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Can Fuel Switching from Wood to Liquefied Petroleum Gas Reduce the Deforestation in Sudan?

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Abstract: The aim of this study was to estimate the quantities of charcoal and fuelwood consumed by rural household in relation to LPG and to investigate the potential of LPG in reducing the deforestation rate in Sudan. The study was conducted in 1998 and 2007 in two rural areas of the Gezira State in central Sudan. Primary and secondary data were collected based on the household survey and reviewing of the literature, respectively. A sample of 121 and 73 rural households were selected randomly from Alshikayrat and Fadasi rural areas, respectively. Descriptive analysis was applied using SPSS program. The study results showed that the average annual charcoal consumption reduced from 374.50 kg in 1998 to 79.80 kg in 2007. The fuelwood consumption decreased from 133.65 kg in 1998 to 38.70 kg in 2007. Charcoal per capita energy consumption reduced from 0.042 TOE in 1998 to 0.0084 TOE in 2007, whereas fuelwood per capita energy consumption decreased from 0.0089 TOE to 0.00259 TOE in 1998 and 2007, respectively. In the same timeframe, wood fuels dependency declined from 78.9% in 1998 to 5.2% in 2007. LPG dependency increased from 21.1% in 1998 to 94.9% in 2007. The study concluded that household shifting to LPG as energy source has positive external effect on deforestation problem in the country. Policies that enhance the LPG price reduction and availability are recommended. The results may help the policy makers and conservatisms to redesign and reframe alternative fuels plans than depending on wood fuels to reduce the deforestation rate.

Key words: Wood fuel, consumption, dependency, conservation, Gezira state

INTRODUCTION

Wood fuel consumption in developing countries of Africa, Asia and Latin America was observed to be a main factor in tropical forests deforestation and the loss of forests was predicated to result in widespread forest biomass energy shortages (Osei, 1993; Haile *et al*., 2009). Even though it has become obvious that wood fuel consumption is infrequently a direct reason of deforestation as most energy demand is fulfilled by forest trees found outside forests lands and agricultural lands clearance (Arnold *et al*., 2006; Bensel, 2008).

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FAO assessed that over half of the two billion people depending on wood fuels at the time were over-cutting forest resources to meet their basic needs and that by 2000 over two billion people would be living in areas facing wood fuels shortages (DeMontalembert and Clement, 1983). In this regard, wood fuel shortages were projected to result in negative social and environmental outcomes (Bensel, 2008).

In the late 1970's, Sudan forests and woodlands covered 38.5% of fuel consumption exceeded the annual growth of forest resource by 70% (WEC/FAO, 1999). The rapid deforestation leads to increased desertification and destruction of the ecosystems. As consequence, soil degraded through high erosion and loss of nutrients leading to agricultural productivity declining as well as downstream (Ehui and Hertel, 1989; Hassan and Hertzler, 1988).

Recently, about 9.5 million Tons of Oil Equivalent (TOE) of biomass energy are consumed annually from more than 3 million hectares of forestlands in Sudan (FNC, 2000). The consequence of trees felling for energy purposes causes a serious deforestation problem (Hassan and Hertzler, 1988). The household sector in Sudan is the most important energy consuming sector. This sector comprises rural and urban households who burn about 90% of the total biomass energy for domestic cooking (Hassan, 1984).

The obvious link between wood fuels use and deforestation and mainly between highly traded urban and rural use and local degradation, formed the basis for policy and program interventions in many developing countries over the past 30 years (World Bank/ESMAP, 2001). These interventions were designed to reduce wood fuels demand in urban and rural areas of the country. In this regard, demand programs emphasized on the promotion and dissemination of improved wood-burning stoves or efforts to facilitate inter-fuel substitution far from wood fuels, regularly through subsidized the availability and pricing of alternative cooking fuels such as kerosene and Liquefied Petroleum Gas (LPG). Whilst petroleum fuels such as Liquefied Petroleum Gas (LPG) and kerosene were relatively scarce and expensive and their use was rationed to when oil import's bill was a heavy burden on the national economy (Hassan *et al*., 2009). Nevertheless, petroleum fuels now become relatively more available, after the discovery and production of the oil in Sudan over the past ten years and represent viable substitutes for traditional biomass fuels in urban and rural areas.

Urban households in Sudan have switched to other cleaner fuels such as LPG and kerosene for cooking and the households in the rural areas have been encouraged to switch to the modern energy source as a solution to the deforestation problem in the country, including the promotion of LPG schemes (e.g., forests gas) and improved wood fuel-stoves, which introduced by the Forests National Corporation (FNC) to reduce the household dependency on forests biomass. Nevertheless, the impact of household switching to LPG on the wood fuels consumption and dependency is unknown. This study attempts to investigate the effect of switching to LPG on biomass fuels consumption in rural areas of the Sudan. Specifically, the study estimates the charcoal and fuel wood consumption and dependency in relation to LPG consumption over time and investigates the potential of LPG in reducing the deforestation rates in Sudan.

MATERIALS AND METHODS

Study Area

The study was conducted in 1998 and 2007 in Alshikayrat and Fadasi rural areas (Fig. 1). The study site located in Gezira State in the east-central part of the Sudan and lies between latitude 13 to 32° North and longitude 20 to 34° East. The State has a total area of 27.549 km^2 which represents 11% of total area of the country. The state is the second most

Fig. 1: The study area

populated area in the country with estimated population of 3.769.000. Most of the population (80.4%) lives in rural areas and the rests (19.6%) live in urban areas (Gezira State Ministry of Agriculture, 2005). Alshikayrat and Fadasi rural areas were selected based on their proximity from LPG distribution companies in the Gezira State.

Data Collection and Analysis

Primary and secondary data were collected based on the household survey and reviewing of the literature, respectively. The questionnaire and focus group discussion was the main tool for obtaining the primary data. The structured questionnaire was developed; pre-tested and revised to service the objectives of the study. Questions on wood fuel (charcoal and fuel wood) and LPG annual quantities consumed by the household in 1998 and 2007 included in the questionnaire. The wood fuel per capita consumption was obtained by dividing the average annual household consumption by the average family size for the specific year. Then value of wood fuel per capita converted to per capita values in tones. After that per capita in TOE was calculated for both charcoal and fuel wood by multiplying values of per capita in tones by 0.72 and 0.43 for each of the two fuels, respectively. The timeframe (1998 and 2007) preceded the introduction and availability of the LPG in the area. The data were cross-checked by personal observation. The respondents in this study were head of household. The number of household was 121 and 73 selected randomly in Alshikayrat and Fadasi rural areas, respectively. Descriptive analysis was applied using the Statistical Package for Social Sciences SPSS.

RESULTS

Household Wood Fuels Consumption

Table 1 reveals that the average annual charcoal consumption in 1998 was 413.00 kg (11.80 sacks) and 311.50 kg (8.90 sacks) for the household in Alshikayrat and Fadasi area, respectively. The same table explains that the overall average annual charcoal consumption was 374.50 kg (10.70 sacks of charcoal) per household in the study area. The findings displayed in Table 1 show that the average annual fuel wood consumption in 1998 was 157.50 kg (3 *Guntar*) and 95.85 kg (2.13 *Guntar*) in Alshikayrat and Fadasi area, respectively, per household. The overall average fuel wood consumption in the study area was 133.65 kg (2.97 *Guntar*) per household (Table 1). The average annual LPG consumption in 1998 was 10.00 kg (0.80 cylinder) and 73.13 kg (5.85 cylinders) in Alshikayrat and Fadasi area, respectively (Table 1).

The findings displayed in Table 1 in 2007 depict that the average annual charcoal consumption was 84.00 kg (2.40 sacks) and 74.20 kg (2.12 sacks) in Alshikayrat and Fadasi area, respectively, per household. The overall average annual charcoal consumption in the study area was 79.80 kg (2.28 sacks) per household (Table 1). In the same table the average annual fuel wood consumption was 40.50 kg (0.90 *Guntar*) and 36.00 kg (0.80 *Guntar*) per household in Alshikayrat and Fadasi area, respectively, in 2007 (Table 1). The overall average annual fuel wood consumption was 38.70 kg (0.86 *Guntar*) per household in the study area in 2007 (Table 1). In the same table, the household LPG average annual consumption in Alshikayrat and Fadasi area was 162.50 kg (13.00 cylinders) and 190.00 kg (15.20 cylinders), respectively, 2007. The overall average annual LPG consumption per household was 172.63 kg (13.81 cylinders) (Table 1).

Wood Fuels per Capita Energy Consumption

Table 2 indicates that charcoal and fuel wood per capita energy consumption was 0.042 TOE (58.44 kg) and 0.0089 TOE (20.88 kg), respectively, in 1998 as the initial phase of introduction and availability of LPG. The same table shows that charcoal and fuel wood per capita energy consumption was 0.0084 TOE (11.74 kg) and 0.00259 TOE (5.69 kg), respectively, in 2007.

Household Wood Fuels Dependency

To examine whether wood fuels dependency in the study rural area was changed or not, households had been asked about their main source of energy in 1998 and 2007. Table 3 shows that the number of household depended on wood fuels was 112 hh (92.6%) and 41 hh (56.2%) in Alshikayrat and Fadasi rural area, respectively in 1998. The overall average number of household depended on wood fuels in 1998 was 153 hh (78.9%) in the study area (Table 3). In the same table, the number of household used LPG in

Table 1: Annual rural household wood fuel (charcoal and fuel wood) and LPG consumption in 1998 and 2007

		Average					
		Charcoal		Fuel wood		LPG	
Year	Village	Sack	kg/hh	Gnntar	kg/hh	Cylinder	kg/hh
1998	Alshikayrat	11.80	413.0	3.50	157.50	0.80	10.00
	Fadasi	8.90	311.5	2.13	95.85	5.85	73.13
	Total average	10.70	374.5	2.97	133.65	2.69	33.63
2007	Alshikayrat	2.40	84.0	0.90	40.50	13.00	162.50
	Fadasi	2.12	74.2	0.80	36.00	15.20	190.00
	Total average	2.28	79.8	0.86	38.7	13.81	172.63

Field survey in 2007

Table 2: Per capita wood fuels consumption in TOE for 1998 and 2007

	Per capita			
	Charcoal		Fuel wood	
Year	kg	TOE/year	kg	TOE/year
1998	(374.50/6.4) = 58.44	(58.44/1000)*0.72 = 0.042	(133.65/6.4) = 20.88	(20.88/1000)*0.43 = 0.0089
2007	(79.80/6.8) = 11.74	(11.74/1000)*0.72 = 0.0084	(38.70/6.8) = 5.69	(5.69/1000)*0.43 = 0.00259

Tone of charcoal = 0.72 TOE, Tone of wood = 0.43 and Tone of LPG = 1.1 TOE; Field survey in 2007

Table 3: Main fuel sources for cooking in 1998 and 2007

		Main fuel used				
		Fuel wood		LPG		
Year	Village	No. of user	%	No. of user	%	Total (%)
1998	Alshikayrat	112	92.6	9	7.4	100
	Fadasi	41	56.2	32	43.8	100
	Total average	153	78.9	41	21.1	100
2007	Alshikayrat	4	3.3	117	96.7	100
	Fadasi	6	8.2	67	91.8	100
	Total average	10	5.2	184	94.9	100

Field survey in 2007

1998 was 9 hh (7.4%) and 32 hh (43.8%) in Alshikayrat and Fadasi rural area, respectively in 1998. The overall average number of households depended on LPG in 1998 was 41 hh (21.1%) in the study area.

The findings displayed in Table 3 for shows that the number of households used wood fuels was 4 hh (3.3%) and 6 hh (8.2%) in Alshikayrat and Fadasi rural area, respectively in 2007. The overall average number of households used wood fuels was 10 hh (5.2%) in 2007. whereas the number of households depended on LPG as energy source in Alshikayrat and Fadasi rural area was 117 hh (96.7%) and 67 hh (91.8%), respectively in 2007. The overall average number of LPG users was 184 hh (94.9%) in 2007 in the study area.

DISCUSSION

Household Wood Fuels Consumption

The current study shows that the wood fuel (charcoal and fuel wood) consumption among households in Alshikayrat was higher than in Fadasi rural area in 1998 and 2007. This higher consumption is largely due to the availability of forests resources and due to the lack of unconventional energy sources in Alshikayrat rural area. However, some studies, for instance, Maikhuri (1991) concluded that wood fuel consumption was greatly influenced by local climate, season of the year and family size. The LPG consumption in Fadasi was larger than Alshikayrat rural area. This higher consumption of LPG in 1998 1nd 2007 was attributed by inter allia factors to relatively higher average annual income and/or to the availability of the LPG in Fadasi rural area.

The information on wood fuels (charcoal and fuel wood) consumption in 2007, showed a dramatic change in rural household consumption behavior in contrast to the annual average consumption of rural household in the study area in 1998. Contrary to wood fuels consumption trends, the annual average LPG consumption increased in 2007 in the study area. This result shows a change in the rural household behaviors and explains that the rural household accepts the new fuel as the substitute for wood fuels. The dramatic reduction in wood fuels consumption trends in the study area would lead to reduce the clearance of

forests for domestic energy or reduce the demand of the wood fuels energy in the study area. It is important to note that if the current trends of wood fuels consumption in the study area substituting by the LPG, there will be a scarcity of wood fuels demand in the rural areas in the near future. The role of new innovations and idea concerning the introduction and the availability of LPG in rural areas of developing countries is essential to conserve the forests. However, studies - in aggregate 16 Asia countries-concluded that wood fuel consumption is unlikely to deplete or remove forest cover on a large scale (RWEDP, 1997; Kaimowitz and Angelsen, 1998). In fact there are also results demonstrating the opposite (e.g., Arnold *et al*., 2006) which indicate wood fuels harvesting being important in some situation of Africa where deforestation is correlated with wood biomass consumption.

Wood Fuels per Capita Energy Consumption

The study results indicates that there was a dramatic reduction in wood fuels (charcoal and fuel wood) per capita energy consumption in the study area when we compared the data of 1998 and 2007. Charcoal and fuel wood per capita energy consumption decreased from 1998 as the initial phase of the LPG introduction and availability. The dramatic change in Wood fuels per capita energy consumption proved and confirmed that rural households shift to LPG as alternative energy source.

The study results on the charcoal per capita energy consumption during 1998 and 2007 was found to be similar to FAO (1994) in northern Sudan rural areas. The result on charcoal also agreed with the FAO (1995), which reported that Gezira State has the highest charcoal per capita energy consumption values all over the country. The fuel wood per capita energy consumption was far less that which estimated by FAO (1994) in northern Sudan rural areas. However, the study result regarding the fuel wood per capita energy consumption similar to FAO (1995) conclusion which assumed that Gezira State-where the study conducted- had the lowest fuel wood per capita consumption all over the country.

Household Wood Fuels Dependency

Household wood fuels dependency pattern in the study area where the LPG is available was studied and monitored at two time points. In 2007, the households depended on LPG in the study area increased. However, in the same time the number of households depended on woof fuels reduced in the study area. These results show a change in the rural household behaviors and explain that the rural households accept new ideas and innovations at diverse rate and this theory called 'diffusion of innovations (Rogers, 2003).

The diffusion is a special type of communication which holds the messages about a new idea (Rogers, 2003). Study results on diffusion on innovation theory suppose that at the very starting just a few innovators first take up new practice, followed by more early adopters. In the sample group, the households with influence in the society assist to disseminate the innovation along a broader scale. Lastly, the stragglers are typically the last to hold the new ideas; they tend to adopt innovations very slowly (Nautiyal and Kaechele, 2008). The study findings are in line with the innovation theory stated by Rogers (2003). We observed few rural households at the beginning who had started to change their behavior from wood fuels dependency as main energy source to LPG. However, dependency on the wood fuels pattern between rural households seems to be affected by the location of the rural area from the energy source, availability of the energy over time and household socioeconomic conditions.

Estimates indicate that the annual loss of forests in Sudan was 1.4% in the last decade (FAO, 2001) and the wood fuels consumption has high impact on forests as it obtained directly from forests and woodlands. In developing countries, the wood fuels from

forests consider as one of the most important causes of deforestation (Maikhuri, 1991; Bearer *et al*., 2008). The current study results confirmed that the impact of LPG started to become evident as wood fuels (charcoal and fuel wood) decreased in rural areas and at the same time the dependency on LPG is increasing.

CONCLUSIONS

The study concluded that the impact of LPG started to become evident as wood fuels consumption decreased in the study rural areas. We observed that the annual average charcoal consumption decreased from 374.50 kg in 1998 to 79.80 kg in 2007 per household, representing the reduction of 64.50% in the average annual household charcoal consumption. Whilst the average annual fuelwood consumption by the household decreased from 133.65 kg in 1998 to 38.70 kg in 2007, representing a decrease of 71% of annual average household fuelwood consumption. Contrary to the consumption trends of charcoal and fuelwood, there was an increasing in average annual LPG consumption for the rural household from 33.63 kg in 1998 to 172 kg in 2007 in the study area. In addition, charcoal per capita energy consumption reduced from 0.042 TOE in 1998 to 0.0084 TOE in 2007, whereas fuelwood per capita energy consumption decreased from 0.0089 TOE to 0.00259 TOE in 1998 and 2007, respectively. In the same timeframe, wood fuels dependency declined from 78.9% in 1998 to 5.2% in 2007, whilst LPG dependency rose from 21.1% in 1998 to 94.9% in 2007. Therefore, the LPG introduction and availability is advantageous in view of conservation of forests and woodlands and consequently leads the way to reduce the deforestation rate in the rural areas and Sudan.

RECOMMENDATIONS

The adoption of policies that keep the LPG prices low will result in reducing the consumption and dependency on the wood fuels which is the main deriver for deforestation in the country. Moreover, using the subsidies to charge the prices of different fuels may add some success in the short run but for the long run efforts will be directed to increase the taxes for wood fuels relative to LPG in urban areas through promoting the distribution of LPG cylinders and stoves to the rural inhabitants at low prices.

Forests represent an important source for renewable energy particularly biomass. Therefore, wood fuels supply policies (e.g. reforestation, afforestation and sustainable management of forest resources) should be encouraged. More collaboration and coordination between related ministries in applying energy policies is required especially at state level. In this regard, forests and energy policies should be harmonized to avoid contradiction and duplication. Finally, more research is needed to evaluate the positive external impacts on adjacent forests and woodlands that show switching from wood fuels consumption to LPG enhances forests and woodlands regeneration and reduces the deforestation rate.

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