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Biogas Technology Diffusion Among Farmers Through Rural Communication Network: A Case from Indonesia

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Abstract

This paper aims to describe the process of farm biogas diffusion among mixed crops and livestock farmers in Indonesia. Social network analysis is applied to a case study in the Yogyakarta Province, to shed light on farmers' knowledge networks. Primary data originate from a social network questionnaire administered to potential biogas adopters. Once mapped, networks were analyzed via the estimation of centrality measures. Consistent with previous literature about developing countries, study findings show that the farmers' degree of connectivity is positively correlated with their likelihood to adopt farm biogas. Direct information exchange among neighbors may be effective in encouraging new adoptions. This research points out the existence of time lags between information retrieval and technology adoption which may be among the motives of the slow rate of farm biogas diffusion in the case study area, besides uneven understanding of the practical implications of biogas adoption. The availability of a structured network of extension services may speed up farm biogas diffusion among farmers in Yogyakarta

Keywords: diffusion of rural innovation; social network analysis; agro-energy knowledge networks; developing countries

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1.0 Introduction

Social, structure, and institutional factors combining with features of local system are really important determinants of innovation adoption among agricultural society (Gava, Favilli, Bartolini, & Brunori, 2017). Smallholder farmers in developing countries often rely on other neighboring farmers to access new technologies, ideas, and other agricultural production methods within a farmer-to-farmer communication network. The communication network has an often greater impact on accelerating the diffusion of selected technologies compared to the formal institution from public or private sectors (Alene & Manyong, 2006; Grisley, 1994).

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The technology diffusion within a farmer society is basically built upon the traditional dissemination among farmers based on what they have seen and tested and thereafter circulatingthe information to their neighbors (Kormawa, Ezedinma, & Singh, 2004). Communication among farmers creates a social network which often promotes the acceleration of technology diffusion (Banerjee, Chandrasekhar, Duflo, & Jackson, 2013; Grisley, 1994). Knowledge exchange and innovation transfer exist through a farmer-to-farmer communication mechanism in which a new technology is diffused and spread throughout the farming society (Alene & Manyong, 2006).

Unfortunately, some complex technologies require more technical advice and knowledge which may not be available in the farming community (Conley & Udry, 2001; Rogers, 2003). However, new technologies with a high complexity are often developed in line with a more advanced farming practice (Chang et al., 2011; Feder, Just, & Zilberman, 1985). In a more complex technology and interaction, knowledge triangle stakeholders—such as research, education, and extension—must be involvedare in the diffusion process (Esposti, 2012). It consequently leads to a slow diffusion among farmers if the technology requires specific technical knowledge to be employed (Batz, Peters, & Janssen, 1999).

Technology diffusion in the farming community seldom follows a single mechanism or strategy. However, there are two important models to explain technology diffusion strategies: (a) the linear model, and (b) the 'one-to-one' exchange of information model (Black, 2000). A linear model basically refers to the institutional mechanism in which the diffusion of a new technology is promoted by public and/or private projects directly to the farmers (Freeman, 1995). Whereas, the 'one-to-one' advice or information exchange model consists of interpersonal communication from adviser to farmers and/or farmers to farmers. A 'one-to-one' information exchange between farmers is considered as a farmer-to-farmer communication mechanism.

A combination of these two models seems to be an ideal strategy to accelerate technology diffusion (Grisley, 1994). Direct contact and advice of public extension service with the farmers network might encourage the farmers' participation in disseminating technology throughout the society (Hoang, Castella, & Novosad, 2006). The appropriate private and public institution advice combined with the farmers existing network could create a rural innovation system which might accelerate the intensification of production and technology adoption (Spielman, Byerlee, Alemu, & Kelemework, 2010; Spielman, Davis, Negash, & Ayele, 2011). On the other hand, perceived as a complex technology, biogas technology diffusion follows the common model of technology diffusion by combining the role of public and private projects and farmer-to-farmer communication. However, the rate of technology diffusion is often at a low level in the farmers' community (Mwirigi et al., 2014; Tigabu, Berkhout, & van Beukering, 2015). A description of the biogas diffusion process in the farming community can be essential to evaluate the biogas project in developing countries. This study aims to describe the process of biogas technology diffusion among MCL farmers in Indonesia through a combination of institutional mechanism and farmer-to-farmer communication network.

2.0 Methodology

A network perspective can be a useful method to understand the relationships and interactions between people and groups and its ability to capture information flows and attributes within the interaction (Spielman, Ekboir, & Davis, 2009). Social

Network Analysis (SNA) can be used to define a set of those actors or nodes—individuals, agents, or groups—that have a relationship with each other which is represented by ties between actors (Hanneman & Riddle, 2005). A farmer network perspective can investigate how the information is shared with the social structure that may affect technology adoption (Goswami & Basu, 2010). The information flow begins with the agents, who are attached to a private or public institution, contacting or meeting with potential farmers in the network to share knowledge about a new technology (Banerjee, Chandrasekhar, Duflo, & Jackson, 2013). These potential farmers, who are most likely placed in the core position of the network, are more active in acquiring new information and knowledge beyond the farmer network (Isaac, Erickson, Quashie-Sam, & Timmer, 2007). When the potential farmers adopt a new technology, it indicates the early diffusion stage of a new technology in the society (Monge, Hartwich, & Halgin, 2008). This new technology is continuously transmitted into the society to other neighboring farmers in the network (von Bock und Polach, Kunze, Maaß, & Grundmann, 2015). Identifying the farmer network allows us to describe the complete process of biogas technology transfer among MCL farmers.

In many empirical studies, network centrality is often used as a predictor of an outcome such as the adoption of an innovation (Spielman et al., 2011). For instance, a study on the diffusion of microfinance in rural areas demonstrates how an individual's centrality in a network may predict the eventual adoption of loans (Banerjee et al., 2013). Another study shows that an actor's centrality can mediate the impact of individual attributes in an organization network (Ibarra, 1993). A study on the core-ness position in a network shows that an individual with a higher degree of centrality and closeness to others in the network indicates an ability to convey a message to others (Borgatti, 2005). The core position more probably becomes a conveyor of the message to their neighborhood (Isaac et al., 2007). In addition, farmers in the core position are considered as potential early adopters who are able to accelerate the technology diffusion (Banerjee et al., 2013).

A case study combined with SNA to analyze farmers' communication networks and social demographic attributes was applied in this paper to obtain a possible answer to such questions, based on evidence of investigation within a scope of a particular group or individuals (Gillham, 2000). The use of SNA captures the complexity of relations among the actors and gives a background understanding of the relations, ties, and attributes among the actors (Coulon, 2005). The research was conducted in Umbulharjo, a rural area in Sleman district of Yogyakarta Province, Indonesia.

The survey about the farmers' network was conducted by involving nine neighboring farmers from the sub-village. The study was based on participants who lived in the same area—including adopters and non-adopters—who were listed in the biogas technology adoption survey prior to this study in 2013. Another requirement was that the participants knew each other and had been informed about the biogas technology. Since the sampling size in the network research had little or no effect on the estimation, the sampling process solely depends on the research objectives (Galaskiewicz, 1991). In order to fulfill the objective of this study, we specifically asked: "With whom do you share the biogas technology information?" Each farmer indicated which of the other eight neighboring eight farms they had given information to or received information from?. The information source about biogas technology was also attributed to the farmer to identify the pattern of how the technology diffused into society. To get data about biogas information sources, we specifically asked: 'From whom the farmers firstly received the information of biogas technology?' We also provided choices to participants whether from (a) public or private institutions such as extension workers, universities, research institutions and NGO's, or (b) from the neighboring farmers. More specifically, a farmer who received the information from a public or private institution was categorized as exposed to the institutional mechanism process. Otherwise, a farmer who received the biogas information from a neighboring farmer was categorized as exposed to the farmer-to-farmer communication mechanism. Other attributes such as age and income level were included as control variables to show the individual's background. The farmer's responses were coded as binary variables indicating the presence (1) or absence (0) of a tie and tabulated into a matrix (Hanneman & Riddle, 2005). Data were analyzed in a descriptive approach by considering the analysis of social network results.

The process of biogas technology diffusion can be described by measuring the group of network centrality which is formed by a relation between two actors in the network. This study employed an ordered pair of farmers as a data collection technique which is commonly used to gather the data to estimate the point of network centrality (Galaskiewicz, 1991). The sampling technique ensures that every actors in the network have at least one related pair. With nine farmers participating in the research, this study employed a 9 × 9 matrix as a sample set in the analysis which was able to take advantage of some aspects of explaining the phenomena based on network theory and technique (Costenbader & Valente, 2003). However, this study is not intended to be generalized beyond this area since biogas adopters' background may vary in other areas.

3.0 Results

3.1 Farmer Characteristics

Among the nine farmers who are included in the case study, there are three farmers who have not adopted the biogas technology (see Table 1). The age range of the farmers is 30 to 72 years, but the average age of the farmers is 49 years. Most of the MCL farmers have finished primary and secondary level education while only one farmer has attained high secondary level education. Meanwhile, the farm household income level is mostly at a lower income level while only one farmer has a higher income level, and three farmers have medium income levels. Regarding farm characteristics, farmers land ownership ranged from 0.1 ha to 0.5 ha, with the average being 0.24 ha.. Cattle ownership among the farm households ranges between one to 10 Tropical Livestock Units (TLU), with the average being 4.6 TLU. Table 1 also shows that the biogas technology initially diffused to the network in 2009, indicated by the year of earliest individual adoption. Most of the early adopters in the network received the information about biogas from an institutional mechanism (NGO or Government).

Table 1. *Farmer's Attributes*

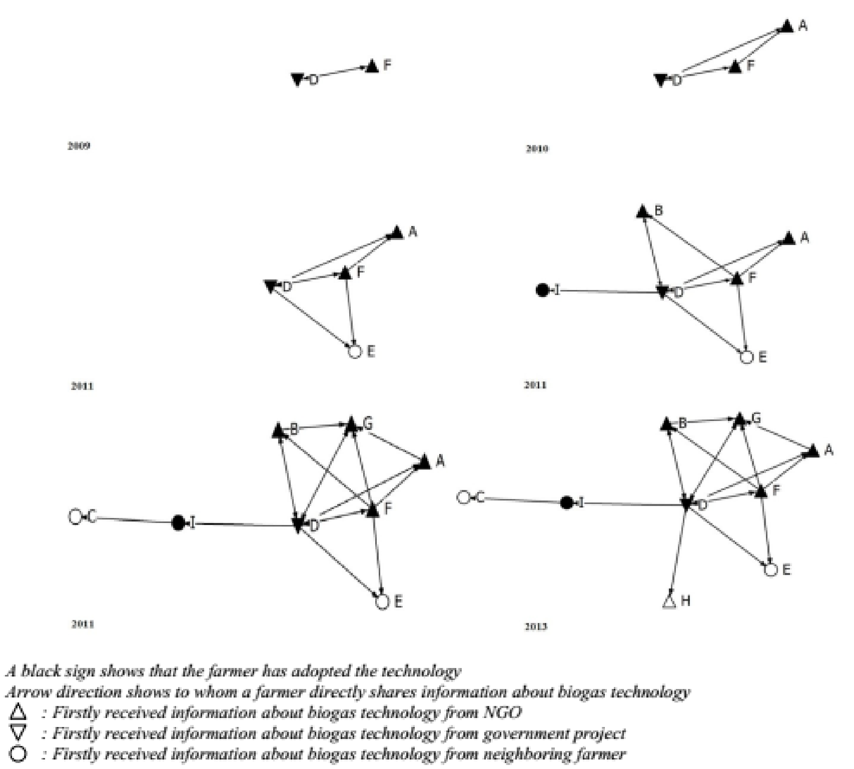
Farmer	Status	Age (years)	Educational level[a]	Income level[b]	Land size (Hectare)	Number of cattle (TLU)	Informed about biogas systems	Adoption of biogas system	Sources
A	Adopter	72	primary	Higher	0.2	7	2010	2011	NGO
B	Adopter	43	lower secondary	lower	0.1	3	2011	2011	NGO
C	Non-Adopter	51	primary	lower	0.3	2	2011	-	Neighbor
D	Adopter	36	lower secondary	medium	0.3	10	2009	2010	GOV
E	Non-Adopter	44	lower secondary	lower	0.1	1	2011	-	Neighbor
F	Adopter	50	primary	medium	0.5	9	2009	2009	NGO
G	Adopter	30	primary	lower	0.25	3	2011	2011	NGO
H	Non-Adopter	69	primary	lower	0.15	3	2013	0	NGO
I	Adopter	45	higher secondary	medium	0.29	4	2011	2011	Neighbor
Average		49			0.24	4.6			

[a] Lower income level (Average income <Indonesian Rupiah (IDR) 2,500,000 per month); medium income level (IDR 2,500,000 to IDR 5,000,000—on average per month); higher level (> IDR 5,000,000—on average per month)
[b] Primary level (≤ six years attending formal education); lower secondary level (seven to nine years attending formal education); higher secondary level (10 to 12 years attending formal education)

3.2 Biogas Technology Diffusion Among the MCL Farmer Network

In accordance with the biogas technology diffusion process, the information flows and the technology adoption indicate that the biogas technology has been diffusing since 2009 (see Figure 1) Biogas technology information sharing by two nodes (farmers)—D and F—becomes the starting point of the information flow in the network. The arrow direction between the nodes indicates the direction of information sharing about biogas technology between two farmers. For instance, the arrows between D and F indicate the information exchange process in which D shares the information about biogas to F and vice versa. Then, one more node adopted biogas in the network in 2010—A—showing the information flows of biogas technology from the previous adopters. Hereafter, in 2011, more nodes are included in the network indicated that five more farmers are exposed to the information about biogas technology. The additional farmers in the network consist of three adopters—B, I, and G—and two non-adopters—E and C. One out of three adopters—I—is initially informed about the biogas from neighboring farmers while others—B and G—have received the information from institutions. The non-adopters—E and C—are both first informed about the biogas technology from their neighbors. In the case of farmers I, E, and C, the information sharing from farmers D, F and I respectively may probably be the first information that they have received about biogas technology. Finally, one farmer—H—who is firstly informed by the institutions is included in the network in 2013. This node is staying in the non-adoption state, up to the time of data collection, although the neighbor farmer has shared the information and experience of the biogas technology.

Figure 1. The diffusion process of biogas technology among the MCL farmers.



Source: Primary Data (2014).

According to the centrality roles, farmer D has a high degree of centrality, eigenvector value, and betweenness centrality in the network (see Table 2). This farmer can be considered as an early adopter of the biogas technology in the network by receiving information from the institutional mechanism model of biogas technology transfer from both NGO and government project (see Figure 1). It may indicate that an individual farmer with a higher degree of centrality and with more ties in the network acts as an information brokerage in the network. The brokerage function of farmer D is very dominant so that most of the information about biogas technology passes through D in the network. The centralization indexes (see Table 2) show that the MCL farmer to farmer communication network is 62.5%, 55.5 %, and 39.3% based on the measurement of Degree of Centrality, Eigenvector Value, and Betweenness centrality respectively. These numbers are close to a maximum centralization index (100%) which means that the biogas information in the network is more centralized to a single farmer. In other words, the information about biogas is unequally distributed within the network. It confirms that the knowledge of biogas technology is more beneficial for an elite group of farmers who have a central position in the network and are well connected to each other (Isaac, et al., 2007).

Table 2: *Individual farmers' attributes and role of centrality in the networks*

Actors	**Degree of Centrality**	**Eigenvector Value**	**Betweenness**	**Adoption Status**
A	3	0.348	0.50	Adopter
B	3	0.348	0.83	Adopter
C	1	0.034	0	Non- adopter
D	7	0.519	24.25	Adopter
E	2	0.245	0	Non- adopter
F	5	0.466	2.75	Adopter
G	4	0.417	8.83	Adopter
H	1	0.129	0	Non- adopter
I	2	0.137	5	Adopter
Centralization Index	62.50%	55.45%	39.30%	

4.0 Discussion

Figure 1 shows that the adopters are more in the central position of the network. Biogas adopters are proven to have more ties or better connections to their neighbors and to bridge the information flow to the other farmers. The tendency of the centralized position of biogas adopters in the network confirms that information of technology and knowledge passes through a brokerage farmer in the central network to the periphery of the network (Spielman et al., 2011). After farmers in the central position of the network have adopted the technology, the diffusion will proceed to the next process in a farmer to farmer communication mechanism. Farmers in the periphery position only receive the information from their neighbors. They have a tendency to stay in the non-adoption state. In this phase, a lag of adoption time is identified as a cause of delay on the technology diffusion. In the early diffusion stage, the time gap between earlier and later adopters will potentially occur and the unequal understanding may prolong this gap (Eder, Mutsaerts, & Sriwannawit, 2015). Lack of bridging ties between two actors causes unequal information distribution which potentially promotes unequal understanding among them (von Bock und Polach et al., 2015). The farmer to farmer communication mechanism is facing problems of sharing the relevant knowledge to create an equal understanding of this complex technology.

The acceleration of technology in the network depends on farmers' perceptions of the relative complexity and risk of the technology and how to deal with an appropriate exchange of knowledge among the members of society (Abdulai & Huffman, 2005; Alcon, de Miguel, & Burton, 2011; Batz et al., 1999). For instance, due to budget constraints, the farming system based on natural ecosystems failed to be adopted by farmers in the uplands of the Philippines because many technologies needed to be implemented at the same time (e.g., soil erosion reduction, pest management, and intercropping (Pannell, 1999). Another case involves the adoption of sickles for rice harvesting in West Java Province of Indonesia and may show a different phenomenon. Perceived as a less complex and risky new technology, the use of sickles for harvesting is easily imitated by farmers in the society (Case, 1992). However, the level of trust about the information sources can lower the risk perception in regard to the complexity of the technology (Poortinga & Pidgeon, 2005). The institutional mechanism is perceived as a reliable information source at an early stage of technology diffusion by farmers in the central position. Farmers in the central position of a network have an essential role in transmitting the information throughout a network (Borgatti, 2005; Freeman, 1978; Isaac, 2012; Valente, 1996). Unfortunately, farmers in the center of the network are not seen as a trusted information source and capable of convincing their neighboring farmers about the advantages of biogas technology adoption. On the other hand, smallholder farmers as potential biogas adopters lack of knowledge-seeker independence (Gava et al., 2017). This may cause the unequal understanding about the technology and create a delay of diffusion of the biogas technology throughout the network.

5.0 Conclusion

Diffusion of biogas technology among farmers relies greatly on those public and private projects within the community that are actively involved in the technology diffusion process and considered as reliable information sources. Elite farmers who are in the central position of the network and who received information about the biogas technology from institutional mechanism have a tendency to adopt biogas technology earlier than other farmers in the neighborhood. These farmers are considered as a diffusion point in the central position characterized by more ties and well-connected to each other in the network. The information about biogas technology then passes through the brokerage farmers and is further transmitted to other farmers in the network. Farmers who first received the information about biogas from their neighbors have a tendency to delay the decision on adopting the technology. It means that the brokerage function within the network cannot work properly. This occurrence creates a lag of time in the adoption process among farmers which causes a slow rate of biogas technology diffusion. A better and more equal understanding about the technology among farmers should be evaluated in order to accelerate the technology diffusion in the local farm networks through self-accessible accurate information.

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