

Research Article

Manure Management Systems and Factors Influencing Biogas Technology Adoption Among Smallholder Dairy Farmers in Northern Tanzania

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Abstract

Manure management system in dairy production is of great concern given the fact that if improperly managed contributes significantly to greenhouse gas emissions. On the other hand, properly managed manure provides fuel (biogas) and organic fertilizer. This study assessed the existing manure management system and factors influencing biogas technology adoption among smallholder dairy farmers in urban (Arusha City Council), peri-urban (Arusha District Council), and rural areas (Hai District Council) in Northern Tanzania. These districts were purposively selected based on the fact that they have a large number of smallholder dairy farmers producing large quantities of manure. A total of 150 households (50 from each study district) were purposively selected. Structured questionnaires were administered to the heads of the household's head, to collect both qualitative and quantitative data. Data on the household socio-economic characteristics were analyzed using descriptive statistics. The chi-square test was used to analyze manure management system variation among smallholder dairy farmers. Logistic regression was also used to determine the factors influencing the adoption of biogas technology among smallholder dairy farmers. The results showed that there were significant variations in manure management systems such as solid storage, daily spread, and anaerobic digester ($p < 0.05$). Logistic regression revealed that socioeconomic factors such as Household income, Household size, and Herd size had a positive influence on biogas technology adoption at ($p < 0.05$). Education level and farm size showed an influence on technology adoption by having an odd ratio greater than one. The findings provide an understanding of the existing manure management system and factors influencing the adoption of biogas technology. The study recommends training programs to be sensitized on the best manure management system to fill the education gap, low-interest loans and subsidies to minimize the initial installation cost of biogas accessories. Additionally, larger herd size farmers and large family size are highly sensitized due to the availability of enough substrate and labour for biogas operation. Further research on the influence of other source of energy on biogas technology adoption in both urban and rural smallholder dairy farmers is required.

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Keywords

Cattle Manure, Biogas Technology, Manure Management System, Smallholder Dairy Farmers

1. Introduction

Smallholder dairy farming (SDF) is a small-scale farming focused on milk production. The farming system is characterized by smallholder dairy farmers owning 1-4 dairy cows [1, 3]. The sector primarily depends on locally sourced feeds such as unimproved grasses and crop residues, which helps to maintain low production costs and hence low output [2]. Moreover, the system is comprised of not more than 5ha of land [3] whereby family labour carries out daily operations. SDF is progressively growing in Tanzania and it is pivotal in the livelihood of both urban and rural dwellers due to its direct contribution to the society and national economy. SDF is scaling up in rural, peri-urban, and urban increased to satisfy the need for animal protein brought on by human population growth and diet education. Around 190,000 farmers in Tanzania sign up for dairy farming each year, with the industry expected to grow by 6% annually [4]. SDF contributes tangible benefits to society by ensuring food security, selling milk and milk products, manure production which is used for different purposes and provision of employment [5]. Adoption of an intensive dairy production system among smallholder dairy farmers is associated with increased production of manure which requires handling and management for environmental safety.

Manure handling and management among the majority of smallholder dairy farmers take less priority because manure is considered like other waste with no value. A well-managed manure is a source of organic fertilizer suitable for soil and increases crop yield [6]. Moreover, it is a source of household income as reported by [7] who revealed that an annual gross income of 1,350 Kshs (10.44 USD) was received from sales of cattle manure. Management system such as solid storage and daily spread was reported as a manure management system dominated among the smallholder farmers [8]. Despite the highlighted benefits of manure, the existing management system among the smallholder farmers is associated with social, health, and environmental challenges such as odor emission which causes conflict between dairy keepers and non-dairy keepers [9]. Moreover, a limited land to accommodate the produced manure and poor handling techniques results in manure runoff that contaminates water sources and causes waterborne diseases among the water users [10, 11]. More importantly, improper manure management systems pose a significant effect on the atmosphere through the emission of methane and nitrous oxide gas from uncovered heap and liquid management practices [12].

Adoption of the best manure management system is a

paramount idea in the world of climate change. Anaerobic digestion (AD) is one of the existing best manure management systems which involve combustion and capturing methane gas at about 50%-75% and carbon dioxide at about 25%-50% under anaerobic conditions [13]. The technology has proved to have valid benefits to the environment due to mitigating GHG emissions, especially methane [14]. This benefit aligns with sustainable development goals (SDG) in improving waste management and minimizing environmental impact. The technology not only ensures environmental safety but also reduces resource misuse, ensures both human and animal health, and fosters Circular Economy (CE) opportunity [15]. The idea of CE is a world strategic plan especially for developed countries to benefit the farmer and the environment through optimum utilization of resources in a closed loop or circular form [16]. According to [17], CE is a systematic utilization and recycling of produced products. Therefore, in dairy farming, cattle dung utilized through biogas generates energy for cooking and lightening and biofertilizer for crops and fish ponds. Despite the benefits, the rate of biogas technology adoption is low hence limiting the CE system among smallholder farmers.

Studies have been conducted to analyze the manure management system, utilization and its health impact on humans [18-20]. There is limited data on the manure management system and less is known on the factors influencing the adoption of biogas technology among the smallholder dairy farmers in Urban, Peri-Urban, and Rural areas of Northern zone-Tanzania. Within this site, there is an ongoing project: Africa and Asian Dairy Genetic Gain (AADGG) and Enviro-cow aiming to develop climate mitigation strategies by assessing emissions from dairy cows. The objective of this paper was to characterize the existing manure management system in the study site and to examine factors influencing the adoption of biogas technology among smallholder dairy farmers. The findings of this study provide useful information to policy and decision-makers to intervene in proper manure management systems for Greenhouse gas emission (GHG) mitigation and promotion of circular economy.

2. Methodology

2.1. Description of Study Areas

The study was carried out in three sites, namely Arusha

City, Arusha District, and Hai District Council) in the Northern zone, of Tanzania. For the purpose of this study Arusha city was termed as Urban, Arusha district as Peri-urban and Hai district council was termed as (Rural). Arusha city council is located between latitude 2° and 6° south and longitudes 34.5° and 38.0° East. The area has an elevation between 1130 and 1450 above sea level [22]. Moreover, the site receives annual rainfall of 500 mm to 1,200 mm and temperatures of 17°C and 34°C [23]. The second site, Arusha district council is located south of the Equator, between latitudes 3.10° - 4.0°N and longitudes 34.47° - 35.56°E . The site is located at an altitude of 1375m to 1400m. The area receives a mean annual rainfall of 880mm and a mean temperature of 20°C . The site experiences the lowest temperature of 17°C in July and the highest temperature of 22°C in March [21]. The third site, Hai district is located between latitude $2^{\circ}50'$ - $3^{\circ}29'\text{S}$ and longitude $30^{\circ}30'$ - $37^{\circ}10'\text{E}$. The site has

three zones namely, Low, mid, and high land where low land receives annual rainfall between 750 and 1,000 mm, midland receives higher rainfall than low land and high land receives heavy rainfall. The temperature of the site ranges from 25°C to 32°C [24]. The Economic activities in these regions primarily revolve around dairy farming and crop production, where cattle manure is utilized for fertilizing both crop and pasture fields. These regions predominantly feature small-holder farmers raising improved dairy breeds such as Friesian and Ayrshire crossed with indigenous Short Horned Zebu under intensive farming systems. There are several existing interventions to improve dairy cattle production in the study sites including Africa and Asian Dairy Genetic Gain (AADGG) and Enviro-Cow initiative. These initiatives focus on developing climate mitigation strategies by assessing the emissions from dairy cows in Africa and enhancing their resilience to climate change effects.

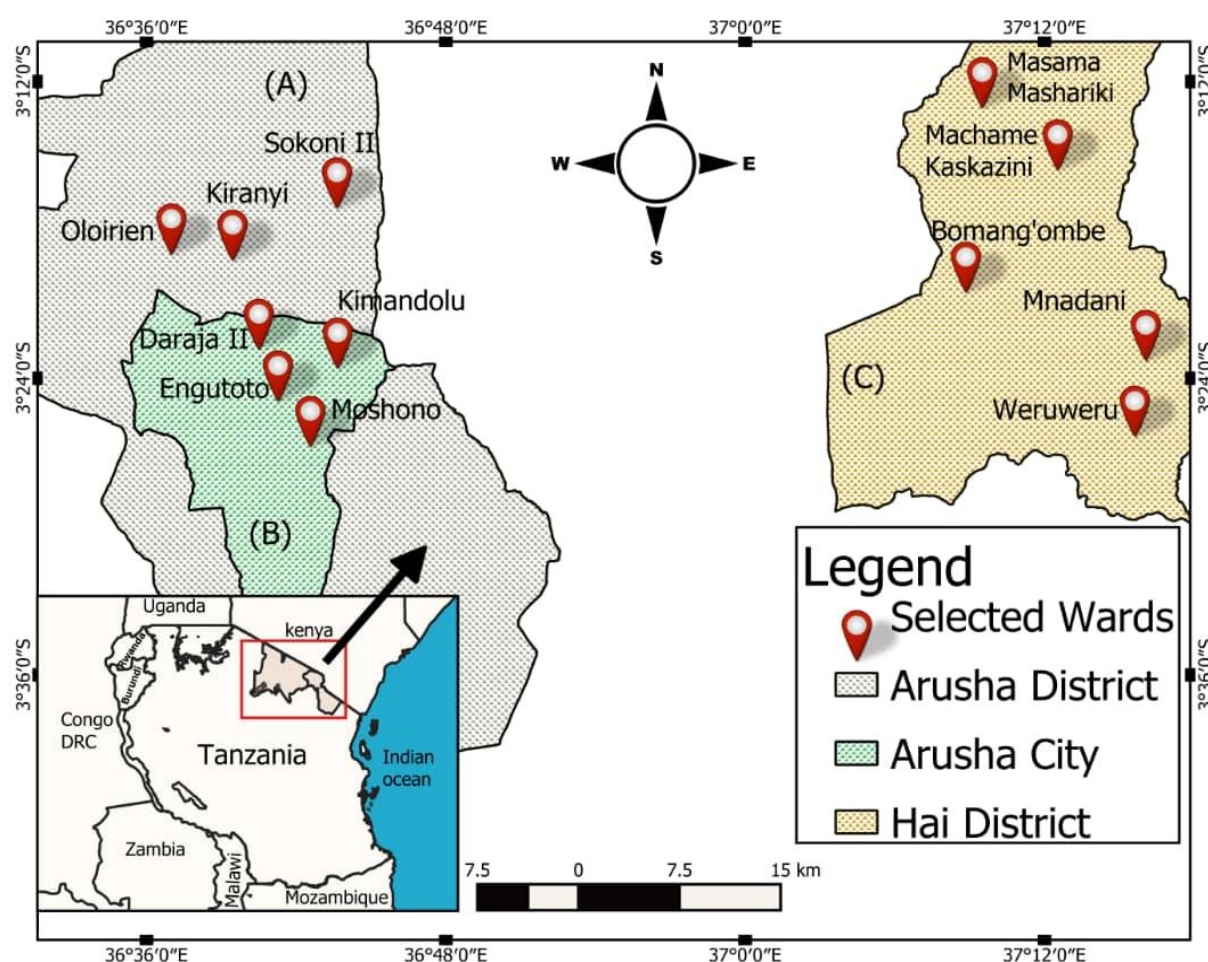


Figure 1. The map of study area.

2.2. Study Design and Data Collection

A cross-sectional study design was adopted where households were systematically selected in which purposive sam-

pling technique was applied. A total of 150 households were purposively sampled (50 from each district), These households were purposively selected based on zero grazing production system and biogas technology adoption. Recruited farmers in the Enviro-Cow project and AADGG were in-

cluded in the study. The data to fulfill the objective of the study were collected between January and April 2024 using a structured questionnaire. The questionnaire covered socio-economic data, manure management system, manure usage, challenges encountered by farmers in biogas technology adoption, benefits of the use of biogas and reasons for abandoning biogas technology. Structured questionnaires were administered face-to-face using the national Swahili language to the household head. Before the actual survey, a questionnaire was pre-tested to the randomly selected households in the study area. At the commencement of the actual survey, selected farmers were visited by enumerators under the guidance of the Performance Recording Agent of the project (PRA) of a project in the particular study site. Key informants' information was also used to supplement questionnaire data from the selected respondent. A total of five key informants, including extension officers and experienced staff in the study area were interviewed using a well-prepared checklist to obtain general information on the manure management system and the state of biogas technology adoption as a best manure management practice. Key informants were purposively chosen based on their expertise, experience, and knowledge.

2.3. Data Analysis

The data collected from the household survey using the Open data kit (ODK) tool were cleaned and analyzed. Statistical Package for Social Sciences (SPSS Version 26) was used for data analysis whereby descriptive statistics including

frequency and percentage were computed. Chi square was used to compare manure management systems across the three study sites.

A logistic regression model was used to determine factors influencing the adoption of biogas technology among small-holder dairy farmers. The impact of the independent variable on the outcome while controlling the other independent variable was expressed as an adjusted odd ratio at a 5% significance level. Before the variables fit into the model, the variables were tested for multicollinearity using the Variance inflation factor (VIF). Variables with greater than 5 VIF imply multicollinearity problems and were excluded from the model.

3. Results

3.1. Household Socioeconomic Characteristics

The household survey revealed that the age of household heads ranged between a minimum of 28 years to a maximum of 80 years. The size of each household varied with at least 2 individuals and up to 7 individuals per household which is composed of parents, children, relatives and non-relatives. Family size reflected the potential labor force available for dairy operations in a particular household. In terms of dairy farming experience, reported households had experience between 1 year and 50 years. Additionally, the number of dairy herds per household ranged between a minimum of 1 to a maximum of 18.

Table 1. Continuous variables distribution in different district.

Variables	Urban				Pri-Urban				Rural			
	Min	Mean	Max	S. D	Min	Mean	Max	S. D	Min	Mean	Max	S. D
Age	28	54.8	80	10.3	38	59	77	8.6	35	53.7	68	9.28
Household size	2	3.18	7	1.17	2	3.12	7	0.8	2	3.68	5	0.98
Farming experience	4	19.8	55	12.9	2	22.3	50	14	1	13.9	45	12.9
Herd size	2	4.22	18	2.87	1	4.64	16	3.7	1	6.86	18	4.99

S. D=Standard deviation, Max=maximum, Min=minimum

The categorical demographic information such as Gender, Marital status, Education level of the household, Farm size, household head income, Training on manure management systems, and awareness of biogas technology were described. Different socioeconomic characteristics were observed. The majority of the farmers were male-headed households. About

40.7% of households occupy a primary level of education while 9.3% have no formal education. Additionally, 59.3% of household income was below 3M per year while 3.3% earned above 5M per year. A large proportion of households about 64% across the three-study site own below one acre of land while 36% own between 1-5 acre of land.

Table 2. Household socioeconomic characteristics for categorical variables.

Variable	Category	Urban (%)	Peri-urban (%)	Rural (%)	Total
Gender	Male	25.3	29.3	22.7	77.30
	female	8.0	4.0	10.7	22.7
Marital status	Married	24.66	27.3	22.7	74.7
	Single	8.7	6.0	10.7	25.3
Education level	No formal school	1.3	2.0	6%	9.3
	Primary	7.3	20.7	12.7	40.7
	secondary	9.3	5.3	6.7	21.3
	Tertiary	15.3	5.3	8	28.7
Farm size (Acre)	Less than one	28.0	23.3	12.7	64.0
	One to five	5.3	10.	20.7	36.0
	Less than 3	18.7	24.7	16.0	59.3
Household income (Mil/yr)	Three to five	14.0	6.7	16.7	37.4
	greater than 5	0.7	2.0	0.7	3.3
Training on MMP	YES	8.7	6.7	13.30	28.66
	No	24.7	26.7	20.0	71.3
Awareness to biogas technology	yes	12.0	15.3	20.0	47.3
	NO	21.3	18.0	13.30	52.7

MMP= Manure management system

3.2. Manure Management System

There are notable differences between the solid storage and daily spread systems in urban, peri-urban, and rural locations (Table 3). Thirty five percent (35.3%) of farmers employed solid storage, where manure was piled up as fresh near cow sheds or within a distance of not more than 10m. Thirty one percent (31.3%) of farmers practiced a daily spread system in

which fresh manure was applied directly to the field crop. Also, 7.3% of farmers practiced composting which involves placing manure in a pit until the compost is ready. Liquid/slurry system was practiced by 5.3% whereby cowshed cleaning water, urine and cattle dung were all flushed together in a designed pit for several months before use. Lastly, the anaerobic digester, which is environmentally friendly management system was less practiced compared to solid storage and daily spread systems.

Table 3. Manure management system in different locations among smallholder dairy farmers in Northern Tanzania.

Location						
Manure management system	Urban (%)	Peri-urban (%)	Rural (%)	Total (N=150) (%)	X ²	P- value
Solid storage	16.7	12	6.7	35.3	9.862	0.007
Daily spread	6.7	10	14.7	31.3	6.755	0.034
Anaerobic digester	4.7	5.3	10	20	4.750	0.093
composting	2.7	3.3	1.3	7.3	1.373	0.503
Slurry/Liquid	2.7	2.7	0.7	6.1	2.128	0.345

3.3. Challenges in Adoption of Biogas Technology

Figure 2 represent challenges on adoption of biogas technology reported by farmers in the study site. Across the

three-location high cost of installation was highly reported (40%) by farmers compared to other challenges, especially in rural locations. However, lack of labour was among the highly reported challenges especially by urban dwellers.

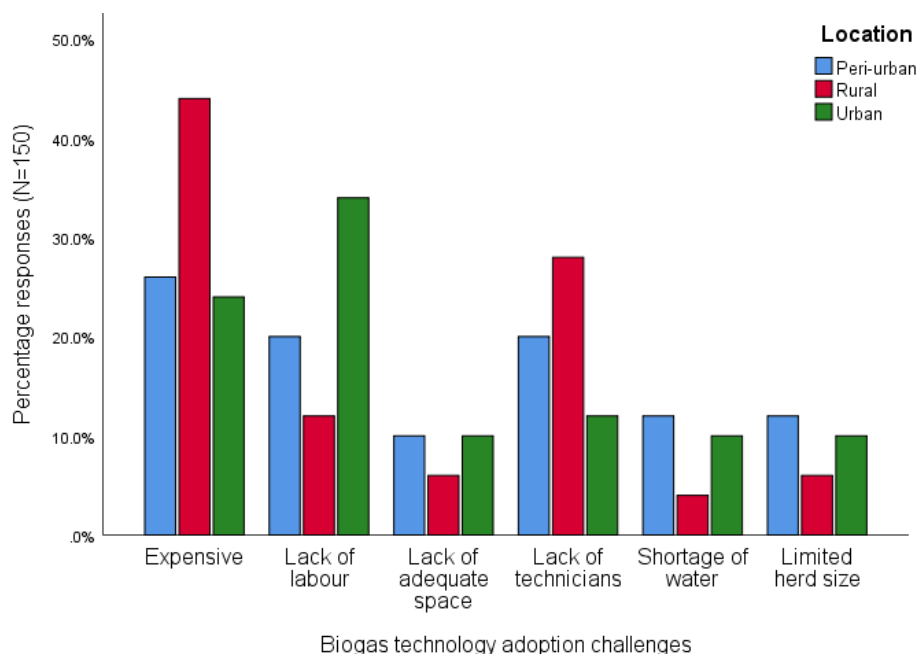


Figure 2. Challenges encountered by smallholder dairy farmers in adoption of biogas technology.

3.4. Benefit of Biogas Technology

Respondents reported several benefits of biogas technology

adoption. Some of these benefits were energy source for cooking and organic fertilizer. However, majority of respondents responses on this were 'not aware' due to lack of knowledge of the technology.

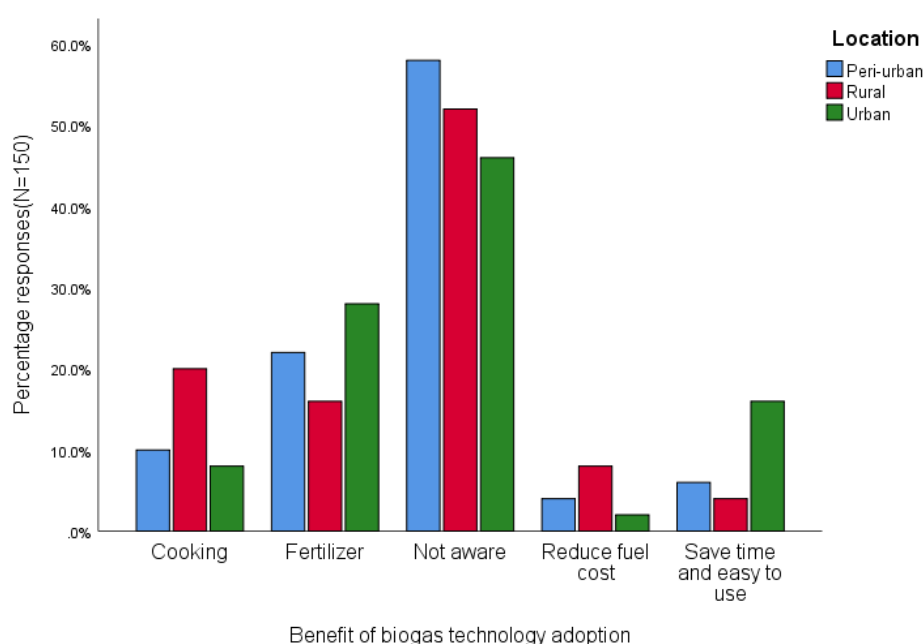


Figure 3. Farmers view on the benefit of adoption biogas technology.

3.5. Abandoning of Biogas Technology

The revealed reason for abandoning of biogas technology were frequent biogas failure which was the most reported reason, shortage of labour, shortage of land and shortage of water among the biogas adopter.

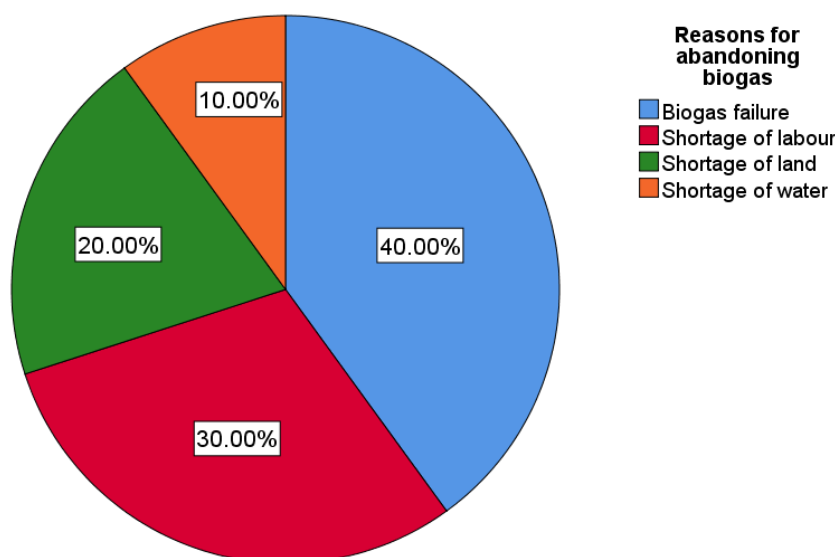


Figure 4. Reasons for abandoning biogas among the biogas technology adopters.

3.6. Factors Influencing Adoption of Biogas Technology

Socioeconomic variables were analyzed using logistic regression mode to test their association with biogas adoption.

Household size, Household income and Herd size were observed to have a positive association with biogas technology with an odd ratio greater than one at $p < 0.05$. Education Level and Farm size were shown to have an influence on biogas adoption with an odd ratio greater than one but not statistically significant.

Table 4. Logistic regression for variables showing factors influencing biogas technology adoption.

Variables	Coefficients	S.E.	Wald	df	P- value.	Odd ratio	VIF
Age	0.126	0.102	1.546	1	0.214	1.135	1.391
Household size	0.856	0.328	6.825	1	0.009	2.354	1.351
Education level	1.08	0.559	3.735	1	0.053	2.944	1.100
Farm size	0.373	1.151	0.105	1	0.746	1.451	1.119
Farming experience	-0.078	0.065	1.445	1	0.229	0.925	1.507
household income	3.495	1.361	6.596	1	0.01	3.2944	1.524
Herd size	0.351	0.173	4.118	1	0.042	1.421	1.203
Awareness to biogas technology	-2.1683	3.348	0.213	1	0.995	0.132	1.521
Training on MMP	-0.885	1.19	0.552	1	0.457	0.413	1.361

VIF=Variance inflation factor, df=degree of freedom, SE=standard error, a Statistically significant association between socioeconomic factors and biogas technology at $p < 0.05$

4. Discussions

4.1. Manure Management System

Solid storage was significantly practiced by smallholder dairy farmers whereby manure was piled near the cow shed or a few meters from the cowshed while others just dropped outside the shed using a spade. The reason could be lack of adequate land for spreading manure close to the homestead. The system is simple in terms of technique and is less labour-demanding. The result agrees with studies by [18, 25, 26] who reported that solid storage is most common where manure is piled within a distance of not more than 10m. Despite the system's simplicity, it contributes to greenhouse gas emissions particularly methane and Nitrous oxide to the atmosphere and loss of Nitrogen which is important for soil and crops through volatilization [27].

Daily spread was widely practiced especially in rural areas (Table 3). After manure was collected from the cow shed, it was spread daily on the field crop. The reason behind this might be the availability of cropland around the homestead which can accommodate produced manure [18]. The system is mostly practiced by rural smallholder farmers compared to urban farmers whose farms are located outside the city [28]. Moreover, the system was significantly used since it is inexpensive and easy for smallholder farmers to use. This might be due to less expenses on storage and labour costs needed because the same personnel used for the daily dairy routine activities is responsible for the task. The use of this system is associated with water contamination and water-borne diseases due to runoff which can have serious detrimental effects on water users such as humans and animals [11].

The anaerobic digestion system was among the management systems less significantly practiced by the smallholder farmers compared to solid storage and daily spread systems. It was observed that the adopters of this system in the study site have a fixed dome design of a biogas plant which involves daily substrate filling (Cow dung). One key informant from the study site reported that the installed digesters in the study site comprised 6m³ and 9m³ which cost TZS 2,300,000 and 3,500,000, respectively. Ultimately, the installation cost could be the reason for the system to be less adopted. In rural smallholder farmers, the adoption of this technology might be due to clean energy use campaigns run by environmental stakeholders to mitigate the climate change brought by deforestation. This was evident as reported in the African biogas partnership program covering a few African countries including Tanzania [29]. Despite the system's advantages, such as greenhouse gas emission mitigation and improving health status, the adoption rate among the farmers is still low compared to Solid storage and daily spread, which are highly practiced [27]. Apart from the environmental and health benefits, the system offers the opportunity for a circular economy which relies on Reducing, Reuse, and Recycle (3Rs) resources [15].

The finding reveals that composting manure management systems were less adopted, where only 7.3% were practiced. This could probably be because the system is costful and labor-intensive in terms of digging, filling the pit, and turning the manure until the compost is ready for use. The finding agrees with [30] who reported that this type of management is less practiced. Furthermore, the absence of extension services regarding the significance of employing composting to turn cattle manure into compost could be another factor [31].

Liquid or slurry manure management systems were not commonly practiced. Only 6.1% of farmers practiced across the three locations. The reason might be due to labor demand because manure in this system contains high moisture content. The study result is similar to the study on the manure management system in Ethiopia by [28, 32]. The system is most common in modern dairy farms in Europe and has been proven to be an efficient and suitable manure management system in large farms in developed countries. This is because of the availability of modern equipment and techniques [33]. The system contributes to the GHG emission especially methane, due to high moisture content which favors methanogenesis if not properly managed.

4.2. Challenges to Biogas Technology Adoption

Some of the obstacles to technology adoption were identified by farmers in the surveyed locations. Farmers' reluctance to adoption of biogas is caused by limited labour for daily dairy management tasks including feeding biogas digesters which are typically performed by family members. This is because young people are reluctant to dairy activities including biogas technology due to direct contact with cow dung due to poor equipment. Unfortunately, the group engages in a pretty job of their preference in urban areas like Machinga, and motorcycles known as bodaboda [34]. This trend caused a family with fewer members to hesitate to adopt the technology. This result is in line with [35] who reported that labor influences biogas adoption. Moreover, limited herd size is a challenge limiting adoption probably because herd size affects the quantity of manure because the dung is a source of substrate for the digesters [36]. Additionally, the unavailability of technicians for installation and maintenance hinders continued operation. This was observed during a survey where some of the biogas plant was found inactive. This challenge discourages both adopters and non-adopters because neighbors are encouraged to embrace the technology by seeing active biogas digesters among adopters [37].

4.3. Reason for Abandoning Biogas Technology

Biogas technology adopters reveal the reason why they dropped the technology. Some biogas users abandon the technology due to the frequent failure of the biogas plant. Some of the beneficiaries reported that the biogas plant did not last long after installation due to malfunctions which

discouraged the consumers. The failure of the plant might be attributed to multiple factors, like the construction and installation of the plant below standard, operation and maintenance factors of the plant [38]. In addition to these, adopters were compelled to abandon the technology due to labor scarcity. This occurred as a result of the household members who typically performed work-related tasks leaving the family for various reasons, which caused the technology to be abandoned [39]. Moreover, the biogas adopters abandoned the technology due to limited space for the biogas accessories brought by other construction activities on the homestead. Another cited cause for the abandonment of biogas technology was water scarcity. Water is essential in mixing the substrate (dung) to promote anaerobic digestion and effectively produce methane gas [40].

4.4. Farmers' View on the Benefits of Biogas Technology Adoption

Farmers responses to the significance of biogas technology were mostly focused on domestic applications, such as cooking, fertilizer, time savings, and ease of use. Nonetheless, over 50% of respondents said that; they were "not aware" of the technology. This could be due to the lack of demonstrations and success stories, insufficient extension services to market the technology, bad impression of biogas as it is considered to be expensive, and a lack of funding for technology. Since the majority of smallholder farmers grow crops and gardens to support themselves and ensure food security, fertilizer appears to be a more significant benefit than the other benefits. For example, a biogas user key informant in the study area stated that he prefers to use biogas slurry in vegetable gardens because it repels pests while another farmer claimed that slurry boosts productivity, particularly in bananas. Therefore, bio-slurry is an alternative to costly industrial fertilizer. These outcomes are consistent with [41].

4.5. Factors Determining Adoption of Biogas Technology

The adoption of biogas technology is positively influenced by household size, whereby for every unit increase in household size, the adoption increases by two folds. This is because in smallholder farmers family members are responsible for daily dairy farming operations, including filling the biogas digester for biogas production. The finding aligns with [42, 43] who reported that a large family member has a high probability of adopting the technology. The family with few members, especially those who are eligible for work, affects the adoption of the technology [36].

The adoption of biogas technology is influenced by the household head's educational attainment. Although it was not statistically significant, farmers with higher levels of formal education appeared to adopt anaerobic digestion systems, as observed in Table 3, by having an odd ratio greater than one.

This is because the education exposes the client and opens their mind to critically observe the most effective methods for handling and managing manure. The finding concurs with the study by [44] who reported that an increase in the year of schooling increases the rate of adoption. This implies that education is a tool to bring changes among dairy farmers for ensuring optimum utilization of resources.

The adoption of biogas technology is positively impacted by the size of the farmer's farm (Table 3). The result was not statistically significant, but has an odd ratio greater than one, which implies positive association. This probably could be due to the biogas accessories requirement, which is space-demanding. The technology requires fixing the animal unit (cow shed), feedstock, and digester closer together to simplify filling of digester. Space is also required for digestate storage before being transported to the field. Studies [39, 45] support the findings. On the other side land also represents the wealth of the farmer that enables them to afford installation and maintenance of a digester, hence the chances of adoption increase [46].

The herd size owned by the farmer had a positive association with biogas adoption. This is because cow dung is a substrate for biogas digesters to generate methane used as a fuel. The amount of manure produced depends on the herd size and animal intake. This finding is consistent with a study by [47, 43] who reported that adoption of biogas is influenced by herd size. However, the amount of manure can be limited by animal management system like extensive grazing, where the animal droppings remain in the grazing area.

Financial status of the household has a significant impact on dairy investments and favorably influences the adoption of new technologies. The reason might be the financial capacity to afford the installation, maintenance, and operating costs; logistic regression results show that households with middle-class incomes have a significant positive influence on the adoption of biogas technology. Studies by [46, 48, 49] are in agreement with this finding. This factor was also reported by the household as a challenge toward the adoption of technology. This implies that smallholder dairy farmers with poor financial status are less likely to adopt low-cost management system. Toward this, access to credit with low interest and subsidies from dairy stakeholders can serve the purpose.

5. Conclusion

The study described smallholder farmers' manure management systems and the factors influencing the adoption of biogas technology as an effective manure management practice. Daily spread, solid storage, liquid composting, and an anaerobic digester are all part of the system that was observed; solid storage and daily spread were particularly popular. The biogas technology system was found to be positively impacted by socioeconomic factors, including household size, education level, household income, farm size, and herd size. Therefore, socioeconomic factors are important to consider in

ensuring the adoption of biogas technology among small-holder dairy farmers.

6. Recommendation

The study recommends a course of instruction to cover the education gap to provide dairy farmers with helpful knowledge and skills on good manure management systems. In dairy, stakeholders should ensure farmers' access to low-interest loans and subsidies on biogas facilities to allow low-income families to own the technology due to minimized initial installation costs. In sensitization of technology, farmers with larger herd sizes and family sizes should be targeted more. This is due to the availability of substrate for the digester and labour for its operation. Further research on the influence of other source of energy on biogas technology adoption in both urban and rural smallholder dairy farmers is required.

Abbreviations

SDF	Smallholder Dairy Farming
SDG	Sustainable Development Goal
CE	Circular Economy
AADGG	Africa Asian Dairy Genetic Gain
GHG	Greenhouse Gas Emission
VIF	Variance Inflation Factor
PRA	Performance Recording Agent of the Project
ODK	Open data kit
SPSS	Statistical Package for Social Sciences
S. D	Standard Deviation
df	Degree of Freedom
S.E	Standard Error
MMP	Manure Management System
Max	Maximum
Min	Minimum
TALIRI	Tanzania Livestock Research Institute
ILRI	International Livestock Research Institute
SUA	Sokoine University of Agriculture
χ^2	Chi- square

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Author Contributions

The work was carried out in collaboration with all authors.

Sabina Dawite: Designed the study, collected the data, performed data analysis, Validation, visualizing, manual script draft writing and editing

David Maleko: Study designing, data collection and statistical analysis, read, validation and improved the manual

script

Ismail Selemani: Study designing, data collection and statistical analysis, read, validation and improved the manual script

Eliamoni Titus Lyatuu: Methodology and visualization

Daniel Mshumbusi Komwihangilo: Methodology

Raphael Mrode: Methodology

Conflicts of Interest

The authors declare no conflicts of interest.

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