

Full Length Research Paper

An assessment of improved and traditional cooking stoves and their implications on forests conservation in Sudan: The case of North Kordofan State

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The aim of this paper is to compare and contrast between improved and traditional cooking stoves with regard to firewood energy consumption, energy utilisation efficiency, cost effectiveness and time consumed in firewood gathering. Primary data were collected using structured questionnaire with 60 of the Improved Cooking Stoves' (ICS) users and non-users in North Kordofan State. Constant Boiling Water and Standard Duration experiments were conducted. The results reveal that improved stove is about three times more efficient in transferring the available heat as compared to the traditional one. However, ICS non-users spend 112 days a year to provide the minimum energy needs for their household while it takes only 54 days for ICS users. Improved stoves reduced per capita wood fuel consumption by 53% and household wood energy expenditure by 35% as compared to the traditional stoves. Efforts should be made by governmental and non-governmental institutions to encourage the adoption and utilisation of the improved stoves so as to conserve forests and consequently improve the livelihood of the rural household.

Key words: Forest conservation, improved stoves, traditional stoves, Kordofan, Sudan, firewood.

INTRODUCTION

The Sudan presently derives over 80% of its total energy use from wood and charcoal, and the highest consuming sector is households (FAO, 2007). At the domestic level, energy is important for cooking, heating and lighting, as well as for agricultural activities and semi-industrial usage. Next to this there are other applications, often-secondary, for instance as insects repellent (FNC, 1995). It is clear that a single heating source can fulfil several functions at the same time. The demand for wood and charcoal in Africa including Sudan is set to increase by over 45% over the next 30 years, due to increases in population and demand for energy (Whiteman et al., 2001). Over harvesting of wood for fuel and charcoal production brings changes to the species composition of forest or savanna. Local people are impacted by having to spend longer and search further to meet their daily fuel

requirements (UNEP, 2002). As estimated by FNC/FAO (1995), an equivalent of 15 million cubic meter of solid wood is consumed each year. As energy supply becomes scarcer, the price paid for fuel wood and charcoal increases significantly. According to the FNC/FAO (1995), up to 30% of a family's income can be spent on wood and charcoal.

A shortage of fuel for cooking is one of the many problems faced by people in the developing world. In general, firewood gathering is a woman's work; however it is burdened with many dangers such as the risk of rape

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and life threatening attacks during their search for much needed firewood, so as to feed their households. In many areas, where the local sources of firewood are completely depleted, women are led to go further and further afield or to pull up the tree roots, getting rid of any chance of the trees growing again. Still if women survive this, they are still exposing the household members to potentially fatal smoke fumes (Practical Action, 2013).

In Sudan, the traditional firewood stove consists of three stones usually assembled in the ground in the corner of the kitchen adjacent to the main living house. The three stones are used to support the cooking pot, which is usually round in shape and made of cast aluminium.

The traditional three-stone fire has served many very well and for a long time, and has been used for cooking and heating purposes, as well as scaring away animals in the wilds. In the settlement, many religious and social ceremonies have been observed around the fire of the traditional three-stone, while the traditional charcoal stove was not designed to save charcoal. The producers built it in a box shape because of the ease of its construction and ready availability of its material (aluminium cans). These cans are ubiquitous and cheap. In terms of production, any unskilled adult can quickly learn to make the stoves because the metal is so pliable and easy to cut.

In terms of performance, traditional charcoal stove had other drawbacks, as there is no way to reduce heat once food is brought to temperature or liquid to boil. Also, it cannot use the small pieces of charcoal, locally called "duga" that compose approximately 30% of the bagged charcoal commonly sold in Sudan. Heat transfer efficiency should be noted as the biggest drawback.

The improved cooking stoves are self-constructed mud stoves, which consist of a protective clay collar into which the cooking pot is inserted. Three half-bricks are built into the inner wall of the stove to support the cooking pot and provide sufficient space underneath the pot for the fuel.

Although many programs and projects contain a component to improve the supply of fuel wood, additional tree planting has not automatically lead to an increase in the supply of wood fuel. Also, plantations which are oriented towards fuel-wood production are being used for non-fuel purposes, for instance, they are used for construction and at the industrial level as pulpwood (Brown, 2000). There is, however, an urgent need for immediate action to conserve, the remaining, forest resources in the country for the future. The stoves' programs have an estimated higher advantage, as an immediate energy conservation measure over other activities. They provide direct benefit to participant households without having to wait for long period. This reason alone is enough to show that stoves' programs can help spur development at the basic level of survival, where they are mostly needed. Since the task of firewood collection almost, always, falls on women and children,

by necessity or conspiracy, the cumbersome condition of traditional kitchen reduces attention due to other critical tasks, such as nutrition and education. If the available wood is used efficiently, then less money will be spent on fuel wood and more important new forest will have time to regenerate (Canada Mortgage and Housing Corporation, 2002). Accordingly, this study attempts to assess improved cooking stoves (self-constructed mud stoves) versus the traditional cooking stoves and their implications in forests conservation in the rural areas of North Kordofan State, Sudan. Specifically, this study compare and contrast between improved and traditional stoves with regard to firewood energy consumption, energy utilization efficiency, cost effectiveness, time consumed in firewood gathering, amount of money saving and forests conservation.

METHODOLOGY

Study area and data collection

This study depended on primary data drawn from household survey carried out in El Ain area, North Kordofan, Sudan. The study area is situated about 26 km South west of El Obied. It lies within an area of about 30,000 ha, surrounding the El Ain Forest Reserve. It is inhabited by more than 23 villages practicing farming, mainly crop production. According to the project plan, the study area was divided into two groups of villages named the improved stoves' user and non-user villages. Each part comprised a number of villages with similar socio-economic characteristic and environmental conditions. Subsistence, rain-fed agriculture is the main means of livelihood for the settled population of the area, with livestock production practiced to varying degrees in all villages.

Based on the homogeneity in the socio-economic characteristics of the population in the study area, random sampling technique was used to select the respondents. One village from each group of improved stove users and non-users were selected. Thereafter, 30 households from each village were randomly selected. Structured questionnaires were developed, tested and revised to gather the required primary data. The survey questions included farmer's opinions about the adopted improved stoves, as well as the future perspectives about energy conservation techniques in the area, while information about stove production and prices were obtained directly from stove retailers and producers. In addition to the primary data, the study made use of the secondary data obtained from both official documents and reports available in the El Ain Forest Project's office.

Experiments

Two applicable experiments were conducted following the laboratory testing procedures of The Environmental

Research Council (ERC) and Renewable Energy Research Institution (RERI) (1989). This is because these institutions are the pioneer organizations that introduced improved stoves in Sudan, and they have recognized that testing and evaluation are an integral part of cook-stove design, production, and marketing.

Constant boiling water test

Firstly, the constant boiling water test was carried out. This is a simulation of a typical cooking practice where the stove is operated initially for a fixed period of high power followed by a longer low power-simmering phase. The fuel consumption and the water evaporation were measured as shown in Box 1.

Standard duration test

The standard duration test compares the periods of time that each cook-stove could maintain the boiling of a standard volume of water, with a fixed mass of fuel. The data obtained from these tests were used to calculate percentage heat utilized, power output, and rates of fuel consumption as shown in Box 2.

From the quantitative measurement made during the tests on both woodstoves and charcoal stoves, the comparative performance data were calculated (Boxes 1 and 2).

When the stoves were operated with firewood, the total heat produced was calculated by subtracting the heat content of the remaining charcoal from that of the firewood consumed, that is, $(FM * 18000) - (CM * 29000)$ where FM is the weight of firewood consumed in kilograms and CM is the weight of charcoal remaining. The calorific values of firewood and charcoal are 18000 and 29000 kJ / kg respectively. The data obtained from these tests were used to calculate percentage heat utilized, power output, and rates of fuel consumption.

The performance of the mud-stove was compared with that of the traditional three-stone fire. For these experiences, the standard source of firewood used consisted of small pieces of 15 cm long with a diameter ranging between 2 and 3 cm. The wood was air-dried to residual moisture content of 5%. Identical flat-bottomed aluminum cooking pots, with well fitting lids were used, with a base diameter of 236 mm. A thermocouple was inserted through a small hole in the center of each lid extending down within 1 cm of the bottom of the cooking pot. The pot used was the one which was found to be the most widely used in the household sector. Each test was repeated three times to reduce the expected errors in measurement.

The tests on the charcoal stoves were carried out and the fuel used was from *Acacia seyal* with uniform size distribution. All lighting and operating procedures were standardized. The tests were replicated four times.

The experiments on the stoves were carried out in a

typical Sudanese rural kitchen setting, consisting of a covered space with three sides' closed and open front, allowing the smoke to escape out, yet protecting the fire from the prevailing winds.

RESULTS AND DISCUSSION

The results indicate that all respondents are totally dependent on firewood, as a primary source of energy. Charcoal represents the topmost important secondary source of energy in the study area, while only 10% of the respondents use agricultural residues (Table 1).

Although firewood availability in the study area varies from site to site, the data show no significant difference between the two-targeted villages in relation to firewood sources. The sources of the firewood include buffer zone (46%), reserved forests (39%) and community forests (12%), while only 3% of the respondents purchased their firewood from the nearby market.

The results revealed that 59% of the respondents purchased their entire charcoal requirement from the market, while 41% depended on their own charcoal production, of whom, 35% made charcoal from the dead wood and only 6% made theirs from the uprooted shrubs and trees in the newly cleaned agricultural land.

Results showed that on average the annual firewood consumption is 0.17 and 0.41 M³ per household for ICS user and non user, respectively, while the average annual charcoal consumption per household are 0.31 and 0.17 M³ for stove user and non user, respectively (Figure 1). When combining the per capita annual firewood and charcoal consumption in the study area, the total firewood consumption reaches to 0.34 m³ while charcoal consumption is 0.72 m³ for the ICS user and non-user respectively. This implies that improved cooking stove non-users consumed more than double the amount of firewood and charcoal of the ICS users.

The value of domestic energy conserved by using ICS was also calculated, and the result shows that the household can save some amount of money equal to 35% of wood energy expenditure (1254 SDG) (Table 2). In some areas in North Kordofan, there are even worse conditions regarding wood energy crisis. High prices for wood and charcoal affect some families and the money has to be squeezed out of very limited cash incomes and usually diverted from buying other essential needs (Schmidhuber, 2006). The only alternative is to spend more time in wood collection. Consequently the absence of wood means eating uncooked food, food being cold and living in the dark.

Regarding time spent in firewood collection in the study area, wood gathering has become a fulltime occupation. In distance, this corresponds up to half a day's walk away, or more. This loss of time places a huge constraint on other activities that are necessary to support the households. Non-ICS users spend as much as 112 days a year to provide the minimum energy needs for their

$$\mathbf{a. Efficiency at High Power Phase (PHU.1) = w_{e1} * 2300 / F_{m1} * c}$$

Where:

- w_{e1} = Weight of water evaporated during high power
- F_{m1} = Weight of fuel used during high power phase
- 2300 = Latent heat of vaporization of water kJ/kg.
- c is the calorific value of the fuel in kJ/kg

$$\mathbf{b. Efficiency at Low Power Phase (PHU 2) = W_{e2} * 2300 / F_{m2} * c}$$

Where:

- W_{e2} = Weight water evaporated during low power phase.
- F_{m2} = Weight of fuel used during low power phase.

$$\mathbf{c. Overall Efficiency (PHU 3) = w_{e3} * 2300 / F_{m3} * c}$$

Where:

- w_{e3} = Total weight of water evaporated during the test.
- F_{m3} = Total weight of fuel used during the test.

$$\mathbf{d. power output of stove during high power phase = F_{m1} * C / (t + 15) \times 60 \text{ kw}}$$

Where:

- t is number of minutes taken to boil water.

$$\mathbf{e. power output of stove during low power phase = F_{m2} * C / (60 \times 60) \text{ kw}}$$

$$\mathbf{f. average power output of stove = F_{m3} * C / (t + 75) * 60 \text{ kw}}$$

$$\mathbf{g. specific consumption (S.C.) = F_m / W_e}$$

= weight of fuel consumed / weight of water evaporated (g/kg)

Box 1. Constant water boiling tests.

a. Time at boiling

Comparative length of time that a standard amount of fuel will maintain boiling water over 95°C.

b. Average rate of fuel consumption = F_m/t in g/min

Where:

- F_m is the total weight in grams of fuel consumed.
- t is the total duration of the test in minutes.

c. Average power output of stove during test = $F_m * c / t$ kilowatts (kw)

Where:

- F_m is total weight in kg of fuel consumed
- c is the calorific value of the fuel in kJ/kg and
- t is the total duration of the test in seconds.

d. Percentage heat utilized (Efficiency in %) =

$$(\Delta T \cdot w_m * 4.2) + (w_e * 2300) / F_m * c \times 100$$

Where:

- ΔT = n° of c° rise of water temperature from ambient to boiling.
- w_m = Weight of water in kg.
- 4.2 = Specific heat of water kJ/kg.
- w_e = Weight of water evaporated in kg.
- 2300 = Latent heat of vaporization of water kJ/kg.
- F_m = weight of fuel used in kg.
- c = calorific value of fuel in kJ/kg.

Box 2. Standard duration tests.

Table 1. Sources of energy in the study area.

Source of energy	Percentage
Firewood	100
Charcoal	52
Crop residues	10

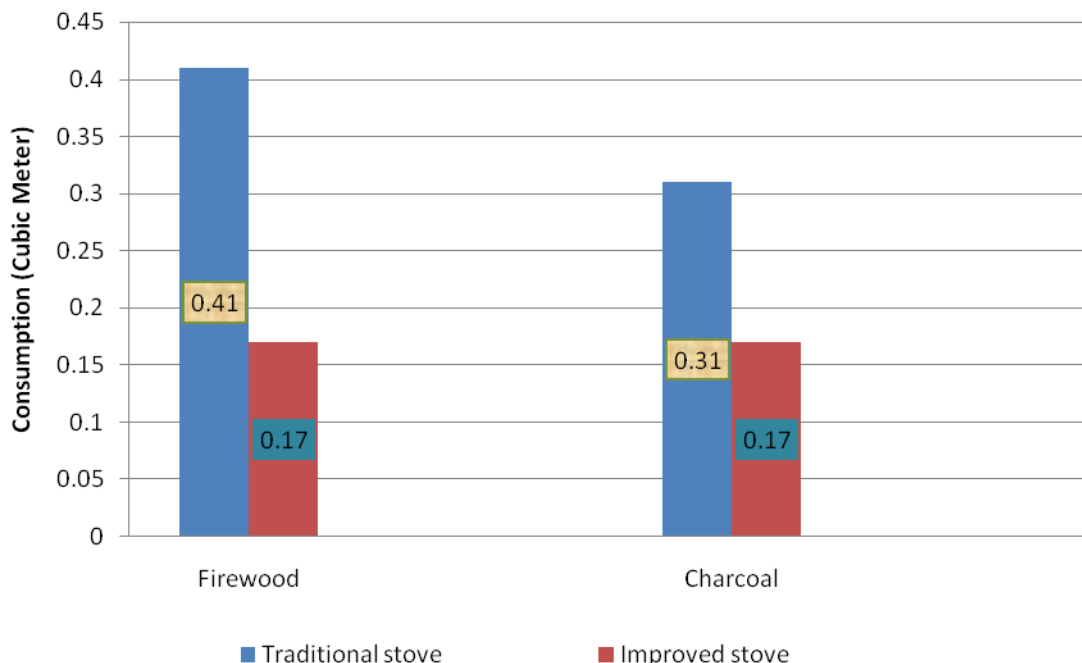


Figure 1. Traditional versus improved cooking stoves firewood and charcoal consumption (cubic meter).

Table 2. Firewood collection and purchasing costs: ICS users versus traditional stove users (SDG).

Variable	Collection costs	Purchasing	Total
Traditional stove	2590	1022	3612
Improved stove	1671	687	2358
Saving	919	335	1254

Table 3. Constant boiling water test with the firewood and charcoal stoves.

Stove details	Initial water temperature	Time to reach boiling	Total wood used	Total water evaporated	Output average	Average specific heat consumption	P.H.U high power	P.H.U low power	P.H.U. average
	C°	minutes	g	g	kW	g/kg	%	%	%
Traditional 3-stone	35	26	1395	635	4.1	2.2	8.8	9.5	9.1
Improved mud-stove	34	15	728	1404	2.4	0.52	25.7	36.5	31
Traditional charcoal stove	35	27	272	530	1.3	0.51	25	32	27
Improved charcoal stove	35	17	240	752	1.3	0.32	31	58	44

PHU = % of heat utilized (Efficiency in %).

household while such requirements take only 54 days per year for ICS users in the study area.

The data obtained from Constant Boiling Water Test (Table 3) and Standard Duration Tests (Table 4) clearly show that the improved mud stove is up to three times more efficient in transferring the available heat to the cooking pot as compared to the 3-stone fire. It was also

found that when operating the mud stove, the feeding rate of the fuel had to be severely restricted to lower the power output of the stove and avoid excess evaporation of the water. This indicates that this highly efficient firewood stove would be ideal when operated with low-grade fuels such as crop residues and small diameter twigs. This is also true for the charcoal stoves which

Table 4. Standard duration tests of firewood and charcoal stoves.

Stove details	Time to reach boiling	Time at boiling	Total time	Weight of wood used	Weight of water evaporated	Average power output	Average specific consumption	Rate of fuel consumption	Average P.H.U.
	minutes	minutes	minutes	g	g	KW	g/kg	g/minute	%
Traditional 3-stone	27	71	98	894	698	2.7	1.28	9.1	15
Improved mud-stove	18	128	146	874	1048	1.8	0.43	6.0	35
Traditional charcoal stove	26	119	160	285	704	1.0	0.40	1.8	30
Improved charcoal stove	17	196	228	221	1522	0.8	0.24	1.4	41

result in 58% and 32% efficiency of the improved stove and traditional stove respectively. From the results of the constant boiling water test, it is likely that in general domestic use, the mud stove will consume less than half the firewood used in a traditional 3-stone fire. Such results are confirmed by the targeted villages, whereas in general the improved stoves are better and efficient than the traditional ones concerning short time boiling, average power output, fuel consumption and other related features of energy conservation.

Generally, improved stoves are effectively meeting the needs of the households, as all the stove users agree that the new stoves have gained proper advantage over the traditional ones such as fast cooking, fuel saving, smoke reduction, long lasting fire time, sturdy and stable. In addition to the fact that heat could be controlled, the fire risk is reduced and food is better cooked.

It could be recommended that efforts should be made by governmental and non-governmental institutions to encourage the adoption and utilisation of the improved cooking stoves so as to conserve forests and consequently improve the livelihood of the rural households.

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