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Biogas from Cattle Dung as a Source of Sustainable Energy: A Feasibility Study

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ABSTRACT

Many studies have stated that the usage of traditional cooking fuels like firewood, dung, and coal has caused many unfortunate deaths in India. The alternative fuel sources like LPG and electricity are in scarce and. Today, researches in the area of biofuel or bioenergy are of prime interest to many researchers to contribute to sustainable energy sources. Bioenergy from cattle dung is one such area, particularly for a country like India where dairy farms is a major supplier of feedstock. In this study, using logistic regression methodology, we have analysed the socio-economic factors influencing the adoption of biogas digesters among dairy farmers in Karnataka, India. The study revealed that the number of cattle and family size are the key factors for biogas adoption and poor knowledge of the family size and cattle ratio is the key hurdle. Using cross-tabulation and some basic mathematical analysis, we concluded that the optimal number of cattle for one adult in a family is 1.

Keywords: Sustainable Energy Source, Biogas, Cattle Dung, Dairy farmers, Socioeconomic Factors, India
JEL Classifications: Q4, P28

1. INTRODUCTION

The energy crisis and green environment are demanding for a carbon-neutral and efficient source of energy (Mohapatro et al., 2014). Increasing crude prices has resulted in expensive LPG and firewood has become a costlier source of energy owing to increased demand from industries. Biogas is an alternative source of energy for cooking in rural India. Harsdorff (2014) and Hemme et al., (2003) states that India is the largest producer of milk and cattle dung in the world. Biogas is a source of renewable energy generated from the organic wastes of animals. Cattle dung is the major source of animal waste used in rural India to generate biogas. In 1950s country had a large number of cattle, however, the production of milk was not self-sufficient. Oxen and buffaloes were used in the agricultural fields for the farming process, hence a good amount of dung or animal wastes were available. However, increased use of technology in farming has reduced the dependence on animals in the agricultural fields, which has resulted in the reduced yield of the dung. So the generation of biogas in rural India is decreasing. Hence, today biogas from animal waste in rural India is dependent on cattle dung generated at dairy farms. According to Mittal et al. (2018), the availability of feedstock is also a major hurdle for the development of biogas energy among households in India.

Some empirical studies on biogas revealed that cattle dung generated at the dairy farm is the best raw material input for the biogas plant. Nandiyanto et al. (2018) suggest, that a combination of dairy farming with a biogas plant is more profitable for rural households. Today the Indian dairy sector stands first in terms of milk production and contributes 20% of the world's total production (Pant et al., 2019). Farmers in India have witnessed many initiatives from the government to boost the milk production in the country, such as key village scheme (KVS), intensive cattle development project (ICDP) and operation flood (OF) (Pandian

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et al., 2015). Dairy enterprise development scheme (DEDS) was launched in the year 2010 to increase self-employment in the field of dairy farming, this may boost the biogas generation among dairy farmers in India. The development in dairy farming may indirectly contribute to increased biogas usage in the country. Smith and Sagar (2014) explored the impact of solid fuel pollution on the health of Indian women and the girl child., According to Gupta and Ravindranath (1997), the low-income families of the urban and rural India are forced to use firewood for cooking, the only feasible substitute is biogas. Policymakers have to come up with suitable strategies to make this biogas transformation possible. Hence, a detailed study on dairy farmers' perception of biogas and the socio-economic factors deciding biogas is the need of the hour.

The aim of this work is twofold; one, to analyze the socio-economic factors contributing to penetration of biogas plant among dairy farmers in Karnataka, India. Two, to find out the optimum number of cattle required to meet the cooking energy requirements for different family sizes because Singh and Sooch, (2004) opined that households in India are not aware of the ratio of family size to cattle requirement.

2. LITERATURE REVIEW

Salam et al. (2020) studied the feasibility of biogas generation at the household level in Bangladesh. The study states that cattle dung is readily available in rural villages, which could be a great source of material for biogas. Yazan et al. (2018) have explored the commercial aspects of biogas using cattle dung and claimed that business model works only for large scale operations which operate with more than 20000 ton per year, and this is the indication of the scale of success for biogas plants in the household levels. Narayan et al. (2018) conducted relevant research and argued that the commercialization of biogas in India is not a feasible solution with the present technology, however, financial incentives for dairy farming and direct incentives for household biogas producers may reduce the LPG subsidy burden on the government. Nandiyanto et al. (2018) in Indonesia, claims that the combination of the dairy business and biogas plant is much profitable rather than just dairy business. A study in the US believes that a farm business with a minimum of 3000 cattle will reach breakeven in the commercialization of biogas and the study also suggests that cooperative biogas plant would yield better results (Lauer et al., 2018). Mittal et al. (2018) state that the availability of feedstock, supply chain, policy support, and awareness among households are the strong barriers to the growth of biogas generation in India. The demand for milk in India is growing at 7% and the production of milk is growing at 4.4%. This is mainly because of the presence of traditional practices in the sector and poor access to finance (Pant et al., 2019; Rao, 2017; Jadawala and Patel, 2017).

Muvhiiwa et al. (2017) study from the South African perspective states that country is technology-ready and it has enough sources of materials to generate biogas in the rural areas; however, lack of awareness is the major challenge for sustainable development. Traditionally farmers in India were using the by-products of their agricultural products as feed for cattle but today many have moved to commercial crops, which has resulted in a reduction of generation of cattle feed. The land available for cattle rearing is also very less (Kumar et al., 2016). In India because of the low genetic potential of the cattle, the cost of milk production is high and the milk yield is not satisfactory (Kumawat et al., 2016), this may lead to farmers stopping dairy business. Hence, the financial incentives of the government will encourage the dairy farming business. Food and Agribusiness Research Management (FARM) (2015) provided an interesting study, that proper utilization of cattle dung for biogas, direct incentives of the government and financial inclusion from organised banks will make the small dairy farming profitable in India. Heubeck and Craggs (2015) worked on the energy yield and concluded that a kilogram of cattle manure yielded 0.18-0.25 m^3 of methane (CH_4). 56M^3 of methane is equivalent to 1 tonne of CO_2. Therefore, methane yield of 400 cattle manures is equivalent to 0.35t of CO_2/day. Bakar et al., 2015 said that biogas kits for dairy farmers are advised as it serves two purposes, i.e. waste management and generation of low-cost energy for households. Wahyudi et al. (2015) opine that 67% of poor Indonesians have occupations in rural agriculture including livestock farming, this is the potential sector to generate biogas by using dairy sector wastes. Keck et al. (2015) studied and reported that in Switzerland, the majority of biogas facilities are attached to the dairy or animal husbandry business. In a report of the international labour organization, Harsdorff (2014) states that increased dairy farming and biogas generation will add 2 million additional jobs in the biogas plants. For the development of farmer level biogas projects in Italy, the government has to think about reframing institutional frameworks with attractive subsidies (Carrosio, 2013). Ibrahim (2012) have studied the opportunity for green energy in Malaysia; the study argues that installing biogas plants in animal farms will give multiple advantages to small scale farmers by reducing their fuel and power costs.

Abdulsalam and Mohammed (2012) provided an interesting fact that in Nigeria, Elephant dung is recommended to use as an alternative source of material for cattle dung based biogas plants; however, the challenge is that elephant is a wild animal. From Indian perspectives, technological advancement and a planned supply chain management are necessary for commercialization of bioenergy generation using cattle dung (Kumar et al., 2012); Hence, it is recommended to use biogas kits in the household levels. Bond and Templeton (2011) informs that among developing countries, India and China are the major biogas digester users; the major source of material for this digester is cattle manure. India has immense opportunity to increase the use of biogas digesters, particularly in the household segment using cattle dung, this would increase the opportunity for employment and contributes for environment-friendly sustainable growth (Bhol et al., 2011).

Gebrezgabher et al. (2010) study reported that by 2020 all Dutch dairy farms and processors will become energy self-sufficient with the combination of biogas, wind and solar; this is because of the increase in the volume of cattle dung and dairy business. A study by Ali et al. (2008) in fisheries of Bangladesh proved that the survival rate of fishes using a combination of biogas slurry and raw cattle dung is better than the use of raw cattle dung or other supplements. California is technologically ready to produce biogas from dairy manure; However, the small scale of dairy's in the region is a challenge (Krich et al., 2005). Singh and Sooch (2004) mentioned that biogas from cattle dung will become a great alternative for natural gas in rural India; However, lack of knowledge and awareness of the ratio of family size to biogas plant size is the major hurdle to harness the full potential. Nagamani and Ramasamy (1999) state that despite improved technology for biogas in India, lack of livestock followed by construction defects are the major hurdles for the success of biogas plant in household levels.

3. DATA AND METHODOLOGY

In this cross-sectional data study, 231 dairy farmers from the Karnataka state of India were randomly interviewed. State Karnataka is the 8th largest state in India; there are 30 districts with a total area of 1, 91,791 km^2. Department of Cooperation (2018) informs that there are 14,256 functioning Dairy cooperatives societies (DCS) and 2.46 million, dairy farmers actively work in the state. A personal and telephonic interview method is used to gather data from dairy farmers.

Among 231 dairy farmers, 181 are biogas users and 50 are not biogas users. For a dichotomous dependent variable (biogas user or not), to analyze its dependency on socioeconomic factors (age, religion, education level, number of cattle, and land size) binary logistic regression methodology is used. Reasons for not adopting biogas plant and the usage of alternative source of cooking energy for these non-biogas users are analyzed. Among 50 non-biogas users, 23 mentioned that the quantity of cattle dung is not sufficient to adopt biogas plants for cooking energy. The cross-tabulation, simple average and cross-multiplication techniques are used to obtain the optimal number of cattle requirements for different family sizes.

4. RESULTS AND DISCUSSIONS

4.1. Dairy Farmers Background and Biogas Adoption

Salam et al., 2020 inform that the background of households plays a vital role in biogas plant adoption decision. In Table 1, we have shown the background characteristics of dairy farm respondents. Among 181 biogas users, 81.20% are Hindus, 13.30% are Christians and 5.5% are Muslims. Concerning factor age, there is not much difference between users and nonusers. 39.20% of users and 52% of nonusers fall in the same category of 41-55 age group. Education level also plays a vital role in biogas adoption in rural areas, data shows that 35.9% of biogas users are Pre metric and 46% of nonusers are metric. Post metric, as the education level increases, even the biogas users' number increases. Data proves that biogas usage is more with large size families, 70% of respondents with a family size of 2-4 are not the users of biogas contradictorily only 2.8% of respondents with a family size of 8 and above are the users of biogas. Further, the number of cattle factor is interesting as maximum numbers are modal values; the maximum biogas users (28.2%) own 3 cattle and the percentage is reducing on both the sides irrespective of the number increasing or decreasing. Finally, 62.4% of biogas users are in the minimum land size category of 0.5-5 acres of land. As the size of the land increases, the number of biogas users is reducing.

4.2. Reasons for not using Biogas as a Source of Energy for Cooking

Many studies have mentioned that the availability of cattle dung and lack of awareness about biogas are the major challenges to the growth of biogas usage in India. In this study, all 50 biogas non-users were aware of the concept and economic benefit of biogas. Various reasons for not adopting of biogas by these dairy farmers are presented in Table 2. For an open-ended question, 46% of respondents said that the quantity of cattle dung is insufficient to meet the cooking energy requirement of the family. The cross-tabulation analysis and an optimal number of cattle for different family size analysis in the last section of this study will address this issue of quantity of cattle dung.

Table 1: Respondents profile

Respondents classification	Biogas users 181	Non-Biogas users 50
Religion		
Hindu	81.20	72.00
Christian	13.30	28.00
Muslim	5.50	0.00
Age group		
25–40	24.90	22.00
41–55	39.20	52.00
56–70	34.80	22.00
Above 70	1.10	4.00
The education level of the family head		
Pre metric	35.90	30.00
Metric	30.90	46.00
PUC/ITI	16.00	16.00
Graduate	16.00	8.00
Postgraduate	1.10	0.00
Family size		
2–4	55.20	70.00
5–8	42.00	30.00
Above 8	2.80	0.00
Number of Cattle		
1	5.00	24.00
2	19.30	24.00
3	28.20	18.00
4	18.20	18.00
5	8.30	10.00
6	7.20	2.00
7 and above 7	13.80	4.00
Land size		
0.5–5 acres	62.40	50.00
5.5–10 acres	26.00	32.00
10.5–15 acres	5.50	8.00
15.5–20 acres	3.30	4.00
Above 20 acres	2.8	6.00

Based on primary data

Table 2: Reasons for not using biogas by dairy farmers

Reasons for not using biogas	Frequency	Percent
Additional man-hour requirement	11	22.0
Availability of land	1	2.0
Capital requirement	5	10.0
Not necessary	1	2.0
Not thought about that so far	7	14.0
Quantity of cattle dung is not enough	23	46.0
Un divided property	2	4.0
Total	50	100.0

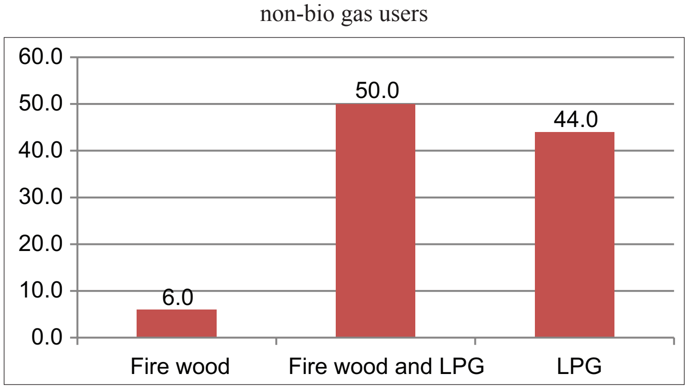
Source: Primary data

The next major issue was additional domestic chores. 22% of biogas non-users specifically mentioned additional manpower requirement for processing cattle dung to generate biogas as the reason for non-usage. 14% of biogas non-users gave very light responses as they are aware of biogas however, they have not thought about the installation so far. 10% of biogas non-users said the heavy capital investment is the hurdle for biogas plant installation and this group is particularly looking for attractive incentives from the government agency in the form of subsidy. Very interestingly 4% of biogas non-users were not sure about their cattle shed as it belonged to undivided family property. 2% of non-bio gas users were big landowners and they seem to have enough alternative sources available in their agricultural fields to manage their energy requirements of cooking and hence, biogas was unnecessary. The last category 2% of biogas non-users mentioned that they don't have sufficient land to place the biogas digesters on their dairy farm.

4.3. Need for Change in Cooking Energy and Dynamics of Cooking Energy Access for Non-bio Gas Users

The pollution caused by burning firewood, dung, coal inside the kitchen is causing more than 1.5 million deaths a year, (Rehfuess, 2006). Parikh et al. (2016) inform that nearly 840 million families in India still depend on solid fuels like firewood or dung, burning which, is a tremendous health hazard for the women and children in those families. More than 66% of rural families in India still use solid energy sources for cooking and electric stoves could be the better source (Panagariya and Jain, 2019). Women in India spend more than 2 weeks a year to collect firewood for cooking energy and the same is resulting in nearly one million deaths in a year (Patnaik and Tripathi, 2017). In the year 2005, 364 million rural Indians did not have access to electricity and 726 million rural families were using firewood, dung, or coal as their source of energy for cooking. (Balachandra, 2011). Figure 1 shows that 50% of non-biogas users are using firewood and LPG as a source of energy for cooking and said that firewood is abundantly available and hence, both LPG and firewood are used as cooking energy. 44% of respondents said they use only LPG for cooking. Only 3 respondents are purely depending on firewood for their cooking energy requirement.

Figure 1: Alternative sources of cooking energy used by non-bio gas users



Source: Primary data

4.4. Factors Influencing the Dairy Farmers to Install Bio Gas Plants

In this study, the dependent variable is a dichotomous binary variable and the independent variables are continuous or categorical variables. Hence, as this data set is not satisfying the assumptions of the normal regression model, we have employed a logistic regression model to analyze the relationship between biogas usage and other socio-economic factors of dairy farmers. Biogas user or not user was the dependent variable for the model, where Y = 1 if the respondent dairy farmer is the user of biogas and Y = 2 if the respondent is not a user of the biogas. An odds ratio is a commonly analyzed statistic in any logistic regression analysis, ratio >1 indicates that the probability of a dependent variable event occurring is more than the probability of an increase in independent variable and vice versa. In our context, if the Odds ratio >1, the probability of biogas plant installation is more with an increase in any of the socio-economic variables. A coefficient indicates that after adjustment for all other independent variables in the model, how that particular independent variable will impact the outcome of the dependent variable. Wald statistics in logistic regression will test the unique contribution of each independent variable with other independent predictors used in the model (Karl, 2020). Table 3 shows that socio-economic factors like family size and the number of cattle have significantly contributed to the installation of a biogas plant by dairy farmers in Karnataka, India. Further Odd ratio in Table 3 indicates that for an additional family member among dairy farmers, the Odds of adapting biogas reduces by 24.1% or in other words the ratio (0.759 < 1) is less than one, hence the probability of biogas plant installation with an increase in the family size of dairy farmers is lower than 1. The Odds ratio for independent variable land size shows that the probability of biogas plant installation is greater than 1 (1.042 > 1) for every one-acre increase in the land size of dairy farmers.

4.5. The Optimal Number of Cattle's Requirement for Varying Family Sizes

The table shows that 46% of non-biogas user respondents stated that the quantity of cattle dung is the main reason for not installing biogas. We have attempted to make family size and number of cattle requirement analysis to give an optimal cattle number for different size of families. In the data collection process, we have enquired 2 related aspects with biogas users. One, with the current number of cattle, what percentage of cooking energy requirement is satisfied and the other one is to generate 100% of their energy requirement, what is the required number of cattle. The methodology used for the analysis is simple average and cross multiplication. In Table 4, computation procedures are neatly explained using column number definitions. Column no 1 shows respondents family size, the second column shows the no of cattle owned by the respondents, the third column shows how much cooking energy requirement is met by biogas, the fourth column shows respondents estimation of the number of cattle required to meet 100% of their cooking energy requirement. The fifth column in Table 4 shows our estimation of the number of cattle required to meet the respondent's 100% cooking energy requirement, the sixth column shows the average of our estimation and respondent's estimation and the last column shows the optimum number of cattle requirements for a family of one member. The same computations

Table 3: Logistic regression output

Variable	Coefficient	Standard Error	Wald	P-value	Odds ratio
Religion	0.005	0.314	0.000	0.989	1.005
Family size	−0.276	0.122	5.095	0.024	0.759
Age of the family head	−0.003	0.015	0.044	0.834	0.997
Education Level of the head of the family	−0.075	0.167	0.199	0.655	0.928
No of cattle's	−0.292	0.109	7.212	0.007	0.747
Land size in an acre	0.041	0.032	1.666	0.197	1.042
Constant	0.906	1.093	0.687	0.407	2.475
Chi-square			21.999		
P-value			0.001		

Source: Authors analysis using primary data

Table 4: Optimal number of cattle requirement analysis

Family size (1)	No of cattle (2)	% Energy demand met (3)	Respondents estimation (4)	Our estimation (5)=[100*(2)]/(3)	Average for full family (6) =[(4) + (5)]/2	Optimal no of cattle for 1 member family (7) = (6)/(1)
5	2	50	3.00	4	4	1
3	5	100	4.00	5	5	2
8	3	50	5.00	6	6	1
7	22	100	5.00	22	14	2
4	4	50	3.00	8	6	1
4	3	100	3.00	3	3	1
4	3	80	2.00	4	3	1
8	8	80	8.00	10	9	1
Average from 181 response estimations						1

Source: Authors analysis using primary data

Table 5: Family size *No of cattle's cross tabulation

Family size	No of cattle's							Total
	1	2	3	4	5	6	7	
2	3	1	1	3	2	1	1	12
3	3	4	0	4	0	0	0	11
4	4	4	3	0	1	0	0	12
5	1	3	2	1	1	0	0	8
6	1	0	2	0	0	0	1	4
7	0	0	1	0	1	0	0	2
8	0	0	0	1	0	0	0	1
Total	12	12	9	9	5	1	2	50

Source: Authors analysis using primary data

are done for all 181 responses; the same is shown in the annexure section. The final average of 181 observations in the last column of Table 4 shows that the optimal number of cattle requirements for 1 member family is 1; this estimate can be used as the base to compute an optimal number of cattle requirements for different family sizes to meet their 100% cooking energy requirement.

4.6. Cattle Requirement and Available Number of Cattle's among Respondents – Feasibility Analysis

In Table 5, numbers with bold and underlined font are the number of respondents who can install biogas plant, based on the number of cattle requirements in each family size category. On the other hand numbers with Italic font style are the number of respondents who are not meeting the minimum number of cattle requirements to manage their 100% of cooking energy demand. Cross tabulation shows that among 50 non-bio gas user respondents, 12 are with a family of 2 members, and the optimal number of cattle required to meet their 100% cooking energy demand is 2. Hence, 9 out of 12 families of this category can adapt biogas as the number of owned cattle with them is equal to or more than the optimal number. Similarly, there are 4 families in 3 family member categories, and 1 family each with family size categories of 4, 5, and 6 who meet the optimum number of cattle requirements.

5. CONCLUSION

Biogas is one source of bioenergy, which can be a good substitute for traditional sources of cooking energy in India. Green environment is looking for sources that can reduce carbon omission and the government agency is also striving to transform the traditional, polluted kitchens to a hazard-free kitchen. Our objective in this study was to analyze the socio-economic factor influencing biogas adoption among dairy farmers in Karnataka, India and the logistic regression analysis proved that family size and the cattle's number are the two key factors. Data also reveals that the cattle number or dung quantity, additional manpower requirement, and initial capital outlay are the reasons for not installing biogas plants. Further, the study found that among 50 non-bio gas user respondents, there are 16 respondents for whom the adoption of biogas is feasible in terms of the number of cattle, However, other mentioned reasons might be a hindrance.

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