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Adoption of using biogas technology as alternative clean energy in West Kordofan state, Sudan

Abstract

The current research was conducted in West Kordofan during 2013 to 2016. The area suffers from drought and rainfall variability due to deforestation as a demand for fuel wood. The study examined the effect of biogas as alternative clean energy to fuel wood. Fifteen biogas units were installed at household level by clean renewable energy. Data was collected through adoption of Participatory Rural Appraisal (PRA) where questionnaires and meeting of key informants were done beside observations from field visits. Moreover, households headed by women were also interviewed. A total of 46 women who benefited from biogas units compared with 190 women who did not benefit from biogas units were purposively selected and interviewed. Supportive data was collected from relevant institutions, scientific papers and authenticated website. Such aspects for instance improvement of workload due to collection of fuel wood, sanitation, healthy aspects was included in the assessment. Statistical Packages for Social Science (SPSS) version 20 was applied for both descriptive and inferential analyses. The results showed that, the only activity practiced throughout the year was cutting of fuel wood by 100% of respondents. Adoption of biogas technology showed a lot of benefits; minimizing workload for fetching fuel wood; reducing cooking hours from 30 to 10 minutes for tea making and from four hours to less than two hours for meal preparation. Smoke inside the kitchen was also reduced and animals' manure accumulation was gently controlled. Results of Chi square test showed strong association of the tested parameters in correlation to biogas adoption technology. Finally, biogas adoption could contribute to women empowerment through saving of fuel wood and sanitation.

Keywords: biogas technology, livelihood, Kordofan, Sudan

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Introduction

Climate change means any change in climate over a time, weather due to natural variability or a results of human activates[1] it's become a major concern to those whom working in the field of agriculture and development in less developing countries[2] these events such as shifts in temperature and seasons[3] have direct and indirect effects on human food security and environment. Sudan is one of the thess countries vulnerable to climate change because most of the rural poor depend on natural biomass for energy and agriculture for food, its facing real degradation due to combine factors such as drought, desertification, over grazing, extension of cultivation land, firewood and charcoal production etc, as well as depletion of forest resources and have potentially rich country with abundant, diverse and un–exploited renewable energy resources that are yet to be used for improving the livelihood of the vast majority of their population.[4]

Deforestation and depletion of forest resources is a contributor to global warming and is often cited as one of the major causes of the environmental degradation as a result, the presence or absence of trees can change the quality of air in the atmosphere. Dependence on remnant energy sources in many countries is increasingly becoming untenable due to environmental problems and rapid depletion[5] while using of renewable energy is a possible resolution to bridge the gap of climate change effects and reduce deforestation.[6] Rural communities in the vulnerable areas urgently need approaches and methods to propose strategies for building resilience to this phenomenon.[7]

Biogas technology appears as an alternative energy source using in Sudan and offering opportunities to become involved in market development program, is a concept of harmonizing the socio–economic development and mechanism of environmental protection.[8] Cattle manure, human excreta and agriculture residues are used in anaerobic bioreactors in many parts of the world to produce methane gas, which is used for the purpose of cooking, lighting and vegetable plantation as well[9] this technology can significantly help communities solve their economical, environmental, health and energy hardships, leading to a much better quality of life if the technology is utilized correctly by the beneficiaries[10] Rural women represent most vulnerable groups to climate variability this attribute to poorer, less educated, lower health status and have limited direct access to ownership of natural resources[11] and climate variability affects their sources of livelihoods[12] therefore enhancing women resilience to climate change effects is suggested as a climate change adaptation strategy.

The main objective of this research is to investigate the adoption of using biogas technology as alternative clean energy in the area of the study, specifically; to state the constrain of using fuel wood and to identify the benefit of using biogas technology.

Materials and methods

Area of the study

West Kordofan State is located in the western part of Sudan, and falls in transition belt between war–effected in the south and the drought affected in the north areas[13] located within latitudes 12° 0′ N, and longitudes 28° 9′ E. The state borders are; North Kordofan, South Kordofan, East Darfur, North Darfur and South Darfur (Figure 1). The total area covered is estimated to be 111,373km^2, extending from low rainfall savanna to high rainfall and hill catena and its vegetation varies greatly.[14]

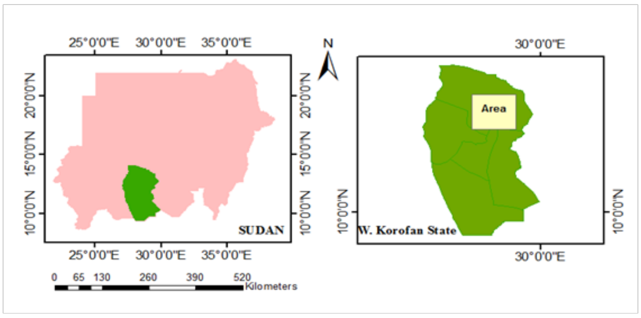

Figure 1 Location of the study area in Sudan (Source; the author 2018).

The region has a varying climate, ranging from desert and semi–desert in the north, to rich savanna in the south. Arid and semi–arid zones cover the largest part of this region.[15] The average rainfall in the state is 651 mm in normal year and ranges from 150mm in the north to the 700mm in the south.[13] The soil ranges from sandy in the north to heavy cracking clay in the south. In between, there are the so–called "gardud" soils.[15] The area is naturally dominated with main grasses include namely Huskneet (*Cenchrus biflorus*), Shuleny (*Zornia glochidiata*) and Bigual (*Blepharislinarifolia*), the trees such as Humied (*Sclerocarya birrea*), Higlig (Balanites), Arad (*Acacia etbaica*) and Sider (*Zizuphus spina*). While shrubs include Kursan (*Boscia senegalensis*), Usher (Calotropis), Mereikh (*Polygala eriotera*) and Aborakhus (*Andropogon gayanus*) according to MAWF, 2009[16] and Tabaldi (*Adansonia digitata*) and Leyun (*Lannea fruticosa*).

The economy of West Kordofan State is predominantly dependent on agricultural production consisting of rain–fed farming of millet, sorghum, groundnut and water melon and traditional livestock raising practiced by nomadic and semi–nomadic agro pastoral and sedentary groups and some activities of horticulture.[17]

Sampling protocol and data collection

Installations of the 15 biogas units were done for two villages: seven in *Khammas Hagar* and eight in *Khammas Eldonki*. A number of 46 households directly benefited from biogas for both cooking and lighting, more women within the neighborhood benefited from this technology as shown in table 1, and 90 households as non beneficiaries making out a total of 236 households were included in the study using purposed sample; this corresponded to 50% of women living in the two villages.

Table 1 Number of households, population and sample size, male and female head–household in the area of study (source; local authority, 2015)

Villages	Households	Male–headed households	Female–headed households	Total population	50% sample size	Benefited households
Khammas Eldonki	882	653	229	6171	115	17
Khammas Hager	580	429	151	4060	75	29
Total	1462(100%)	1082(74%)	380(26%)	10231	190	46

Data collection

Qualitative and quantitative data were collected through primary data tools which include; firstly, Participatory Rural Appraisal (PRA) for family households at the two villages, particularly used historical mapping and seasonal and crops calendar. Secondly standardized household questionnaire was designed beside the PRA in order to assess the improvement on Household (HH) environmental and socio–economic aspects, and make clear distinguish between the categories under study. The third tool is direct observation was carried out as cross–checking tool to find out whether all responses reflected the reality.

Secondary data was obtained from relevant published papers, relevant books and references, and authenticated web sites.

Data analysis

Based on the nature of the data; quantitative and qualitative analysis was applied. The quantitative data were coded and fed to computer and Statistical Package for Social Sciences (SPSS) version 20 was applied to achieving both descriptive and inferential statistics. Chi–squire Test was used to investigate the hypotheses.

Results and discussion

History aspects of the area of study

From the Figure 2 below, indicated that year of drought, loss of animals and migration was during 1992, then there was an increase in population in 1995, pests and diseases attacks followed (1998). There was a failure in crops, people have to sell their animals and migrated (2001), and this was followed by failure in expansion of agriculture (2004). Sell assets and migration (2006). Establishment of primary schools (2007) and Non Governmental Organizations (NGOs) interventions were very clear (2009). Birds attacks destroyed agriculture (2011) then biogas technology was introduced (2013). Focus on alternative source of income and then kitchen repair improvement of women garden (2016).

Socioeconomic characteristics

Demographic results showed that most of the rural people did not receive any kind of education, most families were of medium size (5–8 members), and most were married and most underwent agricultural practices. Many families are headed by women. Similar situation is found in Sub–Saharan Africa where 25–30% of rural households are headed by women,[18] also majority of the respondents were married and depended on farming as a major income source (Table 2).

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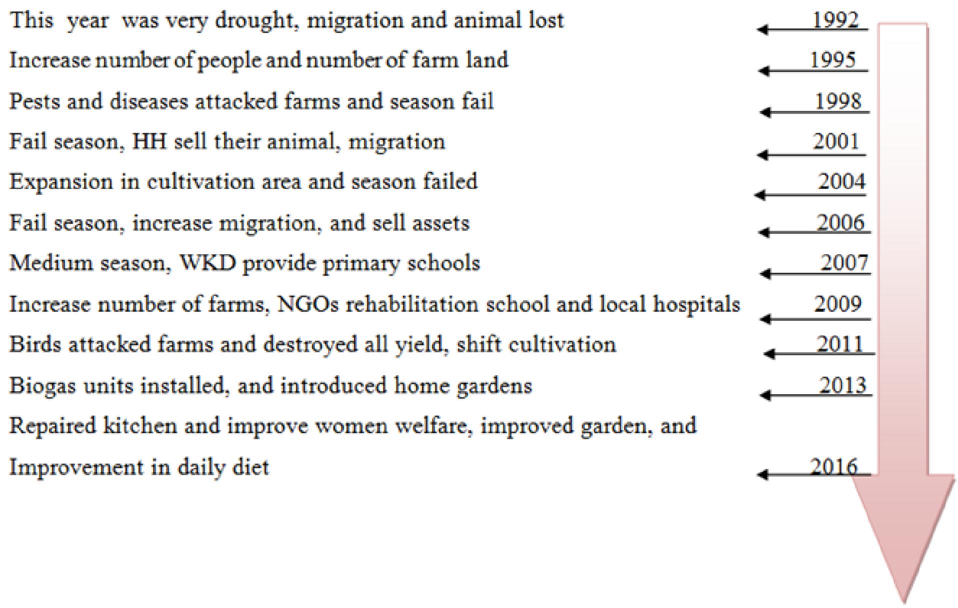

Figure 2 Time line of basic event for last 26 year in the study area.

Table 2 Distribution of the respondent's according to socioeconomic characteristics

Characteristics		Beneficiaries (%)	Non beneficiaries (%)
Age gradation	≤30 years	4.3	8.9
	31– 50 years	45.7	61.6
	≥51years	50	29.5
Education	Informal education	43.4	47.4
	Primary education (1–7)	37	35.8
	Intermediate / higher education (≥8)	19.6	16.8
Family size	≤4 members	24	31.6
	5–8 members	43.4	50.5
	≥9 members	32.6	17.9
Social status	Married	74	76.2
	Divorce	4.3	11.4
	Widow	8.7	6.7
	Not married	13	4.1
Source of income	Farming	87	82.6
	Non farming	13	17.4

Indicating by SPSS; descriptive statistic, Source; field research 2016

Agricultural activities

Cereal crops, cash crops, vegetables and water melon were grown in the study area as a major source of livelihood. Similarly it was shown that for many smallholders in rural communities, the sale of products provides the only outlet to the cash economy. Even in times of food abundance, vegetables sales enable households to diversify their diets.[19] For both cereal and cash crops, sowing were done in June, weed clearing in August while harvest was done in October. For vegetables, sowing was done in April, transplanting in May and harvest in August. For water melon, sowing was done in August, cleaning in October and harvest in February. Crop diversification can improve resilience in a variety of ways: by engendering a greater ability to suppress pest outbreaks and dampen pathogen transmission, which may worsen under future climate scenarios, as well as by buffering crop production from the effects of greater climate variability and extreme events (Figure 3).[20] In Figure 4 it could be shown that cattle grazing were practiced from May to December. Land preparation from February to April, vegetable growing was in November and December. House repairing was done from January to May. Plantation from May to July, weeding from August to October, and harvest from November to January, while fuel wood collection was carried out throughout the year.

Biogas technology adoption and socio–economic aspects

The results revealed that time spent for meal preparation varied from 2–5 hours while Chi–square test showed that there was strong association between biogas and period of meal preparation. (Table 3), also more than half of the respondents purchased and gather fuel wood while the rest purchased charcoal, the money spent on purchasing reflected the respondent's affordability as half would spend 30 SDG per week for fuel wood and less than 50 SDG per week for charcoal. Purchasing both firewood and charcoal was less among the beneficiaries as an alternative energy source was then available. However, most respondents used fuel wood for food, tea and coffee preparation. It should be noted that the respondents' feedback was a reflection for the past 5 years and therefore such results could not be justified. Such activity was done throughout the year resulting in forest deforestation and environmental deterioration (Table 4).

Energy sources for cooking were fuel wood or charcoal or both. Areas of Fuel wood collection was mainly from nearby forests, the distances travelled was 5 km for most of the respondents but can go up to 16 km which could due to other areas as agricultural, scrub or wetlands (Figure 5) (Figure 6).

In the current study, distance travelled ranged from 5 to 16 hours which reflected the severity of land degradation and deforestation. Chi–square showed strong corrections of all these parameters and use of fuel wood (Table 5).

The results attained in Table 6 indicated the average time of biogas cooking hours was ≥5 hours/day. 100% of respondents said the gas produced is enough for preparing meals, tea and coffee, moreover respondents used biogas lighting for food, social benefits in strengthen relation, academic benefit, local clubs, meeting place, health issue and local celebration. 100% of the respondents thought that the biogas technology decreased the constraints of collection firewood and overcome the constraints inside the kitchen. Some of the prevalent health problems caused by the smoke inherent to traditional ways of cooking and heating, particularly open fires include: sneezing, nausea, headache, dizziness, eye irritation and respiratory illnesses.[21] Biogas improves health of the rural people by providing a cleaner cooking fuel thus avoiding these health problems. Women and children have the greatest risk of these health problems and children under 5 years are at high risk of contracting acute respiratory illnesses such as, pneumonia. In this study a strong correlation was obtained between respiratory diseases and adoption of the biogas technology.

The Chi–square tests shown strong correlations between the uses of biogas technology with strengthen of community relations (Table 7). Money savings per month from using the biogas technology ranged between 199 to 400SDG (Table 8). The percentage was the highest for the range 299–300SDG (Figure7). The correlation was shown to be significant between household consumption and use of biogas which would reflect the benefits of biogas technology adoption (Table 8). Furthermore, a strong association was obtained between biogas technology adoption and use of fuel wood regarding pollution occurring inside the kitchen. Similarly, income savings made in terms of time and money to search for fuel and purchase other traditional fuels (wood, charcoal and kerosene) respectively; and income generation from the sale of biogas to the neighboring towns was observed in Ethiopia from installation of 14,000 biogas digesters.[22]

Perception of biogas performance was rated as very good among nearly half of the beneficiaries and non–beneficiaries, both groups were motivated for the adoption of the technology and most acknowledged the benefits of biogas uses (Table 9). However, association of the different rates with biogas performance was not significant. In line with this, it was shown that there are some cases of successful biogas intervention in Africa, which demonstrate the effectiveness of the technology and its relevance for the region. The lessons learned from biogas experiences in Africa suggest that having a realistic and modest initial introductory phase for biogas intervention; taking into account the convenience factors in terms of plant operation and functionality; identifying the optimum plant size and subsidy level; and; having provision for design adaptation are key factors for successful biogas implementation in Africa.[23]

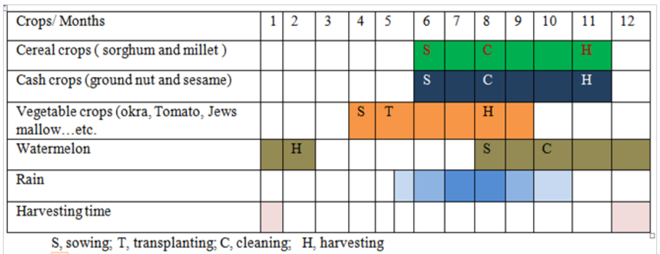

Figure 3 Crops type and Rain Calendar of the respondents.

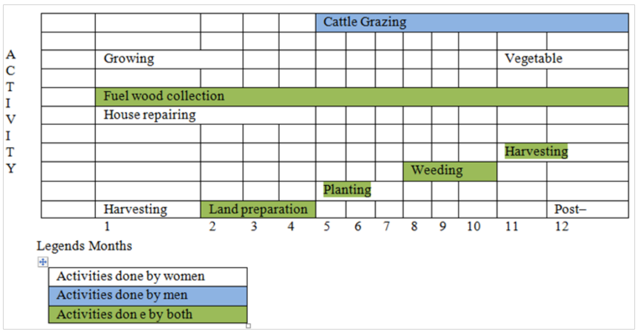

Figure 4 Seasonal calendar for the different activities in study area

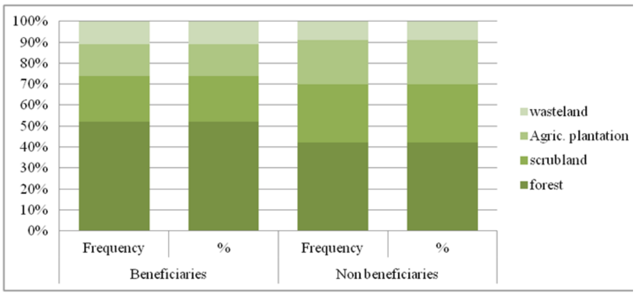

Figure 5 Places of collection firewood within the area of the study

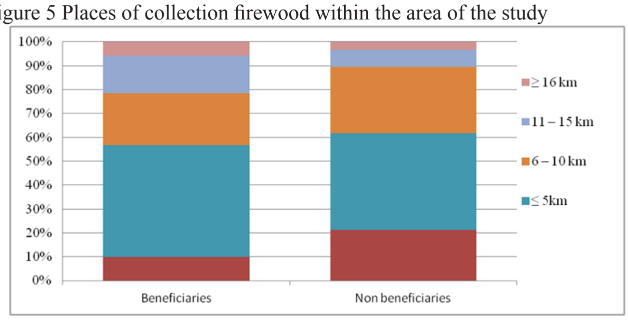

Figure 6 Distance where the respondents walked to access fuel wood.

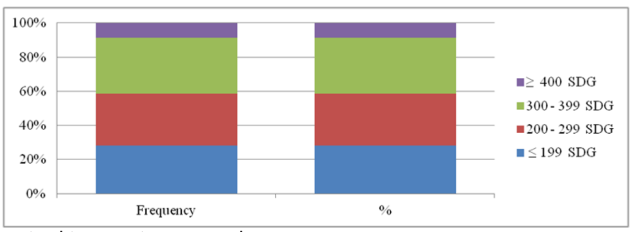

Figure7 Amount of money saving due to using biogas unit per month.

Table 3 Chi–square test for association between use of biogas and period of preparing diet per day

Length of unit performance	Period of preparing diet				Total	Sig.
	≤2 hours	3 hours	4 hours	≥5 hours		
Hours	2	0	0	1	3	0.021
Two hours	6	9	7	0	22	
Three hours	2	6	7	0	15	
Four hours	1	0	3	0	4	
Five hours and More than five hours	0	1	1	0	2	
Total	11	16	18	1	46	

P≤0.05, significant, indicating by Chi–square Test: source; field survey (2016)

Table 4 Distribution of the respondents according to the cost of fuel wood

		Beneficiaries (%)	Non beneficiaries (%)
Price in recent years	Increased	100	71.6
	Not increased	–	28.4
HH Firewood cost per week	≤30 SD	17.4	67.4
	31–50 SD	41.3	25.3
	51–70 SD	37	5.3
	≥71 SD	4.3	2.1
HH Charcoal cost per week	≤49 SD	45.7	56.8
	50–79 SD	37	32.6
	80–109 SD	10.9	8.9
	≥110 SD	6.5	1.6

Indicating by SPSS; descriptive statistic, Source; field survey 2016

Table 5 Chi–square test for association between the distances of fuel wood collected last 5 year and HH using fuel wood through months

Distance	HH using fuel wood through months				Total	Sig.
	one week	two week	three week	whole month		
1–5 km	18	5	1	0	24	0.007
6–10 km	6	5	0	0	11	
11–15 km	3	1	3	1	8	
≥6 km	2	0	0	1	3	
Total	29	11	4	2	46	

P≤0.05 = significant, indicating by Chi–square Test: source; field survey (2016)

Table 6 Benefits and constraints of biogas technology

		Beneficiaries (%)
Time of work	≤2 hour/day	41.3
	3–4 hours/day	15.2
	≥5 hours/day	43.5
Methane gas purpose	preparing food, tea and coffee	100
Electricity purpose	gave light to prepare food	21.7
	lighting home for students	13
	lighting for crop harvesting	12.2
	lighting for multipurpose	50

Table Continued

		Beneficiaries (%)
Social purpose	strength relation between neighbors and celebration	21.7
	academic benefit	8.7
	local Clubs and committee meeting place	13
	Health issue	2.2
	strength relation, academic benefit, local Clubs, meeting place, health issue and local celebration	54.3
Constraints (collection/ inside kitchen)	Decreased and overcome	100

Indicating by SPSS; descriptive statistic, frequency, Source; field survey 2016

Table 7 Chi–square test for association between social benefit and using biogas technology

Social profit	Benefit of biogas technology		Total	Sig.
	Yes	No		
Strength relation between Neighbors	5	5	10	0.002
Academic benefits for students Both secondary and primary	4	0	4	
Local Club	5	0	5	
Meeting places	1	0	1	
Health issues	0	1	1	
Strength relation, students benefits, Local Club, meeting place and Health issues	24	1	25	
Total	39	7	46	

P≤0.05, significant; indicating by Chi–square Test: source; field survey (2016)

Table 8 Chi–square test for association between HH consumption and money saving per month from using biogas units

Mmoney saving from using Biogas units						
HH consumption	≤199 SDG	200–299 SDG	300–399 SDG	≥400 SDG	Total	Sig.
Disbursed	8	13	14	2	37	0.041
Not disbursed	5	1	1	2	9	
Total	13	14	15	4	46	

P≤0.05, significant, indicating by Chi–square Test: source; field survey (2016)

Table 9 Perception of the respondents towards biogas technology

		Beneficiaries (%)	Non beneficiaries (%)
Performance	Very good performance	60.9	41.6
	Good and need to improvement	30.4	37.4
	Inadequate for rural community	8.7	21.1
Interesting	People came to gain information	54.3	34.7
	Their information were highly spread among community	15.2	32.6
	Majority of respondents enthusiastic to adoption	30.4	33.2
Benefits	Benefited trail	84.8	70
	Not benefited trail	15.2	30

Z8\321ndicating by SPSS; descriptive statistic, Source; field survey 2016

Constraints of using fuel wood and biogas units

Constraints confronted from using fuel wood were due distance travelled, heavy load, cost of purchasing and transportation as well as smoke inside the kitchen causing various diseases. Wood fuel gathering is a hard and time consuming duty for women. For instance, it is estimated that women can spend 2–6 hours per day in collecting wood fuel[24] depending on the country and region. For instance, one study in Limpopo, South Africa found that the rural women spend 5–6 hours,[25] while another study in a different region of South Africa report that the women spend over two hours. This takes away time that could be better utilized in other productive activities such as income generation or education particularly for girls who have to be absent from school to undertake such task. Biogas plants thus can help in reducing the workload of women and girls in collecting firewood. Burning traditional fuel releases smoke which contains toxic pollutants such as carbon monoxide, hydrocarbons and particulate matter.[26]

As far the health conditions from the use of firewood were concerned, it was shown that the respondents suffered from smoke and ash inside the kitchen thought that it caused conflagration, and respiratory infection, (Figure 8).

The Chi–square test for association between different constraints in the past 5 year revealed that there was a significant relation ($p\leq 0.05$) in the cost of type of energy used and transportation costs (Table 10).

Adoption of biogas technology was faced by some constraints. These were due to weak training (2.2%), dissertation of the units during the harvest season and carelessness (Figure 9). A significant association was obtained between using of firewood and adoption of biogas technology. Similarly it was pointed out that the effort of maintenance and control on biogas plants often does not meet the level of literacy skills of rural population[27] and[28] (Table 11). In the anther beneficiaries have consumed there methane gas successfully with less prices paid (Figure 10).

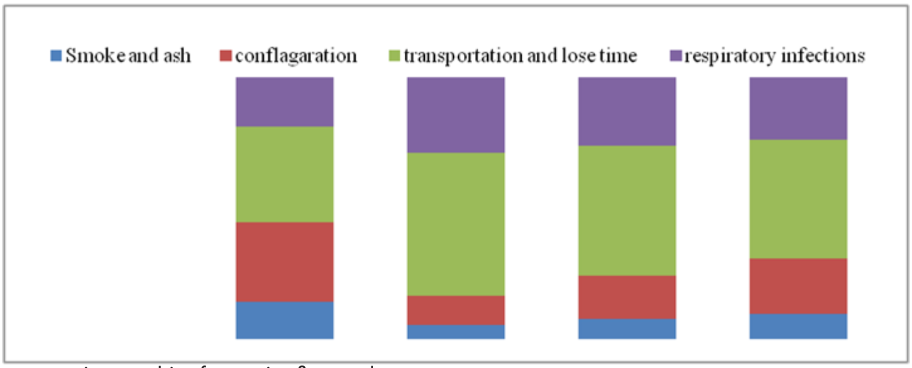

Figure 8 Type of problems or constraints resulting from using firewood.

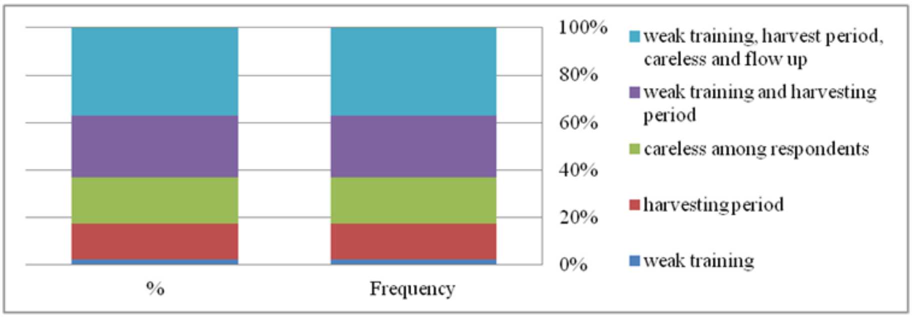

Figure 9 Constraints of using biogas unite in the area.

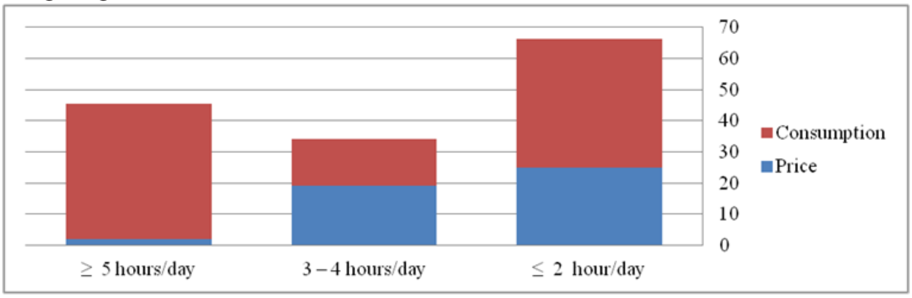

Figure10 Consumption and price of the biogas that beneficiaries utilized.

Table 10 Chi–square test for association between different constraints in the past 5 year

Types of constraints	Using firewood for cooking in last 5 years			Total	Sig.
	Firewood	Charcoal	Firewood and Charcoal		
Long distance and Burden from gathering fuel wood	5	0	3	8	
Carrying heavy loads	4	0	3	7	
Price paid and transportation fees	2	3	4	9	0.05
Time spent	0	0	1	1	
Long distance, Burden, heavy loads, price paid and time spent	10	0	11	21	
Total	21	3	22	46	

P≤0.05, significant, indicating by Chi–square Test: source; field survey (2016)

Table 11 Chi–square test for association between constraints resulting from using fuel wood and adoption of biogas technology

Types of constraints	The perception of the respondents about biogas technology			Total	Sig.
	Very good performance	Good and need improvement	Inadequate for rural community		
smoke and ash	14	9	0	23	0.041
Conflagration	2	0	0	2	
respiratory infections	0	2	0	2	
smoke and ash, and respiratory infections	12	3	4	19	
Total	28	14	4	46	

P≤0.05, significant, indicating by Chi–square Test: source; field survey (2016)

Conclusion and recommendations

Deforestation remains the only activity carried out throughout the year making rural poor suffering from distance travelled, carrying heavy loads, still others suffer from the high cost of either fuel–wood or charcoal. The biogas technology was shown to reduce time of cooking, provided smoke free environment inside the kitchen as well reduced accumulation of dung outside the kitchen. Smoke arising from burning fuel–wood posed hazards on human health, women and children were the most affected.

Adoption of biogas technology resulted in various benefits: reduction of workload, money saving, health and environmental improvements, community strengthen that rose from the use of light in clubs, celebration events and education. Perception of the respondents towards biogas technology as an energy alternative showed wide variation and reflected the little knowledge although interest to learn about it was very high. Application of biogas effluents in women garden as fertilizer improved vegetables yield and improved family income. However, some constraints still face this adoption which could be due to weak training, harvest season where the family leave the unit without attendance and due to just carelessness, however, all little percentages of the beneficiaries expressed such opinions. Biogas production using the existing domestic resources therefore, has a potential to provide a number of benefits to the rural communities. Many of these benefits are directly linked to the Millennium Development Goals of reducing income poverty, promoting gender equity, promoting health and environmental sustainability. Finally study comes out to some recommendation such as; Most renewable energy technologies require long development periods and dedicated stakeholders are important for building up experiences and competencies, also it is important to establish contacts between research and university groups and experienced contractors to provide reliable and pertinent information about the biogas technology and its potential to local authorities, politicians, and the public in general.

Enhancing women resilience to changing environmental conditions is often recommended as a climate change adaptation strategy. To effectively achieve this, it is necessary first to understand the factors that determine women resilience, and their relative importance in shaping the ability of women to adjust the complexities of environmental change. Moreover, agricultural income–generating activities in Sudan such as farming, and fruit and vegetable home–processing enterprises should be encouraged.

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Conflict of interest

The author declares that there in none of the conflict.

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