LOW-COST FUEL ECONOMY WOOD STOVES AS A RENEWABLE ENERGY ADAPTATION MECHANISM IN MAKURDI LGA, BENUE STATE, NIGERIA

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Abstract
In recent years, the biggest threat to human life and advancement has been the occurrence of climate change. Wood stoves continue to be the main source of cooking energy in areas like Makurdi Local Government Area (LGA) in Benue State, Nigeria, where access to reasonably priced and sustainable energy is limited. But conventional wood stoves are frequently ineffective, emitting too much smoke and using a lot of fuelwoods, which increases greenhouse gas emissions and deforestation. The development and effectiveness of inexpensive, fuel-efficient wood stoves as an environmentally friendly adaptation strategy are examined in this study. Three native hardwoods—*Daniella oliveri*, *Prosopis africana*, and *Terminalia superba*—are evaluated for their fuel efficiency and burning qualities as treatments in fuel-efficient wood burner designs. Randomized Complete Block Design (RCBD) was used to compare the variables (fuel-wood/time) in the data collected. The result shows that, treatment 3-*Daniellia Oliveri* recorded the highest quantity of fuel-wood used (consumption) in the two devices (close and open stove) 1.1333kg and 1.0333kg respectively. This research provides valuable insights into the potential for low-cost, fuel-efficient wood stoves to serve as an adaptive strategy in Makurdi LGA, fostering climate resilience and reducing deforestation. The adoption of these stoves could support sustainable forestry practices, lower greenhouse gas emissions, and enhance the health and economic well-being of local communities.
Keywords: Fuelwood, Woodstoves, Deforestation, Efficiency

Introduction
Climate change incidence has recorded the greatest overwhelming threat to human survival and development in recent times (Intergovernmental Panel on Climate Change (IPCC) assessment 2007). There is also substantial evidence that complete climate change mitigation cannot be contemplated in the near term, therefore communities all over the world will continue to experience major disruptions in economic and social activities in the coming decades, at scales that could prove difficult or impossible to reverse (Intergovernmental Panel on Climate Change (IPCC) assessment 2007). Fuel wood consumption remains the major source of fuel for over half of the world's population with more than 50% of annual wood production utilized in developing countries in form of fuel wood (Aide 2002). The huge carbon footprints associated with fuel wood consumption informed the decision to test the use of low-cost fuel efficiency wood stoves as a climate change adaptation measure in

reducing vulnerability among rural communities in Benue State.

The main goal was to ascertain the most effective use of inexpensive fuel-efficient wood stoves for home cooking by considering the amount of fuel wood needed and the cooking time. The specific objectives were to compare the duration of cooking using the low-cost fuel efficiency stoves and the open traditional stoves. Secondly to compare the quantity of fuel wood used in heating water using the low-cost fuel efficiency stoves and the open fuel wood stoves.

Materials and methods

The Study Area

The experiment was carried out in Asase North Bank – in Makurdi Local Government Area of Benue State Capital. The local government is situated at latitude 7^o 49^1 and 7^o 52^1 to the north and Longitudes $8^0$36’ and $8^0$$40^1$E with area of about 16km^2 East within the Guinea Savannah region.

The North and South Banks of the Benue River naturally split Makurdi town into two masses. The North Bank comprises of Agan, Mbalah, North Bank I and II, Clerk/market. Makurdi has a typical tropical climate with clearly distinct dry and rainy reason. Dry season commences from November to March while rainy season starts from April and ends in October and ranges from 150 – 180cm. Temperature fluctuates between 23^{0}c during the rainy season to as much as 38^{o}C during dry season (Terdoo, Ndabula, Abaje, 2020).

Data collection

Three different species of wood P*prosopis africana, Terminalia superba and Daniellia oliveri* and mixture of the three species, *two* fuel-wood stoves (the open stove and low-cost fuel-wood stove), and two cooking pots, weighing balance, trowel, stones/bricks, clay/mud, water and a stop watch were used for the study.

The open stove is the traditional tripod (3) stones used by women in domestic cooking and the low-cost fuel-wood stove constructed around three stones with mud. In each of the stoves, equal quantity of wood species (3kg) was used to boil 1.5litres of water in 2kg pot and with an optimal distance from the ground of 20 – 25 mm (0.8-1 inch) at a given time simultaneously. The initial weight of fuel-wood was taken before and after boiling and the remnants of the fuel-wood was reweighed to determine energy used. Each of the four treatments was replicated three times for each type of stove making a total of twenty-four (24) replications.

Data analysis

Collected data was analyzed using Randomized Complete Block Design (RCBD) to compare the variations (fuel-wood/time)

Results and discussion

The data obtained from the experiment was presented in Tables 1a, 1b, 2a and 2b. The result shows that, treatment 3-*daniellia oliveri recorded* the highest quantity of fuel-wood used (consumption) in the two devices (close and open stove) 1.1333kg and 1.0333 kg respectively, followed by treatment 1-*Prosopis africana* with open stove recorded

0.9333 quantity of fuel-wood used than close stove with 0.8333 kg, also followed by treatment 2-*Terminalia superba having* high quantity of fuel-wood used in the close stove 0.7000 than Open stove with 0.6333 and lastly Treatment 4 - mixed species (*Prosopis*, *Terminalia* and *Daniellia* species) with open stove higher with 0.5667 kg than close stove having 0.4000 kg in fuel-wood used. It is observed from the result that quantity of fuel-wood used in boiling 1.5 liters of water in close stove in T2 and T3 is higher than that of open stove given that the two energy forces have limited fuel economy. The difference in the treatments may be as a result of composition of cellulose, the hemicelluloses, lignin and extractives (Arno, 1989). Therefore, Treatment 3 and 1 are highly volatile as compared to Treatment 4 and 2 respectively. While the variation in the devices may be due to the nature of the stoves as a fuel for combustion (US forest service 1987). Thus, traditional cooking stove (open stove) commonly used by women for household cooking have low conversion efficiency, wasteful of energy since there is no control of Oxygen supply. Whereas the low-cost fuel wood stove (close stove) has higher heat efficiency or broader capacity to control the heat output of the stove and is associated with lower fuel wood consumption. This confirms with report on fuel-efficient stoves which aims to improve the poor efficiency of open fires and thus to conserve scarce fuel wood resources (Foley and Moss's 1985). And finally, the observed variation due to environmental factor (Antal and Gronli, 2003).

In Table 1b attached, the analysis of variance results indicated significant difference ($p < 0.05$) in quantity of fuel wood used in boiling 1.5 liters of water using the devices and the treatments showed difference between them (Fig. 2 and 3). The mean values for the treatments (*prosopis africana*, *Terminalia superba*, *Daniella Oliveri* and mixture of species recorded T1, T2, T3, and T4 respectively in kilograms (kg) were; Open stove: 0.9333, 0.6333, 1.0333 and 0.5667 close stove; 0.8333, 0.7000, 1.1333 and 0.4000.

This shows that treatment 3-*Daniellia oliveri* takes longer time to boil 1.5 litres of water irrespective of the high fuel wood consumption and followed by treatment 1, 2 and 4 using traditional cooking stove (open stove) whereas in the low-cost fuel wood stove (close stove); treatment 4 takes shorter time to boil the water followed by treatment 1, 2 and 3 respectively.

The observation shows that fuel wood Consumption of species in the used treatments are directly proportional to the device used and also the ability of a given species of fuel wood to convert to charcoal and this chemical reduction of organic matter are only favorable under controlled condition (like close stove); This observation is in line with the statement of Prins and Ptasinki 2006. And also, the Thermal efficiencies associated with wood combustion systems typically range from 65 to 80%, depending upon the condition of the wood and the combustion regime (stove) employed (Tillman and Anderson 1983).

Conclusion and recommendations

Traditional cooking stoves are still widely used in Asase Community on Makurdi Town's North Bank and are becoming more and more common in the town's rural and majority urban neighborhoods. Innovations in low-cost fuel wood stoves and improvements to existing fuel wood stoves may offer effective substitutes. Promoting these technologies would help reduce the cost of buying fuel wood, cut down on cooking time, lessen the impact of fuel wood harvesting demand, and address some of the more challenging issues brought on by climate change. As an adaptation strategy, it will also assist in addressing the increasing difficulties brought on by a changing climate.

Considerable efforts have to be devoted to quantifying the stove's economic value and how this affects household's acceptance of the cooking system. And also encourage agroforestry practices.

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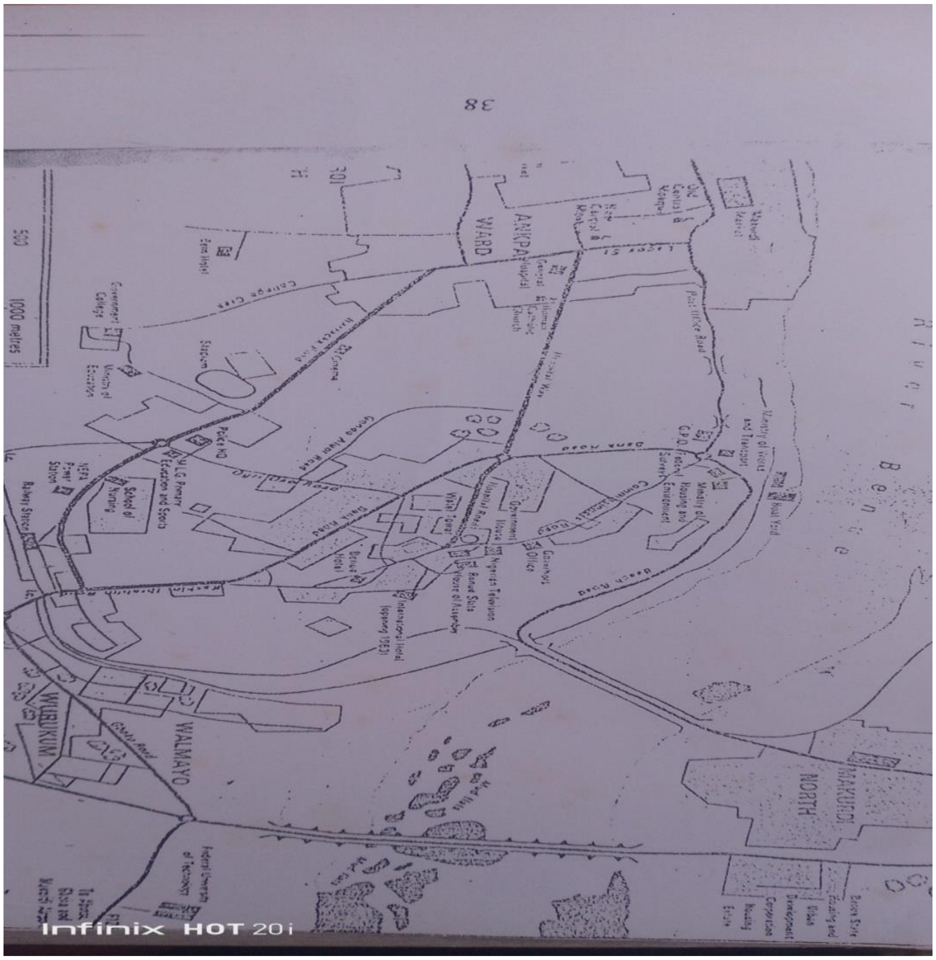

Figure 1: Map of Study Area

Table 1a: Quantity of fuelwood used in boiling 1.5 litres of water

	T1	T2	T3	T4	Total Replication	Mean Total (MR)
Open Stove						
R1	1.0	0.6	1.0	0.5	3.1	0.775
R2	0.8	0.5	1.1	0.7	3.1	0.775
R3	1.0	0.8	1.0	0.5	3.3	0.825
Treatment total (OS)	2.8	1.9	3.1	1.7	9.5	
Mean Total	0.9333	0.6333	1.0333	0.5667		
Close Stove						
R1	0.5	0.6	1.0	0.2	2.3	0.575
R2	1.0	0.5	1.5	0.5	3.5	0.875
R3	1.0	1.0	0.9	0.5	3.4	0.85
Treatment total (CS)	2.5	2.1	3.4	1.2	9.2	
Mean Total	0.8333	0.7000	1.1333	0.4000		

Table 1(b) Analysis of variance for quantity of fuelwood used in boiling 1.5 litres of water

	Sum of Squares	df	Mean Square	F	Sig.
Open Stove					
Between groups	0.463	3	0.154	11.563	0.003
Within Groups	0.107	8	0.013		
Total	0.569	11			
Closed stove					
Between groups	0.833	3	0.278	3.876	0.56
Within Groups	0.573	8	0.072		
Total	1.407	11			

Post Hoc tests ($p < 0.05$)

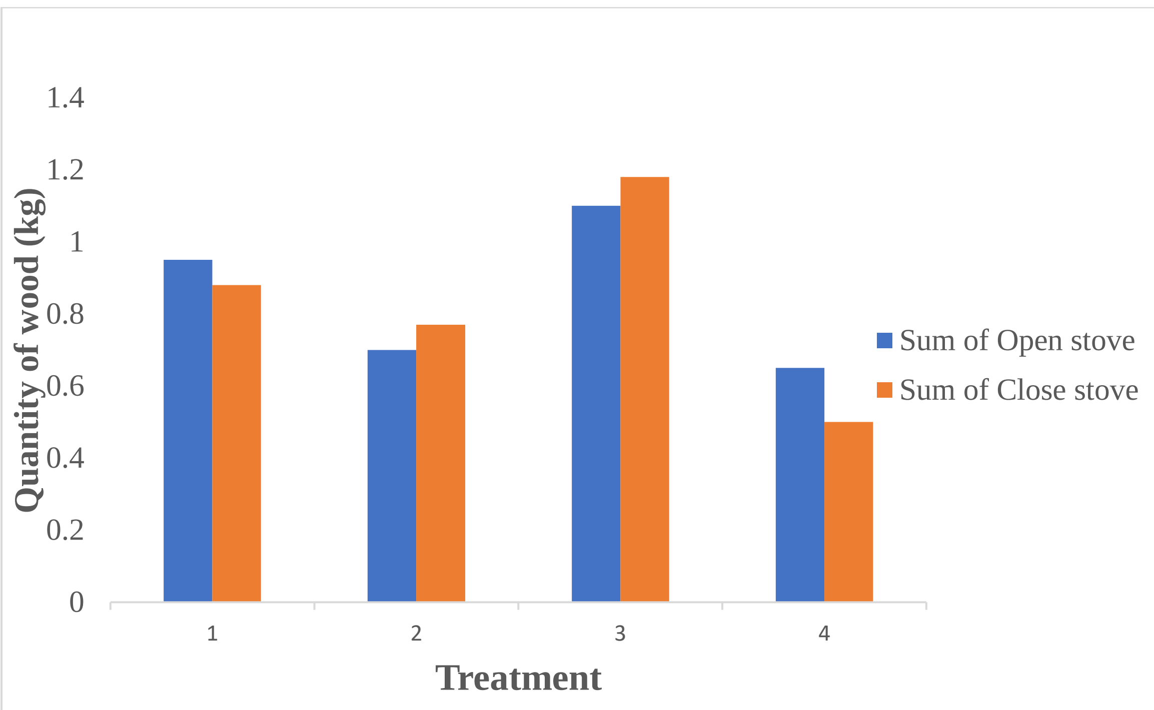

Figure 2: Quantity of wood used in boiling 1.5 liters of water

Table 2a: Time taken in boiling 1.5 liters of water

	T1	T2	T3	T4	Total Replication	Mean Total (MR)
Open Stove						
R1	19	15	19	10	63	15.75
R2	14	13	16	9	52	13.0
R3	13	14	16	9	52	13.0
Treatment total (OS)	46	42	51	28	167	
Mean Total	15.3333	14.000	17.000	9.3333		
Close Stove						
R1	5	5	10	7	27	6.75
R2	8	10	8	7	33	8.25
R3	10	10	8	5	33	8.25
Treatment total (CS)	23	25	26	19	93	
Mean Total	7.6667	8.3333	8.6667	6.3333		

Table 2(b): Analysis of variance for time taken in boiling 1.5 liters of water

		Sum of Square	Df	Mean Square	F	Sig.
T open stove	Between Groups	97.583	3	32.528	8.871	.006
	Within Groups	29.333	8	3.667		
	Total	126.917	11			
T close stove	Between groups	9.583	3	3.194	.737	.559
	Within groups	34.667	8	4.333		
	Total	44.250	11			

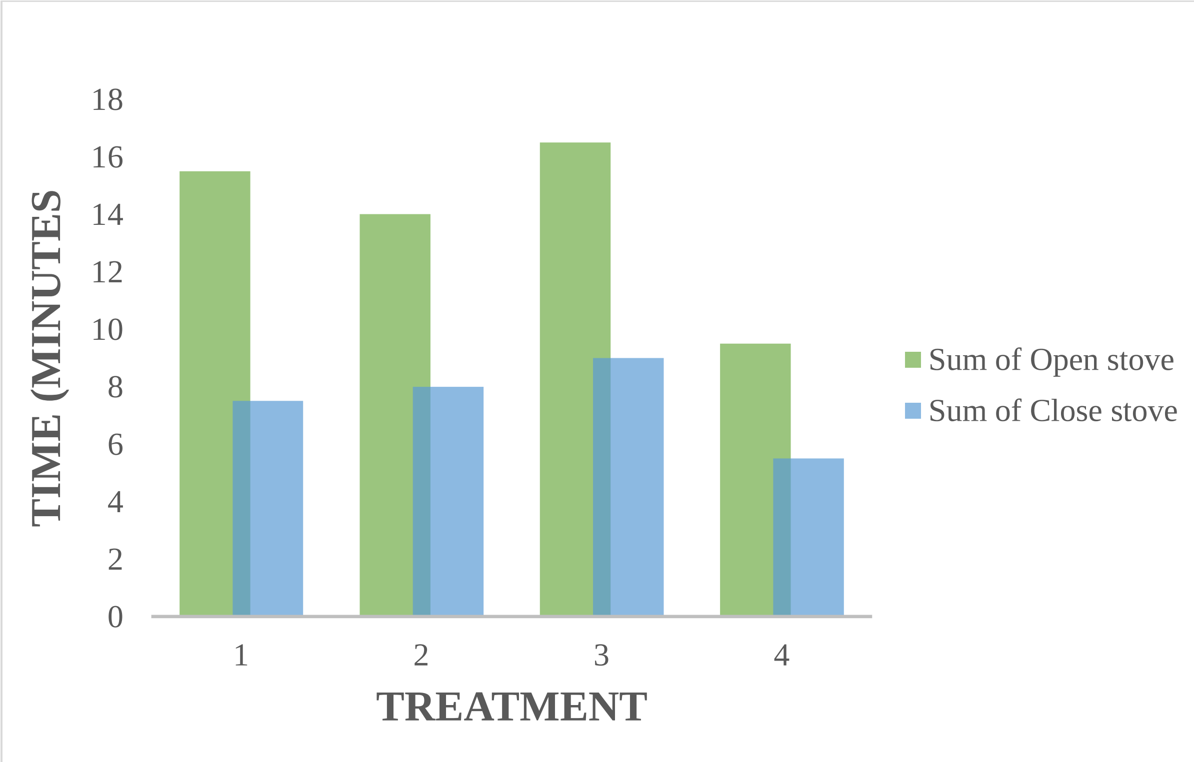

Figure 3: Time taken in boiling 1.5 liters of water