 15% are aged above 45 years of aged. About 71% of the responders had higher education certification, revealed higher the level of literacy among the responders, while only 1% of the responders had non-formal education. 24% of the responders had secondary school certificate while 4% of the responders attended primary school. North-West had highest proportion of responders (78%) with tertiary level of education, whereas North-East had 62% while North-East had 72%. North-East is only zone among the surveyed areas that had non-formal education responders. This result showed that there higher literacy proportion in all of the study areas. For the size of household, the results revealed that 51% of the total number of responders had a family of 1-5, whereas as 32% had a family size of 6-10 people, the remaining 17% had a family size of 10 to above. North-Central had the highest number of individuals (61%) with household size of 1-5, whereas, North-East, 37% of the respondents had family size of 6-10, only a few respondents had family size of 10 to above, with most (23%) being in the North-West. The result on occupation showed 52% of the respondents are into farming as their main occupation, with North-East had highest proportion (57%) of individuals into farming business, and followed by North-West with 55% of respondents. North-Central had the highest number of self-employed (22% of respondents), and followed by North-East with 18% of respondents, whereas North-West had least number of self-employed (11%). The proposition of employee in all study zone is 30%, North-East had 32% of the employee responders, while North-Central had 30%, whereas as North-West had least number of employee responders (27%). This results on occupation implied that Jigawa State is an agrarian state, with good number of individuals are into farming business.

Table 2. Socio-economic characteristics of respondents in the surveyed zones

Variables	North Central		North East		North West		DF	χ^2 -value	p-value	% Mean
	Freq	%	Freq	%	Freq	%				
Gender(sex)										
Male	86	86	76	76	89	89	2	6.78	0.034	84
Female	14	14	24	24	11	11				16
Age										
18-25	3	3	11	11	7	7	4	14.78	0.0052	7
26-45	87	87	78	78	69	69				78
>45	10	10	11	11	24	24				15
Level of education										
Non-formal	0	0	5	5	0	0	6	22.16	0.0011	1
Primary	7	7	0	0	4	4				4
Secondary	31	31	23	23	18	18				24
Tertiary	62	62	72	72	78	78				71
Household size										
1-5	61	61	49	49	44	44	4	8.55	0.0733	51
6-10	26	26	37	37	33	33				32
>10	13	13	14	14	23	23				17

Occupation										
Farming	45	45	57	57	55	55	6	7.45	0.1139	52
Self-employed	25	25	11	11	18	18				18
Employee	30	30	32	32	27	27				30
Unemployed	0	0	0	0	0	0				0

4.2 Current Energy Used and Their Sources

The result of the study on current energy used, their sources and money spent on fuel purchase and environmental implications across surveyed zones were presented in Table 3. Results displayed a non-significant difference for sources of energy and environmental impact ($p>0.05$). The result showed that 82.3% of the respondents are using firewood as a mean source of energy, North-East had highest number (88% of respondents) of individual that are using firewood as sources of energy, whereas, North-Central had 80% of the respondents for firewood users, North-West had least number (79) of respondents that are using firewood among all the three study zones. Meanwhile, across the surveyed zones, 12.3% are using charcoal as a source of energy. North-Central had substantial amount (17%) of respondents that are using charcoal, while in North-West, 14% of the surveyed participants are using charcoal. North-East had least proportion (6%) of charcoal users. Only few (5.3%) respondents are using liquefied petroleum gas (LPG) among all the three study zones. Highest number (7%) of LPG users are in North-west, whereas, North-East and North-Central have 6% and 3%. Unfortunately, none of the respondents are using biomass briquettes, electricity, and kerosene. This results confirmed the abject use of firewood as sources of energy in Jigawa State, which contribute to the annual flooding in the state due extreme cutting of tree (deforestation). Monthly expensive of fuel recorded across the surveyed zones, the result displayed significant difference ($p=0.00084$). The results showed that 54.3% of the respondents are spending greater than 5000 Naira on fuel sources, 44.7% of the respondents are spending between 2000 to 5000 Naira per month, while the remaining 1% are spending less than or equal to 2000 Naira per month on fuel sources. Highest number of spenders are recorded in North-Central (67%), whereas, in North-East, 54% of the respondents spent greater than 5000 Naira monthly, and 42% from North-West spent >5000 Naira. Meanwhile, only 3% are spending less than 2000 Naira, this respond are recorded only in North-East. North-West recorded a highest proportion (58%) of those spent between 2000 to 5000 Naira, while North-East and North-Central recorded 43% and 33 of respondents that spent 2000 to 5000 Naira. This results revealed the affordability, and availability of firewood across the study zones, which is another factor to mitigate while propelling proper solution to extreme deforestation in Jigawa State. Across the surveyed zones, individuals usually purchased firewood (77%), and 14.3% of the respondents were collecting (tree cutting) while 8.3% of the respondents were purchasing and collecting at same time. Moreover, opinion about environmental implication of cutting tree among three study were recorded. Almost all the respondents (92.6) agreed that there negative environmental impact of haphazard cutting of tree, whereas 7% of the respondents are not entirely agreed with environmental impact of cutting tree. Only few (0.33%) individuals are not sure of the negative implication of cutting tree.

Table 3. Primary sources used by respondents and awareness of environmental impact.

Variable	North Central		North East		North West		DF	χ^2 -value	p-value	%Mean
	Freq	%	Freq	%	Freq	%				
Primary source										
Firewood	80	80	88	88	79	79	10	7.46	0.11	82.33
Charcoal	17	17	6	6	14	14				12.33
LPG	3	3	6	6	7	7				5.33
Kerosene	0	0	0	0	0	0				0
Biomass Briquette	0	0	0	0	0	0				0
Electricity	0	0	0	0	0	0				0
Month cost of fuel (Naira)										
0-2000	0	0	3	3	0	0	4	18.84	0.00084	1
2500-5000	33	33	43	43	58	58				44.67
>5000	67	67	54	54	42	42				54.33
Sources of firewood										
Purchase	79	79	66	66	87	87	4	12.89	0.0118	77.33
Collect	13	13	22	22	8	8				14.33

Both	8	8	12	12	5	5				8.33
Aware of environmental impact										
Yes	97	97	88	88	93	93	4	7.01	0.1353	92.67
No	3	3	11	11	7	7				7
Not sure	0	0	1	1	0	0				0.33

4.3 Awareness and perception of Biomass Briquettes

Results in Table 4 revealed the level of awareness and perception about biomass briquettes, willingness of the respondents to transit to biomass and to learn how to produce biomass briquettes if the training will be given. The level of awareness displayed non-significant difference across the surveyed zones ($p > 0.05$, $\chi^2 = 4.71$). Majority of the respondents (76%) have not heard of biomass briquettes period to this survey, the remaining 24% responded positive. North-Central had highest level of awareness of biomass briquette with 31% responded positively, whereas, North-West had least level of awareness (18%). The opinion about biomass briquettes could be a suitable alternative to firewood revealed a significant difference ($p = 0.04$, $\chi^2 = 9.71$), majority of the respondents (71%) believed biomass briquettes could be a sustainable substitute to firewood, while about 10.6% of the participants responded negatively, whereas, few respondents (18.3%) are skeptical about potential of biomass briquettes as an alternative to firewood. These response could be attributed to low level of awareness of biomass briquettes. Interviewer engaged respondents in to discussion about potential of biomass briquettes, majority of the respondents (89%) are willing to transit to biomass briquette. In North-Central, 97% of the respondents are willing to transit to biomass, in North-East 91% showed interest to switch to biomass briquettes, while 79% of the respondents from North-West showed positive response to transit to biomass briquettes. Only few individuals (2.67%) across the study zones responded negatively about willing to switch to biomass briquettes while 8.3% are undecided. Moreover, the results also presented the proportion of respondents that are willing to learning the technique of making biomass briquette, if the training will be given freely. The H-test displayed significant difference ($p = 0.01$, $\chi^2 = 12.37$) for respondents agreed to undergoes the training. 92% of the respondents across the study regions showed interest to learn the process of making biomass briquettes, few individuals (1.33%) responded are not willing to learn, whereas, 6.67% of the respondents are undecided. North-West region had highest proportion (97%) of individuals that are ready to learn the technique of producing biomass briquettes, whereas North-Central and North-West have 93% and 86% of the respondents willing to learn. Only North-West region recorded few individual (4%) that are unwilling learn the techniques. This results, revealed that majority of the respondents across the three study zones are willing to learn the technique of making biomass briquettes, if government could provide the training.

Table 4. Awareness and perception of respondents about biomass briquettes.

Variables	North Central		North East		North West		DF	χ^2 -value	p-value	%Mean
	Freq	%	Freq	%	Freq	%				
Had you heard of biomass briquettes before this survey?										
Yes	31	31	23	23	18	18	2	4.71	0.0947	24
No	69	69	77	77	82	82				76
Do you believe biomass briquettes could be a suitable alternative to firewood?										
Yes	63	63	81	81	69	69	4	9.70	0.0458	71
No	11	11	8	8	13	13				10.67
Maybe	26	26	11	11	18	18				18.33
Willingness to transition										
Yes	97	97	91	91	79	79	4	17.76	0.00138	89
No	0	0	3	3	5	5				2.67
Maybe	3	3	6	6	16	16				8.33

What would encourage you to switch to biomass briquettes?

Lower cost than firewood	26	26	34	34	18	18	6	12.91	0.0445	26
Easy availability	5	5	9	9	4	4				6
More efficient than firewood	13	13	5	5	11	11				9.67
Environmental benefits	56	56	52	52	67	67				58.33
Others	0	0	0	0	0	0				0
Would you be interested in learning how to make biomass briquettes if training were provided?										
Yes	93	93	86	86	97	97	4	12.37	0.0148	92
No	0	0	4	4	0	0				1.33
Maybe	7	7	10	10	3	3				6.67

5. CONCLUSIONS AND RECOMMENDATIONS

The study highlighted the environmental implication of deforestation including land degradations, loss of biodiversity, extreme desertification. Biomass briquettes and its benefits has been discussed and introduced as a sustainable alternative to the excess use of firewood. A survey was conducted in three zones of Jigawa state, North-central, North-East, and North-West. In each zone, three local government areas were subsampled. A total of 300 individuals participated in the survey. The survey results revealed that the majority of the participants are male with a higher level of education, farmers, and employed. Most of the respondents are using firewood as a source of energy, and are spending greater than 5000 Naira for fuel sources. Most of the respondents believed and agreed that using firewood as a source of energy posed environmental challenges to human livelihood. The majority of the respondents have not heard of biomass briquettes before this survey. A high proportion of respondents are willing to switch to biomass briquettes, and are ready to undergo training on how to produce biomass briquettes.

As per the survey's results, it is highly recommended that government, non-governmental organizations, community leaders, and other institutions should engage more in campaigning/ public awareness about the environmental implication of deforestation and the harmful effect of using firewood as an energy source while advocating biomass briquettes as a sustainable alternative. Capacity building training on the production of biomass briquettes should be given across the state. Jigawa state government should provide subsidies and incentives to biomass briquettes investors, so that biomass briquettes could be inexpensive, and easily available within the state.

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