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The impact of biogas technology adoption for farm households – Empirical evidence from mixed crop and livestock farming systems in Indonesia

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ABSTRACT

This paper aims to study the impact of biogas technology adoption as a livestock waste technology to support Mixed Crop and Livestock (MCL) farming among smallholder farmers in Indonesia. A cross sectional survey was conducted to collect data from 351 farm households (171 biogas adopters and 180 non-adopters) in the province of Yogyakarta. This study employed treatment effects analysis based on propensity score matching techniques to evaluate the impacts of biogas technology adoption among the farm households. The results showed that the adoption of the biogas technology reduces firewood consumption of smallholder farm households in Indonesia. Unfortunately, the impact on the use of slurry for organic fertilizers and the use of gas (*Liquid Petroleum Gas*, *LPG*) as another household cooking energy could not be evaluated. This study empirically showed that the benefits of the biogas technology had not yet been optimized at the household level which may partly explain the slow rate of biogas technology diffusion among farmers. However, the consumption reduction of firewood as a benefit of using biogas contributed to behavioral changes of the women in the households especially with respect to firewood collection and cooking activities.

1. Introduction

Despite its potential multiple social and environmental benefits, the biogas technology is facing a low rate of adoption when it is transferred to smallholder farmers in developing countries [1,2]. This may slow-down the pace of the technology dissemination process among the potential users [3]. The speed of technology diffusion is actually characterized by the expected benefits of the technology which can be obtained by farmers [4,5]. Technologies with relative high complexity and major risks may lead to a slow technology diffusion among farmers [6]. Most of the smallholder farmers in developing countries are more likely to adopt a new technology if they observe that their neighbors positively obtain benefits by adopting that technology [7]. Thus, an individual farmer may adopt a new technology faster when he has documented evidence and observed the expected advantages of the technology from the neighbors.

The use of biogas for cooking in farm households seems unsuccessful since they keep using the firewood combined with Liquid Petroleum Gas (LPG) in their cooking activities [8]. Previous studies revealed that inadequate information concerning biogas was the most prominent weakness of the biogas technology diffusion to smallholder farmers. Difficult access to relevant extension services and other information sources caused insufficient knowledge of biogas and a low trust in the technology among farmers [9–11]. Those insufficiency of knowledge and trust about biogas were manifested in low technological capabilities among smallholder farmers in adapting the technology, taking economic risks, and modifying their behavior to apply the technology [12]. For instance, farmers perceive that the digester construction was too complicated and led to overcapacity compared with the amount of manure production on small scale farms [9,13,14]. Therefore, many farmers prefer to consume firewood, gas and/or oil as their household energy supply because they perceive that the price of biogas is not lower than the price of fossil based energy sources [11]. These are some of the main problems preventing farmers to use the biogas technology in their farm households.

Aside from the problems preventing the technology adoption, farmers acknowledge that the use of biogas may decrease the energy consumption even though it may not substitute the fossil based energy consumption [15]. Farmers may also gain advantages from the biogas' residue as the use of organic fertilizer which may decrease the use of chemical fertilizers [16]. In a broader perspective, livestock manure also significantly contributes to gas emissions which may increase the

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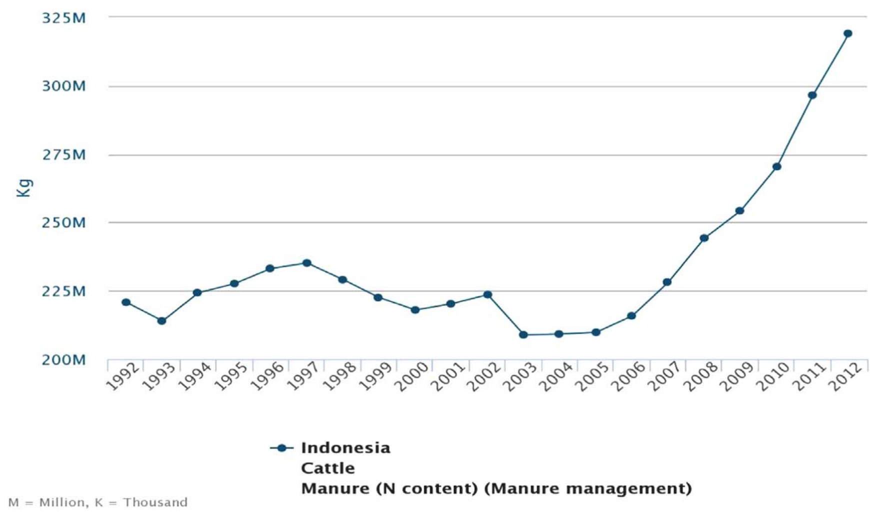

Fig. 1. Gasses emission produced by cattle's manure in Indonesia [25].

risks of global warming [17]. Therefore, an indirect broader impact may also be achieved by animal waste treatment in anaerobic digestion which supports the environmental conservation and reduces the impacts on climate changes [11,18,19].

2. Biogas technology development in Indonesia

In Indonesia, livestock waste has increasingly contributed to environmental problems especially in farming areas. Data from FAO [25] indicate that the livestock manure in Indonesia have increased the methane and nitrogen oxide emissions since 1990 (Fig. 1). With limited land and other limited farming resources, Indonesian smallholder farmers are mostly practicing Mixed Crop and Livestock (MCL) farming as a strategy to integrate their sparse resources [18]. There are about 42% farm households in the Indonesian population and 55% of them are smallholder farmers who are intensively farming MCL systems [20]. The implementation of MCL farming is extremely essential for smallholder farm households as about two thirds of the world's rural poor farmers rely on this practice as the backbone of the farming system [21,22]. Closer linkages between crop and livestock provide opportunities for a more efficient nutrient recycle within the farms, a more intensive practice of crop farming as well as provision of fodder for the livestock [22]. Thus, the interactions in the MCL farming system may be considered as a dynamic model where the crop, livestock and socio-economic components of farm households are integrated [23,24].

However, the dynamic interactions in MCL farming with limited resources are susceptible to water and air pollution risks, especially from the livestock waste which is triggered by the livestock's manure at farm level [26]. Therefore, anaerobic digestion was aimed at optimizing the manure treatment by distributing the excess of the nutrients as high quality organic fertilizer, a reduction of odor and pathogens, and biogas as a renewable energy may be applied as a mitigation technology for animal waste treatment [10,17]. With this treatment optimization, the environmental problems might be reduced as well as providing new opportunities for farm households.

On the other hand, during the years 2000–2011, the Indonesian energy consumption increased by nearly 3% per year on average. The total consumption is expected to increase along with the economic growth by 4.7% per year during 2012–2030 [27]. As share of the total energy consumption, the household energy consumption contributed to 30% during 2000–2011. Although the growth is considered low, the use of renewable energy in the household is politically promoted to decrease the dependency of the fossil based energy which can reach up to 80% of the total energy supply in Indonesia [28]. In the specific context of biogas as a livestock waste treatment, the adoption of biogas might reduce household expenses for fossil-based cooking by at least 40% [29–32]. Therefore, with respect to smallholder farmers, the technology may help them to supply renewable energy for cooking as well as to synergize their limited resources in an integrated farming system.

As an innovation, the biogas technology was introduced in Indonesia around 1970 and had largely been disseminated since 1980 by the Ministry of Agriculture [33]. Both private and public institutions have participated in the development of the technology for more than the last 30 years. For instance, more than 7000 household type digesters have been built by an international NGO, SNV The Netherlands, across the country by the end of 2012 [34]. However, the total number of biogas digesters is low in Indonesia compared to many other developing countries. At the farm level, two types of digesters, which are the household and the communal types, are commonly used by farmers. The communal type with a large scale digester is affordable for farms with more than 30 cattle [35]. Meanwhile, a smaller household type digester with the range size from 4 m^3 to 12 m^3 may be more affordable for a smallholder farm household who usually owns two or three cows in their herd [13,33,36]. This smaller type of digesters is more valuable for smallholder farmers due to its lower investment and maintenance costs to produce multiple benefits such as biogas and organic fertilizers [13,36,37]. However, based on the experiences with the technology dissemination within the last 35 years, we observed a slow rate of biogas technology diffusion among MCL farmers in Indonesia as well as in other developing countries.

Observing the benefits of a new technology can actually promote the speed of diffusion in the farm society. Among farmers, the main expected benefits of biogas technology adoption are the provision of biogas for cooking and supply of organic fertilizer [8]. These benefits are expected to lead to a reduction of the household's use of conventional energy for cooking from firewood and gas [38] as well as reduction of the use of chemical fertilizer in crop farming [39]. Previous studies at farm household levels have mainly revealed the differences between non-users and users of biogas to show the impact of the technology adoption without revealing whether the biogas adoption mainly caused the differences or other factors may explain those differences [8,30,31,40–44]. However, there is a lack of studies of the biogas technology diffusion to answer whether the technology had provided the intended benefits or expected impacts among the users after they had installed biogas in their households [3]. Therefore, an empirical model of treatment effect is needed to show the specific impact of the technology adoption by isolating the impact of other potential factors that may influence the impact of biogas technology in