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Abstract. The aim of this paper was to determine the factors influencing biogas adoption as a livestock waste management among smallholder farmers in Indonesia. The study emphasized the positive influence of farmer engagement on the technology transfer process. A cross-sectional survey was conducted in Yogyakarta Province, Indonesia by involving 351 respondents who were smallholder practicing the Mixed Crops and Livestock (MCL) farming from 2013 to 2014. The results of Logit regression showed that the biogas technology adoption in Indonesia was influenced by attainment of formal education, women involvement in decision making, number of cattle in the household, household's income, availability of biogas instalment funding, and the degree of connectedness to stakeholders in the agricultural technology transfer system. The study concluded that the availability of biogas installation funding and better engagement to the technology transfer stakeholders positively influenced the biogas technology adoption among MCL farmers.

1. Introduction

Biogas technology for smallholder farmers household has been promoted across the Asia countries as an applied technology in livestock waste management [1]. Sub Saharan African countries have also gained momentum on the promotion of biogas technology since 2007 to support their household activities such as cooking and heating [2]. The use of biogas is aimed to substitute for the fossil-based energy consumption which increases by 3% per year along with the population growth [3]. However, Indonesian is facing the low rate of biogas technology adoption compared to other Asian and Sub Saharan African countries [4]. The low rate of biogas technology adoption indicates that the few numbers users have installed the biogas technology within a high number of potential users in the population.

Biogas is perceived as a technology to provide renewable energy and slurry for organic fertilizers by treating various wastes from animals [5]. Smallholder farmers expect that by adopting biogas, they will reduce the use of firewood, conventional gas, and even chemical fertilizers [6]. As an innovation, biogas technology is often characterized as a technology with high investment and maintenance costs with a required number of cattle in the farm household [7]. Studies in biogas technology adoption showed that socio-economic characteristics (e.g. age, education, family size, and in position of having access to a formal credit) and farm heterogeneity (e.g. land size and number of livestock) may constrain farmers' decisions to adopt or to reject new technologies [8-10] The availability of biogas installation financial support in a biogas project scheme can be the most important determinants for the biogas technology adoption process [11-12].

However, a study on biogas technology transfer was lacked on the study on the knowledge exchange among stakeholder of technology transfer. The study aimed to identify the influence factors of biogas technology adoption emphasizing on the degree of the farmer connectedness towards to the technology transfer stakeholders. It may explain why the low rate adoption occurred in the context of the developing countries especially Indonesia.

2. Methods

The study was designed as a cross-sectional survey research through personal interviews with the farm household head by using a questionnaire. The Yogyakarta Province was selected as the survey area where more than 80% of the farmers are smallholders practicing mixed farming [13]. The primary data were collected from 351 smallholder farmers with less than 0.5 Ha of land tenure [13]. Biogas adopters were selected according to their willingness to participate in the research in the surveyed area and, at least, one biogas non-adopter was selected for each biogas adopter in the same area [11].

Table 1. List of the variables

Acronym	Variable Description	Type of Measurement	Expected Sign
Dependent variable			
adopt	Adoption of the biogas technology	Dummy (1=Yes, 0=No)	
Personal characteristics			
age	Age of respondents	Years	-/+
educ	Formal education level	Years	+
sizehh	Size of household	Numbers	+
women	Women involvement in decision making	Dummy (1=Yes, 0=No)	+
group	Membership of a farmer's group	Dummy (1=Yes, 0=No)	+
Household's economic status			
income	Household's income	Thousand rupiah	+
credit	Having access to formal credit	Dummy (1=Yes, 0=No)	+
Farm characteristics			
land	Household's land tenure	Hectares	+
cattle	Number of cattle in the household	TLU[a]	+
Presence of external factors			
fund	Availability of biogas installation funding	Dummy (1=Yes, 0=No)	+
agentexps	The degree of connectedness to the stakeholders	Proportion of 1	+

[a)] TLU is a Tropical Livestock Unit where a 250 kg mature cow equals 1 TLU [14]

[b)] The adopted formula for the degree of connectedness is $E = \frac{T}{N}$ [15], where E is a degree of connectedness to the stakeholders; T is the number of personal contacts; and N is the number of stakeholders that in this study is restricted to four agricultural technology transfer institutions (extension workers, research institutes, universities, and NGO)

The technology adoption process can be seen as a binary choice problem, where two different outcomes (adoption or non-adoption) may be observed. In the model, the parameters of biogas technology adoption decision based on personal characteristics, household economic status, farm characteristics, and presence of external factors were estimated (Table 1). A Logit model was used to estimate the model. In the decision-making process, it is assumed that the farmer weighs the marginal advantages and disadvantages of technology adoption. Parameters of technology adoption are not usually observable. However, a linear relationship of the biogas technology adoption can be assumed and expressed as a latent variable, y_i^*, a function of observed explanatory variables, x_i, and an error term,ε_i:

$$y_i^* = x_i'\beta + \varepsilon_i \tag{1}$$

Thus, the adoption of the biogas technology can be explained by a binary model with only two given answers: if yes, $y = 1$ and otherwise, $y = 0$. Furthermore, the probability of $y = 1$ is described by a general formula as following:

$$Pr(\,Y_i = 1 \mid x_i\,) = G(x_i, \beta) \tag{2}$$

where G is a function with the only values zero and one which may be specified in the following way:

$$\Pr(Adopt = 1) = G(\beta_0 + \beta_1 x_1 + \cdots + \beta_k x_k + e) \tag{3}$$

where the Pr($Adopt$ = 1) measures the probability of biogas technology adoption by the individual farmer given the explanatory variables $x_1, \ldots, x_k$. The β_0 is the intercept and $\beta_1, \ldots, \beta_k$ are the estimated parameters for the explanatory variables while e is an error term. The Logit model is based on the logistic distribution:

$$G(z) = \frac{\exp(z)}{1+\exp(z)} \tag{4}$$

In the Logit model, the logistic distribution is a cumulative distribution function for a standard logistic random variable.

3. Results and discussion

Table 2 showed the summary statistics for the explanatory variables of the biogas technology adoption among the respondents. Furthermore, the estimation to predict the biogas technology adoption among smallholder farms in Indonesia consisted of two models (Table 3).

Formal education attainment, a higher income, and cattle ownership significantly increased the probability of biogas technology adoption (Table 3). Studies of Indonesian farmer's behaviour on technology adoption supported the finding that the level of formal education of farmers positively influences the propensity to adopt new technologies [16]. A farmer with a higher income had more affordability to finance the biogas in terms of investment and maintenance [17]. The cattle ownership implied that the number of cattle kept in the households is required to produce manure for biogas [11]. The number of cattle also indicated the size of the household's capital assets in farms [18].

Table 2. Descriptive summary statistics of the explanatory variables

Variables	Min	Max	Mean	
			Adopters (n=171)	Non-Adopters (n=180)
age	23.17	75.92	51.55	52.24
educ	0.00	21.00	9.25	7.37
sizehh	1.00	11.00	4.00	3.69
women[1]	0.00	1.00	0.88	0.59
group[1]	0.00	1.00	0.71	0.63
income	30.00	133,675.00	27,888.65	13,446.19
credit[1]	0.00	1.00	0.64	0.56
land	0.01	1.05.00	0.25	0.16
cattle	0.00	15.00	3.01	1.19
fund[1]	0.00	1.00	0.91	0.14
agentexps	0.00	1.00	0.35	0.24

[1)] Mean of dummy variables is a frequency of 1

Table 3. Logit regression analysis predicting the determinant factors of biogas technology adoption

Variables	*Coef. (SE)*	*ME (SD)*	Variables	*Coef. (SE)*	*ME (SD)*
Personal characteristics			*Farm characteristics*		
age	-0.01	-0.001	land	0.01	0.001
	(0.02)	(0.002)		(0.99)	(0.08)
educ	0.10*	0.01*	cattle	0.40***	0.03***
	(0.06)	(0.01)		(0.14)	(0.01)
sizehh	0.10	0.01	*Presence of external factors*		
	(0.16)	(0.01)			
women	1.36***	0.11***	fund	3.99***	0.33***
	(0.46)	(0.04)		(0.42)	(0.03)
group	-0.61	-0.05	agentexps	1.19*	0.10*
	(0.43)	(0.04)		(0.72)	(0.06)
Economic aspects			constant	-10.71***	NA
				(3.06)	
log (Income)	0.40**	0.03**			
	(0.16)	(0.01)			
credit	-0.67	-0.17			
	(0.43)	(0.10)			
Number of observations			351		
LR joint significant test			2.82* (df=1)		
McFadden Pseudo R^2			0.591		
Log-likelihood			-99.49 (df=12)		
Chi-Square			287.37***		
Total correctly predicted (%)			88.60		
% correctly predicted (adopters)			90.06		
% correctly predicted (non-adopters)			87.22		

- ME (Marginal Effect) is the Partial Effect of Average (PEA), SE (Standard Error), SD (Standard Deviation), NA (Not Applicable)
- The joint significant test is according to the model 1
- *P < 0.1; **P < 0.05; ***P < 0.01

Availability of biogas installation funding showed the highest effect on the propensity for technology adoption compared to all the other explanatory variables. The high significance of the fund indicated that the biogas technology instalment in farmer society is highly dependent on the availability of installation funding [12, 19]. Any dependencies towards the external funding might potentially hamper the sustainability of the technology dissemination especially when the financial support was not available. Therefore, potential adopters should be encouraged to participate in the process of technology transfer rather than by giving the biogas instalment grant for free [20].

The connectedness of farmers into biogas technology transfer process encouraged the farmer to obtain adequate information and knowledge about the technology which may lead to better understanding of biogas technology [10, 21]. However, with less than 40% of the degree of connectedness among the farmers (see Table 2), the farmer interactions with stakeholders were considered at a low level. Farmers had not actively participated in the knowledge exchange activities about new technology in the technology transfer process. As consequences, farmers were facing a lack of understanding of biogas technology and its relevant knowledge. This situation caused that the biogas technology had not been optimally utilized among biogas adopters and the potential adopters prefer to delay the technology adoption [6-7]. Therefore, knowledge dissemination to provide an understanding of biogas technology should be expanded by tightening the interaction between farmers and the rural technology transfer stakeholders such as extension workers, researchers, NGO’s, and universities.

4. Conclusions

This study confirmed that biogas technology adoption among MCL farmers in Indonesia is influenced by attainment of formal education, women involved in the decision making, number of cattle in the household, the household's income, availability of biogas instalment funding, and the degree of connectedness to stakeholders in the technology transfer. Availability of biogas installation funding indicated to have a very dominant effect on technology adoption among smallholder farmers. Meanwhile, the farmer participation into a knowledge exchange was influential in biogas technology adoption indicated by the significant role of connectedness to the technology transfer stakeholders.

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