Dairy cattle manure utilization by smallholder dairy farmers in West Java, Indonesia

Ening Ariningsih[1], *Erwidodo*[2], *Aldho* Riski Irawan[3,*] and *Handewi* Purwati Saliem[2]

[1] Research Center for Behavioral and Circular Economics - National Research and Innovation Agency, Jln. Gatot Subroto No. 10, Jakarta, Indonesia
[2] Research Center for Economics of Industry, Services, and Trade - National Research and Innovation Agency, Jln. Gatot Subroto No. 10, Jakarta, Indonesia
[3] Indonesian Center for Agricultural Socio Economic and Policy Studies - Ministry of Agriculture, Jln. Tentara Pelajar No. 3B, Bogor, Indonesia

Abstract. Besides producing milk and other products, dairy farms also generate manure polluting the environment. This study aims to identify smallholder dairy farmers' utilization of dairy cattle manure in West Java and the reasons that hinder it. This study uses IndoDairy end-line survey data, covering 410 dairy farmers in four districts in West Java (Bandung, Garut, Cianjur, and Bogor) in December 2021. A qualitative descriptive analysis was employed. The results show that only 42.8% of smallholder dairy farmers in West Java utilized cattle manure for fertilizer, a source of energy (biogas), and/or media for raising earthworms. At the same time, the rest, 57.2%, discharged it into their surroundings. Among the reasons the smallholder dairy farmers did not appropriately manage the manure were as follows: too difficult to adopt the technology (27.5%), high adoption cost (21.0%), farmers are already satisfied with the current practices (10.1%), limited input availability (9.5%), limited land (9.0%), lack of information of technology (8.1%), and many labors are needed (7.8%). Given the environmental problem that can be caused and the economic potential of dairy waste, the government should provide efficient and practical dairy waste management technology accompanied by intensive training and assistance.

1 Introduction

As one of the biggest milk-producing centers in Indonesia, West Java has an essential role in providing milk to meet ever-increasing domestic needs. This province is the third-largest milk producer after East Java and Central Java. In 2020, this province had a population of dairy cows of 122,505 heads, producing 293,490 tons of fresh milk, which accounted for about 31% of the total national milk production [1]. In addition to fresh milk and other products, dairy farms produce waste such as manure. Manure can have economic value if processed and utilized appropriately, such as for biogas [2–8] and fertilizer [9–11]. However, most dairy farmers in this region discharge it into their surroundings [12–14]. It

* Corresponding author: ir.aldhoriski@gmail.com

is estimated that as much as 60–90% of dairy cattle manure is released without any treatment, causing environmental pollution [12].

Together with nutrient leaching and run-off from fields, nutrients leaching from discharged manure can cause eutrophication, which occurs as a response to the excess nutrients in water surfaces, including nitrogen (N) and phosphorous (P) from livestock manures [15]. The released manure can also lead to contamination of drinking water sources due to the leaching of nitrate ($NO3^-$) [16], and to soil acidification, due to ammonia emission (NH3) [12]. The discharged manure ends up in local streams and rivers. A recent study [12] estimated that the dairy population in the Lembang region, West Java, contributes 2.5% to the total N pollution of the Citarum river.

Besides environmental pollution, cattle manure discharged into farms' surroundings causes local nuisance [12] and even human toxicity, especially in regions with a high population density [17]. The piles of manure deposited in the inhabitant's living environment cause a strong lousy odor that is not only annoying but also attracts flies [18], which could be a vector for several diseases, such as diarrhea [18,19].

Dairy cattle manure provides nutrients to plants and organic material to the soil and creates an essential component in the life cycle [20]. Utilizing cattle manure as a source of energy (biogas), bio-fertilizer, and other use can potentially reduce discharged manure and the problems it causes. Nevertheless, the utilization of dairy cattle manure is hampered for various reasons [12]. It is crucial to comprehend the current practices of dairy cattle manure management as well as the potential use and the reasons that hinder its utilization, so the appropriate recommendation can be proposed to the government to reduce discharged manure to the environment. Therefore, environmental problems can be overcome while improving farmers' income.

Some previous studies have examined the utilization of dairy cattle manure in various locations in Indonesia [12,21–27]. Most of them focused on its utilization for biogas. However, no study has examined the utilization of dairy cattle manure at the household dairy level in West Java. This study aims to identify smallholder dairy farmers' utilization of dairy cattle manure in West Java and the reasons that hamper its utilization by farmers. Recommendations are prepared based on current practices, the potential use of dairy cattle manure, and barriers to dairy cattle manure utilization.

2 Materials and Methods

This paper used data and information from the IndoDairy Smallholder Household Resurvey (ISHR) database, covering 410 dairy farmers in four districts in West Java (Bandung, Garut, Cianjur, and Bogor) conducted in December 2021. The dairy farmers included in this resurvey those among the 600 dairy farmers involved in the IndoDairy Smallholder Household Survey (ISHS) in 2017 who still managed dairy cattle at the time of the resurvey. The farmer samples in ISHS were taken proportionately to the total dairy farmers in the research location and randomly selected. The distribution of the dairy farmer samples according to research location is presented in Table 1. Data and information were collected through in-depth interviews using structured questionnaires, applying CommCare software on tabs. The data and information collected were analyzed using a qualitative descriptive approach. In this study, manure refers to the general term for feces, either with (e.g., slurry) or without urine (e.g., cow pies). Therefore, the dry material content might vary [14].

Table 1. Distribution of dairy farmer samples in research location.

No.	District	ISHS (2017)		ISHR (2021)		Exit (2017–2021)	
		N	%	N	%	N	%
1.	Bandung	300	50.0	204	49.8	96	50.5
2.	Garut	140	23.3	86	13.9	54	28.4
3.	Cianjur	80	13.3	63	15.4	17	8.9
4.	Bogor	80	13.3	57	21.0	23	12.1
Total		**600**	**100.0**	**410**	**100.0**	**190**	**100.0**

3 Result and discussion

3.1 Characteristics of dairy farms in West Java

Table 2 shows that the average dairy cattle ownership is 4.4 animal units (AU), while the average dairy cattle business is 4.7 AU. This finding is in line with the report published by USDA and GAIN [28], which revealed that smallholder dairy farmers typically keep 3–5 dairy cows with average milk production below 10 liters per day. The small-scale causes smallholder dairy farming to be inefficient [29], resulting in the high cost of milk production in the smallholder dairy farms. This situation makes it difficult for farmers to develop their businesses. The higher number of managed cattle compared to the number of owned cattle indicates the presence of a shareholding between the dairy farmers and the dairy cattle owners.

Table 2. Dairy cattle owned and managed by smallholder dairy farmers in West Java, 2021.

Category of cows[2]	Cow owned		Cow managed	
	AU[1]	(%)	AU[1]	(%)
Lactating cow (1)	2.7	61.1	2.8	60.8
Non-lactating cow (1)	0.4	9.0	0.4	8.4
Pregnant heifer (1)	0.4	8.8	0.4	8.8
Heifer (0.5)	0.3	6.3	0.3	6.3
Calf (0.25)	0.4	9.0	0.4	9.0
Non-productive cow (1)	0.0	0.0	0.0	0.0
Bull (1)	0.3	5.9	0.3	6.7
Total	4.4	100.0	4.7	100.0

Note: [1]AU = Animal unit; [2]Figures in brackets are conversion factors

According to Yusdja [30], the structure of dairy cow's milk production consists of large-scale businesses (more than 100 heads), medium businesses (30−100 heads), small-scale businesses (10−30 heads), and smallholder businesses (1−9 heads). Based on these categories, Table 3 shows that about 91.7% of the total respondent farmers are smallholder dairy farmers, while 8% are small-scale dairy farmers. Only two farmer respondents belong to the medium-scale category, and none belong to the large-scale category. Dairy farming has become the main occupation for 92.0% of smallholder dairy farmers in West Java. Some farmers in the smallholder category have a main occupation other than dairy farming, while almost all farmers in small-scale and medium categories make dairy farming their primary occupation.

Table 3. Characteristics of dairy farms by scale in West Java, 2021.

No.	Description	1–9 AU	10–29 AU	30–100 AU	>100 AU	All
1	Number of dairy farmers[2]	376	32	2	0	410
		(91.7%)	(7.8%)	(0.5%)	(0.0%)	(100.0%)
2	Age (years)	49.9	50.8	52.0	0.0	50.0
3	Education (years)	6.4	7.9	10.5	0.0	6.6
4	Dairy farming as the main occupation[2]	344	31	2	0	377
		(83.9%)	(7.6%)	(0.5%)	(0.0%)	(92.0%)
5	Land managed (ha)					
	- Food crops	0.06	0.80	0.04	0.00	0.12
	- Dairy farm	0.16	0.14	0.80	0.00	0.16
	- Grass	0.08	0.12	0.30	0.00	0.09
	- Oth. cattle than dairy cattle	0.12	0.30	0.00	0.00	0.13
	- Horticultural crops	0.01	0.11	0.00	0.00	0.02
	- Not used/idle	0.01	0.04	0.00	0.00	0.01
	- Others	0.01	0.00	0.00	0.00	0.01
	- Total	0.45	1.51	1.14	0.00	0.53

Note: [1]AU = Animal unit; [2]Figures in brackets are percentages from the total farmers in the corresponding aspect.

Average dairy farmers' landholding was only 0.53 ha. Table 3 shows that the land allocated for dairy farms does not increase linearly with the increase in the scale of dairy farms. However, the land allocated for grazing rises with the increase in the scale of cattle management. The percentage of households using land for dairy cattle is low (29.7%), with an average land area of 0.16 hectares. The farm households that allocate land for dairy cattle are farmers with larger-scale dairy farms. Meanwhile, small farmers generally use part of the yard area or merge with the house for cattle sheds, so the land area for dairy cattle is not recorded. Some farmers do not even have land for their cowsheds but use land in the tea plantation area provided by PTPN VIII, a state-owned company. This evidence is in line with previous research, which stated that part of some dairy farms is landless [14].

The scarcity of land for food crops, horticultural crops, and forage production leads to limited recycling of cattle manure as fertilizer. Suppose the dairy farmers have food and horticultural (vegetable) crop farming as a side business of dairy farm households. They can integrate it with dairy farming because, as in practice, manure (dung) can be used for fertilizer, while waste from food crops and vegetable crops is used for cattle feed. In addition, only 65% of dairy farmers plant grass/forage for feed with a limited land size, i.e., on average, 0.09 ha.

3.2 The utilization of dairy cattle manure by farmers

Assuming one dairy cow produces 20 kilograms of manure per day [31], on average, one dairy farmer's household has 94 kilograms of manure per day. In West Java, dairy cattle manure production reaches approximately 2,45 thousand tons per day or 73,5 million tons per month. Table 4 shows that only 42.8% of dairy farmers in the research locations utilized dairy cattle manure, either part or all, as fertilizer, source of energy (biogas), and media for growing worms. However, 57.2% of them practically discharged it into the environment without any treatment at all. A similar condition was found in Lembang Sub-district, where manure (either feces, urine, or both) was discharged into the environment

from most farms, used as a soil amendment, sold, or given away to other farms [13]. Likewise, some farmers, due to limited land, do not manage cattle manure properly and arbitrarily place it around the barn, thus affecting the cleanliness of the barn and causing a foul/stinging odor. Since most of the barns are close to farmers' houses and sometimes might be in a neighborhood with a high population, it will be a nuisance to the inhabitants.

Table 4. Dairy cattle manure utilization by dairy farmers by the district in West Java, 2021.

Manure utilization	Bandung		Bogor		Cianjur		Garut		All	
	n	%	n	%	n	%	n	%	n	%
1. Fertilizer	49	21.6	14	23.0	14	21.9	25	28.7	102	23.2
2. Source of energy/biogas	25	11.0	7	11.5	5	7.8	5	5.7	42	9.6
3. Media to raise worms	44	19.4	0	0.0	0	0.0	0	0.0	44	10.0
4. None	109	48.0	40	65.6	45	70.3	57	65.5	251	57.2

Fig. 1. Piles of manure around the barns at the research site.

In all research locations, manure disposal is generally not appropriately managed. It is simply thrown away. Farmers rarely use manure because they are in a hassle and they have no time, so they immediately dispose of it. However, some respondents (23.2%) use it as fertilizer, and a small percentage of respondents who have a manure processing unit for biogas use it as an energy source (9.6%) (Table 4). In addition, some farmers in the Pangalengan KPBS area use manure as a medium to raise worms (10.0%).

Utilizing manure for fertilizer is the most common practice done by farmers. They use it for food crops, horticultural crops, grass and other forage, and other plants. However, only a few farmers processed the manure for commercial purposes. For practical reasons, the food and horticultural crop farmers prefer to use subsidized chemical fertilizers. With the subsidized fertilizer limitation effective since May 2022, using manure as fertilizer would become one alternative to overcome the high price of chemical fertilizers. A previous study shows that most farmer respondents (79%) in Argentina, Brazil, and Chile would use manure as a substitute for chemical fertilizers [32].

Meanwhile, the limited land area for dairy farms and forage production has consequences. Since there is no grazing area, the dairy cows are kept in the barns, tied all the time, with no access to grazing. The limited land also challenges recycling cattle manure as a fertilizer. Applying manure to land for grass/forage production might cause over-fertilization because much manure is concentrated on small parts of land [13].

Biogas is one type of energy that can meet energy needs in rural areas. Manure utilization for biogas provides several advantages, namely reducing the unpleasant odor of livestock manure, preventing the spread of disease, reducing the effect of greenhouse gases, generating heat and mechanical/electrical power, and providing by-products in the form of

solid and liquid fertilizers [33]. However, the utilization of cattle manure for biogas is still limited. Most farmers constructed the biogas installation (biodigester) with the help of dairy cooperatives that give them credit.

In the Bandung District, access to an earthworm market supports farmers in doing vermicomposting. Aside from earthworms, farmers also get vermicompost, better known as '*kascing*,' which has high economic value. According to Ramos et al. [34], 30 days of vermicomposting is enough to get a high-quality organic fertilizer. However, 120 days are necessary for producing matrices.

3.3 Constraints to dairy cattle manure utilization

Limited land is an essential constraint for dairy farmers in West Java to manage dairy cattle manure appropriately. Farmers have limited land for forage and food crops of an appropriate size that can absorb dairy cattle manure and for processing it before applying it to the land.

The lack of incentives and sanctions causes most farmers to dispose of manure in the surrounding environment. Most farmers (80%) acknowledge processing cattle manure. However, farmers' lack of awareness causes only 2.9% of farmers to consider manure management a significant obstacle in the dairy industry. Table 5 shows various reasons stated by the dairy farmers for not carrying out dairy cattle manure processing. These include too difficult to adopt (27.5%), adoption cost is too high (21.0%), already satisfied with the current practice (10.1), limited input availability (9.5%), limited land availability (9.0%), lack of information on the technology (8.1%), and needs a lot of labors (7.8%). The reasons stated by the dairy farmers depict cumbersome management of the dairy cattle manure and a lack of knowledge.

Table 5. Reasons for not processing cattle manure stated by dairy farmers in West Java, 2021.

Reason	Bandung		Bogor		Cianjur		Garut		All	
	n	%	n	%	n	%	n	%	n	%
1. Too difficult to adopt	46	29.1	13	31.7	16	30.8	23	25.8	98	27.5
2. Adoption cost is too high	38	24.1	3	7.3	12	23.1	22	24.7	75	21.0
3. Already satisfied with the current practice	12	7.6	5	12.2	5	9.6	14	15.7	36	10.1
4. Limited input availability	12	7.6	8	19.5	7	13.5	7	7.9	34	9.5
5. Limited land availability	9	5.7	2	4.9	2	3.8	2	2.2	32	9.0
6. Lack of information on the technology	12	7.6	3	7.3	6	11.5	8	9.0	29	8.1
7. Needs a lot of labor	15	9.5	4	9.8	2	3.8	7	7.9	28	7.8
8. Not suitable with the surrounding condition	9	5.7	1	2.4	1	1.9	3	3.4	14	3.9
9. Current practice is better	4	2.5	0	0.0	1	1.9	3	3.4	8	2.2
10. Benefit is too long to be gained	1	0.6	2	4.9	0	0.0	0	0.0	3	0.8

Reasons 1 and 2 refer to the use of dairy cattle manure for biogas production. Farmers perceive that it is difficult to adopt the technology. This difficulty is due to some technical

problems such as lack of technical expertise, construction errors (leak biogas reactors), unreliable design, and manual handling. This is exaggerated by expensive construction costs. These factors hinder the development of biogas for the utilization of livestock manure by smallholder dairy farmers.

A study by Zahra et al. [12] revealed some constraints to the utilization of manure were mainly the scarcity of land, lack of a manure market, and lack of economic profitability of solutions. From the potential large-scale users' side, the main constraints to manure utilization were related to (cost) price, quality, and practical aspects, including the continuous availability of manure and ease of handling, transport, and application.

3.4 Some alternatives for dairy cattle manure management

Along with the increase in population, income, and awareness of the importance of consuming healthy foods, the demand for milk will continue to increase. Hence, the dairy industry is expected to continue growing to meet the increasing demand for milk. On the other hand, if not appropriately managed, dairy cattle manure produced by dairy farms will increasingly threaten the environment because a large dairy cow concentration would create more pollution. Furthermore, the transformation to intensive feeding generates fewer pollutants than household husbandry while potentially leading to intensive discharge [32,35]. This condition forces the implementation of good manure management so that pressure on the environment can be reduced. According to Herrero et al. [32], policymakers and stakeholders should encourage dairy farm manure reuse through incentives, technologies, and appropriate strategies to improve nutrient usage and reduce overall environmental pollution.

One alternative for utilizing dairy cattle manure is by implementing conservation dairy farming. It is a dairy farming system that produces most feed and forages with no-till, continuous diversified plant cover, and manure injection. The system has recently been developed and tested in Pennsylvania and has been proven to have the potential for soil fertility balance, reduced in-stream N, P, and sediment concentrations, and mitigated overland loss of nutrients and N volatilization. As a result, it improves water quality without sacrificing yield [36]. However, this system needs a more sizeable area that the farmers in West Java find challenging to meet due to land scarcity and limited capital and knowledge.

Due to the limited agricultural land managed by dairy farmer households, the opportunity to use manure for agriculture is obtained from its use outside the land they manage. Dairy farms are generally located in relatively high or mountainous areas with cool temperatures, suitable for growing vegetables, tea, and coffee, including coffee agroforestry. In these locations, there are tea plantations managed by PTPN VIII. Even in Bandung and Garut districts, some of the dairy cowsheds occupy the land of PTPN VIII. The barn is a communal barn located far from residential areas to reduce pollution for the surrounding community.

Horticulture, tea and coffee plantations, and coffee agroforestry have huge potential and opportunities for using dairy cattle manure. On the one hand, horticulture, tea, and coffee farmers are encouraged to use and become a market for organic fertilizers derived from dairy cattle manure. If necessary, agriculture in these locations is encouraged to become organic farming. PTPN VIII, with its vast tea plantations, is expected to be the driving force for the use of organic fertilizer from dairy cattle manure. On the other hand, dairy farmers are encouraged to process cattle manure into quality organic fertilizer in a profitable business framework to receive adequate incentives. For this reason, cattle manure processing technology that can be applied easily and practically by dairy farmers

and organic fertilizer application technology on agricultural land by end-users are needed, as well as training for farmers/end-users.

Dairy cooperatives must be encouraged to bridge dairy farmers as producers of organic fertilizers with farmers/farmer groups and PTPN VIII as end-users of organic fertilizer produced by dairy farmers. If necessary, formal agreements are made between dairy farmers and farmers/farmer groups/PTPN VIII to ensure the continuity of production and marketing as well as the quality of the organic fertilizers produced. Cooperatives are also expected to seek land for manure processing managed by cooperatives to overcome land limitations for processing and storing organic fertilizer. Thus, there is a need for a solution to collect manure from dairy farmers to the manure processing unit and transport the organic fertilizer to end-users. Parallel to technical solutions to the manure discharging issue that makes recycling of manure extremely difficult, a spatial development strategy is needed for the dairy sector in West Java, with land-based dairy farming being key to sustainable development [12].

4 Conclusions and recommendations

Most dairy farmers discharge dairy cattle manure to the surroundings, while others utilize it for fertilizer, a source of energy (biogas), and/or medium for raising worms. Lack of incentives for processing manure, no marketing access, and no sanction for discharging it to the environment have made farmers ignorant of its environmental pollution impacts.

Manure processing into organic fertilizer is one of the main alternatives that can be taken. Other manure utilization, such as biogas and medium for raising worms, needs to be continuously developed, as well as exploring the other potential uses for manures. In addition, it is necessary to conduct socialization, education, and advocacy on using manure for dairy farmers and farmers/end users. In addition to incentives, namely economic benefits for dairy farmers, to encourage sustainable manure management, there is also a need for sanctions (law enforcement) for farmers who dispose of their manure into the environment. For this reason, it requires support and commitment from all parties involved with facilitation from the government.

Dairy farmers should be encouraged to process dairy cattle manure under the management of dairy cooperatives. On the other hand, horticulture, tea, coffee farmers, and PTPN VIII should be encouraged and advocated for using organic fertilizer sourced from dairy cattle manure. The government should facilitate the technology for processing manure and organic fertilizer application in the field, which is practical and easy to implement.

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