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The Determinants of Biogas Technology Adoption and its Implication on Environmental Sustainablity: The Case of Aletawondo Woreda, Sidama Zone, South Ethiopia

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Abstract
The study aims to assessing the role of biogas technology in saving biomass, mitigating green-house gases (GHG) emissions, and maintaining environmental sustainability in Aletawondo woreda. The sample size, 196 households were selected and interviewed in systematic random sampling techniques. Data was analyzed using descriptive statistics and binary logit with the aid of STATA. Adoption of biogas technology significantly determined by proximity to water, access to credit, cattle size, availability of trained mason, land size and annual income. On average 1066.80kg biomass and 25.2 liter kerosene reduced; 2160.93kg CO_2equivalent GHG emissions to the atmosphere mitigated annually per adopter households in the study area.
Keywords: Biogas, Biomass, Health, GHG, Environment

I.INTRODUCTION

Biomass energy in the form of firewood, charcoal and crop residues plays a vital role in the basic welfare and economic activities in many Sub Saharan Africa (SSA) households, where they meet more than 90% of household energy needs (EIA, 2010; KIPPRA 2010). In developing countries, over 500 million households still use traditional biomass for cooking and heating (UNEP, 2009).

In Ethiopia, biomass accounts for 92% of the total national energy consumption in 2010. Petroleum fuels and electricity met merely 7.6% and 1.1% of the national energy consumption, respectively. The household sector accounts for 89% of total final energy consumption (74% by rural and 15% by urban households).

Biogas technology is an integrated waste management system that is a clean, renewable, naturally produced and under-utilized source of energy. It is reviewed as a promising sustainable solution for farm households because it can help to solve major environmental problems such as soil degradation, deforestation, desertification, CO_2 emission, indoor air pollution, and reduce GHG emission by replacing firewood and agricultural residue fuels, Karthik Rajendran; 2012. Socioeconomic factors such as household income, fuel wood and kerosene cost, land ownership, livestock practice, and land size have a significant effect on the adoption of biogas technologies (Walekhwa et al, 2009**)**.

Substitution of traditional fuels by biogas is expected to result in generally positive impacts on household health due to reduced exposure to smoke and improved management of waste, Mekonnen Lulie, 2009). Given the inter-related challenges of environmental deterioration and energy demand, climate change, indoor air pollution and human health, accelerated and large-scale dissemination of biogas technology is therefore now necessary more than ever before. The key energy challenges facing the study area and the region is how to affordably produce high quality cooking gas and also how to widely disseminate biogas energy technologies.

1.1 Statement of the Problem

Replacing firewood with biogas would have a positive effect on deforestation, which would improve the local environments, ecosystems, problems with erosion and mitigate GHG, Bajgain, Shakya, 2005. Some researchers such as Muriuki; 2014, Zerihun; 2014, Bekele; 2011 and Anushiya; 2010 have analyzed the role of biogas energy for environmental protection, climate change mitigation and poverty alleviation, especially in rural areas where agriculture is the main source of income.

Biogas as an alternative to the use of biomass for energy was introduced in Ethiopia since 1979. Households directly benefit from domestic biogas; reduced use of fuel wood, improved living conditions and improved soil fertility through the use of bio-slurry. According to report by National Biogas Programme Ethiopia, 2013; the dissemination of biogas technology to rural household was 8608 domstic biogas at national level and only 250 in the study area. Eventhough these efforts, it is not clear why some households in the study area adopt the technology while many others do not adopt. It is also not examined how biomass energy use affects the quality of environment in general, indoor air pollution in particular and how biogas technology as alterative use of energy and contributes for environmental sustainability.

Therefore, the purpose of this study was to identify the factors that influence adoption of biogas technology in typical households, the role of biogas use on mitigating green house gass emissions, and assess the effect of biogas energy on environmental sustainability in the study area.

1.2 Research Objectives

The general objective of this study is investigating the determining factors that influence the adoption of biogas technology and its implication on environmental sustainability by households in the study area.

The specific objectives are:

To estimate biomass saved and forest conserved by use of biogas energy by farm households.

To analyze the role of biogas for greenhouse gas emission reduction in the study area.

To investigate the determinants for biogas technology adoption by farm households.

II. METHODOLOGY OF THE STUDY

2.1. Description of the Study Area

The study was carried out in Aleta – wondo woreda which is located in the South Eastern part of South Nation Nationality and People's Regional state at 64km and 337 km from regional capital city, Hawassa and Ethiopia capital city, Addis Ababa respectively.

Aleta-wondo wereda has a total area of 27,823 hectare which is divided in to 28 administrative kebeles. The total population of the Wereda is 188,932 of which male 96624 and female 92208. The average household size is 5.6 persons including heads of household which is larger than the corresponding figures in official statistics for rural HHs in the country (4.9 persons) and SNNPR (4.9 persons). Hence, the total number of households is 33,738 of which 2,815 (8.3%) are female headed and the occupational status 96% of the population lives by farming (CSA, 2007). The altitude of the Wereda ranges between 1,750 to 2,600m and its temperature lies between 10°c to 23°c and the average annual rain fall is 1,400 mm. The Woreda covered with forest is estimated to be 1, 170.85 hectare (4.2%). The Wereda's total cattle population is 99,082, and there are 9,409 goats, 18,361 sheep and 69,761 local and 1,576 improved breed poultry and there are also 14,789 bee hives (A/Wondo Woreda Baseline Survey Report, 2011). Regarding the energy supply, the Wereda's population mainly depends on biomass source of energy utilization. The main type of biomass fuel in the Wereda is fuel wood followed by crop residue and charcoal (Woreda Energy Baseline Survey Report, 2011). There is biogas program in 13 kebeles from the total of 28 kebeles. Around 250 domestic biogas technologies were introduced and disseminated to farm households since 2010, WWMEO annual report, (2014).

2.2. Sample Size and Sampling Procedures

The sample size was determined by using Arkin and Colton's formula (1963) at 95% level of confidence and 5% level of significance and level of precision is 7% (0.07) which is given by:- **$n= N z^2 P (1-P)/ ((N) d^2 +Z^2) P (1-P)$**: Where, n= Sample size, Z= the value of standard variant (at 95% of confidence level), Z= 1.96, P= estimated population proportion (0.5), d= standard error or level of precision (0.07). The 196 sample households were selected through multi stage sampling techniques, which is commonly used probability sampling technique in a situation where the ultimate unit of selection requires certain series of stages in this study. Five kebeles from 13 biogas program implementing kebeles of Aletawondo were selected, which had enabled the researcher to collect the data related to biogas users and non-users experiences.

2.3. Method of Data Collection

Primary data was collected through observation, structured personal interviews with household heads and key informants, and focus group discussions. Households survey interview questionnaire consisted of both open and closed ended questions, which were employed to collect primary data their existing situation of biogas technology adoption and utilization as well as biomass consumption. The primary data collection included socio-economic and demographic characteristics of households (age, gender and education of household head, household size, proximity to water, access to credit, proximity to cement, sand and stone market), and detailed biomass use; fire wood and crop residue consumption patterns and biogas technology benefits**.** Prior to data collection, four data collectors were recruited and hired who have minimum of Bachelor Degree and are able to understand English and speak local language.

2.4. Data Presentation and Analysis

Descriptive such as frequencies, mean, standard deviations and cross tabulations were used to display the data before detailed analysis with the use of SPSS. Tests of significance, specifically t-tests and chi-square (X^2) were used. The p-values were instrumental in informing the results of this study and the significance difference was set at $p<0.05$. SPSS, STATA and Excel computer software were used to analyze objectives one and two. These were made and guided through some accepted conversion factor for the execution of the data analysis in this research.

The most commonly used econometric models in adoption studies are the limited dependent variable models such as logit and probit (Bekele and Drake, 2003) and both are well established approaches in studies on technology adoption (Burton et al., 1999). The choice of whether to use a probit or logit model, both widely used in economics, is a matter of computational convenience (Greene, 1997). Logistic regression has been used when the dependent variable is a dichotomy and the independent variables are of any type and it applies maximum likelihood estimation after transforming the dependent into a logit variable, Garson, 2008. The conventional model, LPM, though having citable advantages, has meaningful limitations, such as generation of predicted values outside the 0-1 intervals (which violets the basic principles of probability), the heteroscedastic nature of the variance of the disturbance term, and the non-reasonability of assumption of normality in the disturbance term (Greene, 1991). With such drawbacks of LPM, a non-linear probability models (logit and probit), are suggested to satisfy the limitations of the former (Amemiya, 1981 and Maddala, 1983). However, the choice of logit model over the probit is that the former is easy and extremely flexible to manipulate, leads to meaningful interpretation (Hosmer and Lemeshow, 1989), and simpler in estimation than the probit model (Pindyck and Rubinfeld, 1981). That is to say, the conditional probability p approaches zero or one at a slower rate in logit than in probit. As a result, a binary logistic regression model was used to analyze farm households' biogas technology adoption in the study area. Thus, to achieve specific objective three in this study, logistic model were used to investigate the factors which influences biogas adoption and utilization. The variables often considered in biogas energy adoption decision include age, educational status, income level, household size, gender of the household head, size of land owned by the household and the cost of alternative fuels (Somda et al., 2002). Following Gujarati (2003), the logistic distribution function for the biogas adoption decision by household can be specified as: $P_i = \frac{1}{1+e^{-z(i)}} = \frac{1}{1+e^{-z(i)}}$, where $Z_i = \beta_o + \sum \beta i X_i + e_i$.

2.4.1 Definition of Variables and Expected Hypotheses

Biogas Adopter Households (HHADOPT): household decision for biogas adoption is dependent variable in binary logit model and it is a dichotomous nature that takes a value of 1 if the household adopter; and 0, otherwise. It is to identify the potential explanatory variables and to formulate hypotheses regarding their possible effects on the dependent variable.

Table 3.1: Explanatory variables and expected hypothesis

Variable	Description	Variable type	Value	Expected sign
HHAGE	Age of household	Discrete	Measured in years	(+/-)
HHGENDER	Gender of household	Dummy	1 = male, 0 = female	(+/-)
FAMSIZE	Family size of household	Discrete	Measured in # of HH	(+)
HHEDUCA	Education of household	Discrete	Measured in year	(+)
LANDSIZE	Land size of household	Continuous	Measured in hectare	(+)
CATLSIZE	Cattle size of household	Continuous	Measured in number	(+)
HHINCOME	Monthly income of household	Continuous	Measured in ETB	(+)
CREDACES	Access to credit	Dummy	1= accessible, 0 = not	(+)
WATACCES	Proximity to water	Continuous	Measured in kilometer	(-)
MASNAVAI	Availability of trained mason	Dummy	1 = available, 0 = not	(+)
SANACCES	Proximity to sand market	Continuous	Measured in kilometer	(-)
STONACES	Proximity to stone market	Continuous	Measured in kilometer	(-)
CEMACCES	Proximity to cement market	Continuous	Measured in kilometer	(-)

Source: Own survey data, 2016

2.4.2 Model Specification Tests

Goodness – of – Fit Test: The goodness-of-fit of the logit model was measured by the McFadden (2002) with likelihood ratio statistics as the basis of inference with a chosen significance at 10%, 5% and 1% probability level. The adequacy of binary logistic model was examined by goodness-of- fit test for the purpose of whether the fitted model adequately describes the observed outcome of biogas adoption in the data through Hosmer–Lemeshow goodness-of-fit test.

Multicollinearity Tests: Pair wise correlations were computed from survey data to check the existence of high degree of association problem among dummy independent variables. A value of 0.75 or more indicates stronger relationship b/n dummy independent variables (Maddala, 1992). The decision rule for pair wise correlation coefficients says that when its value approaches 1, there is a problem of association between independent dummy variables.

Variance Inflation Factor (VIF) was also checked for continuous variables using STATA 12.0. According to Maddala (1992), VIF can be defined as: VIF (xi) $= \frac{1}{1-R^2} \frac{1}{1-R^2}$, the larger the value of VIF, the more will be the collinear of variable x_i. The rule of thumb is that if VIF for each variable in the model (VIF) is ³ 10, there is a problem with multicollinearity, and therefore adjustment methods need to be applied.

III. RESULTS AND DISCUSSIONS

Model Specification and Test Results; goodness-of-fit tests, none of them show a significant difference – the regression model was adequate. The results of goodness-of-fit test shows that the model was significantly adequate to fit the observed data at $X^2 = 4.81$, p = 0.7777. The model with more variables fits significantly better and the result for nested model-1 in model-2 were found significantly adequate at $X^2 = 34.42$, p = 0.0000. The VIF values were less than 10 and it shows that all the continuous independent variables have no multicollinearity problem. In pair-wise correlation test there is no a problem of high degree of association among independent dummy variables.

3.1. Factors Influencing Biogas Technology Adoption in the study area

In informing and interpreting, econometric model result, marginal effect was instrumental and employed for this study. Cattle size, access for credit, land size, availability of trained mason, annual income, proximity to water point, proximity to sand and stone market and gender of household head were found factors influencing biogas technology adoption decision in the study area.

The study result shows that households' home distance to water point was statistically significant and negatively affects biogas adoption at 1% significance level. Cattle size, access for credit and availability of trained mason variables were statistically significant and positively influences adoption decision at 5% significance level. Besides, land size and annual income were statistically significant and positively affects adoption decision at 10% significance level. And household's home distance to sand & stone market and gender of household head were significantly affects to adopt biogas technology at 10% significance level in the study area.

Table 3.2: Logistic regression estimates factors affecting households' biogas adoption decision

Variables	B	S.E.	M.E
CATLSIZE	0.954	(0.392)**	0.1492938
CEMACCES	0.011	0.177	0.0017677
CREDACES	3.353	(1.329)**	0.3754223
FAMSIZE	0.327	0.670	0.0511745
HHAGE	-0.153	0.110	-0.0240017
HHEDUCA	0.054	0.197	0.0084202
HHGENDER	-1.221	(0.707)*	-0.2309339
HHINCOME	0.0003	(0.0002)*	0.0000503
LANDSIZE	2.170	(1.254)*	0.3395644
MASNAVAI	5.916	(2.293)**	0.6406308
SANACCES	-0.073	(0.043)*	-0.0114235
STONACES	-0.335	(0.197)*	-0.0523826
WATACCES	-4.005	(0.892)***	-0.6266359
_CONS	-3.408	3.875	

Number of observations = 196	Wald Chi^2 (13) = 56.18
Log likelihood function = -26.186761	Prob. > chi^2 = 0.0000
M.E: Marginal Effect	Pseudo R^2 = 0.8072
***, ** and * indicates Significance levels at 1%, 5% and 10% respectively.	

Source: Own Survey data, 2016

3.2. Biogas Technology Implications in the Study Area

3.2.1. Benefits of Biogas for Replacing Fuel wood, Crop residue and Kerosene

In Aleta-wondo woreda, non-adopter households consumes on average 2058kg biomass (fire wood and crop residue) annually but for adopter households is 991.20kg per household. There was a considerable saving adopter over non-adopter households by 1066.80kg (51.8%) of biomass (fire wood and crop residue) per year per household. Concerning kerosene, per non-adopter households consumed on average 25.68 liter of kerosene annually and the average annual kerosene consumption for adopter households is 0.48 liter per household. There is a considerable saving of 25.2 liter (98.1%) of kerosene per year per household in the study area.

In monetary value biomass costs 1955 ETB by non-adopter and 941 ETB by adopter, and kerosene 341 ETB by non adopter and 6 ETB by adopter per household per year. A considerable saving of moneny from biomass and kerosene is about ETB 1249 by adopter per household per year in the study area.

3.2.2. Biomass and Kerosene Consumption Vs GHG Emission

In Aletawondo woreda, average annual GHG emissions by adopter households are 1929.86kg, 1.17kg and 15.06kg CO_2equivalent of biomass, kerosene and biogas respectively; whereas the average annual GHG emission by non-adopter households are 4006.92kg, 62.6kg and 37.5 kg CO_2equivalent from biomass, kerosene and raw manure respectively. In aggregate the average annual green house gas emission by adopter households is 1946.09kg, whereas by non-adopter is 4107.02kg CO_2eqv. There was a considerable reduction of GHG emission by 2160.93kg CO_2equivalent (52.6%) of GHG emission per year per household.

3.2.3. Benefits of Biogas for Manure Management

In the study area the production of manure and utilization are properly managed through biogas plants by adopter households. On average 11.55 tons of dung were produced and utilized for biogas per year per adopter households; and on average 7.09 tons of dung was produced by non-adopter households and 2.13 tons, 2.84 tons and 2.13 tons are utilizing for composting, directly apply on farm and leave on field respectively.

3.2.4. Benefits of Biogas for Chemical Fertilizer Substitution

Bio-slurry is a good organic fertilizer that can replace or reduce the application of chemical fertilizer. Adopter households were utilized 47.19kg DAP and 47.19kg Urea before biogas installation and 14.69kg DAP and 14.69kg Urea after biogas installation; non-adopter households were utilized 47.77kg DAP and 47.77kg Urea. This result shows, a considerable savings and substitutes chemical fertilizer is 32.5kg (68.9%) DAP & Urea due to installation of biogas technology.

3.2.5. Biogas Benefits Analysis, Health and Sanitation

Of the interviewed respondents, with statistics distributions 23.5%, 18.4%, 83.7%, 84.7%, 82.7% for adopter households and 67.3%, 61.2%, 16.3%, 25.5%, 19.4% for non-adopter households gives answers as cough & itchy eye problem, headache problem, smoke free, had clean kitchen, reduces burning respectively.

3.2.6. Implication of Biogas on Environmental Sustainability

Substitution for Biomass and Kerosene Fuels: when biomass is obtained from renewable sources (fire wood, dung-cakes) the produced carbon-dioxide is assumed to be absorbed by the vegetation from which they originate. Thus, in the study area, each biogas adopter household had saves and can replaces 1066.80kg biomass (fire wood and crop residue) and 25.2 liter kerosene annually due to installation of biogas.

GHG Emission Reduction: The average annual GHG emissions are 1929.86kg, 1.17kg and 15.06kg CO_2equivalent biomass, kerosene and biogas consumption for adopter households respectively and the average annual GHG emission are 4006.92kg, 62.6kg and 37.5kg CO_2equivalent from biomass, kerosene and raw manure for non-adopter households respectively. There is a considerable reduction of GHG emission by 2160.93kg CO_2equivalent (52.6%) per year per household.

Health and sanitation: The change in sanitation and cleanliness had been a matter of great satisfaction brought about by biogas and biogas induced way of toilet construction. On the other hand, health problems, such as, cough & itchy eye problem, headache problem, smoke free, clean kitchen and reduced burning when cooking and lighting are the major benefits of biogas technology gained by adopter households in the study area.

Manure Management: The problem of manure exposing on fields were alleviated by installation and utilization of biogas technology. Thus, adopter households were best actors for manure management, and contributing for environmental sustainability.

Bio-slurry utilization: Adopter households are utilized 47.19kg DAP and 47.19kg Urea before biogas installation and 14.69kg DAP and 14.69kg Urea after biogas installation. The substitution effect of bio-slurry for chemical fertilizer results in high contribution for maintaining of soil micro-nutrients and soil structure and thereby keep healthy and sustainable environment in the study area.

Forest Conservation: The reduction in fuel wood consumption saves the forest resources and ultimately the bio-diversity becomes conserved. In the study area, each biogas plant saves 1.067 tones fire wood annually per year. The saving of trees from the saved fire wood could directly be attributed to biogas installation. The ongoing installation of biogas technology was the best measures for alleviating the problems, and the study result shows biogas technology can replacing fuel wood and fossil fuel and thus, much contributing for environmental sustainability.

IV. CONCLUSION

The purpose of this study therefore is to identify the factors that influence adoption of biogas technology and its implication on the household's health and environmental sustainability in the study area.

The sample size was determined statistically giving equal chance for adopter and non-adopter households and a total 196 sample households were selected through multi stage sampling techniques. Data was collected and analyzed using descriptive statistics with the aid of SPSS_20 and econometrics model; binary logistic regression was employed with the aid of STATA -12. Prior to running binary logit model for the estimation of explanatory variable coefficients and related parameters, goodness of fit, likelihood ratio and multicollinearity problem were tested and checked whether or not the model adequate for the survey data. Most of households highly depends on biomass source of energy and then environmental degradation has becomes a cross cutting issue that could be mitigated. The study result shows that the probability of a household adopting biogas technology increases with proximity to water or proximity to water sources, access to credit, cattle size of the household, availability of trained mason, land size, annual income, gender, and proximity to sand and stone market.

The empirical findings shows that; the average annual per capita biomass (fire wood and crop residue) and kerosene consumptions are 2058kg and 25.68 liter by non adopter and 991.20kg and 0.48 liter by adopter households respectively. From this there was a considerable savings of 1066.80kg (51.8%) and 25.2 liter (98.1%) biomass (fire wood and crop residue) and kerosene respectively per year per household per biogas plant. In monetary value a considerable saving of moneny from biomass and kerosene is about ETB 1249 by adopter per household per year. The annual average GHG emissions are 4107.02kg CO_2equivalent from non-adopter households and 1946.09kg CO_2equivalent from adopter households and it has a considerable emission reduction is 2160.93kg CO_2equivalent (52.6%) of GHG emission per year per household in the study area.

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