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by J Mustabi

Global Journal of Environmental Science and Management
(GJESM)

Homepage: https://www.gjesm.net/

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ORIGINAL RESEARCH PAPER

Climate change mitigation and adaptation through livestock waste management

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ARTICLE INFO

Article History:
Received 01 Nivember 2022
Revised 03 January 2023
Accepted 10 March 2023

Keywords:
Adaptation
Climate change
Livestock waste
Mitigation
Perception

DOI: 10.22035/gjesm.2023.04.***

ABSTRACT

BACKGROUND AND OBJECTIVES: Farmer characteristics are recognized in this study. The characteristics, perceptions, willingness to adopt climate change mitigation, and awareness of livestock farmers toward livestock waste management are the main points for determining appropriate climate mitigation rules.

METHODS: This study was conducted in Enrekang and Barru Regencies of South Sulawesi. International Business Machines- Statistical Package for the Social Sciences 27 was used for this study. In descriptive statistics, data were compiled, and the age, long husbandry experiences (year), number of family member, number of farming assistant, gender, education, farmer group participation status, side job, type of business, cattle ownership status, number of cattle (head), and weight total of cattle's manure (kilogram per day) were examined qualitatively. A chi-square test was used to compare the experimental results (perception and knowledge of livestock manure management) with practical livestock manure management.

FINDINGS: This study found that the average age of farmers in the study area is 45 and 11.2 percent received have high formal education level from a university. Most of the cattle are male at 86.7 percent. Poor manure management system at 76.30 percent manure un-managed and un-appropriate farmer groups with more than 60 percent of the farmers un-joined farmer's group. Almost 50 percent of the cattle farmers are willing to learn manure management. Nevertheless, this study found that the respondents' knowledge and practical manure management, as well as the respondents' knowledge (0.837) and perception (0.343) of practical manure management, do not have any significant connection.

CONCLUSION: This study determines the full condition of cattle farmers in Barru and Enrekang Regencies. Barriers include low level of education, age of farmers, lack of manure management, and lack of willingness to join farmers group. Nevertheless, drivers, such as willingness to adopt manure management and high levels of experience in cattle farming, were also found. Enriching the knowledge and perception of farmers is essential in managing livestock wastes to mitigateof climate change.

NUMBER OF REFERENCES	NUMBER OF FIGURES	NUMBER OF TABLES
91	3	6

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Note: Discussion period for this manuscript open until January 1, 2024 on GJESM website at the "Show Article".

INTRODUCTION

Global demand for food, livestock feeds, fiber, and fuel has increased because of population growth and changing dietary patterns (Mairura et al., 2022). In 2019, the demand for meat reached 70 million tonnes and is predicted to rise to 74 million tonnes by 2023 (Meat Livestock Australia (MLA), 2020). In other words, the consumption of animal proteins will soar dramatically in densely populated areas of the world (McAuliffe *et al.,* 2018). The increase is also more associated with income and urbanization than with most other food groups that actually can be recycled (Sivakumar et al., 2022). In line, livestock is truly capable of converting protein sources that are not edible to humans into high-value protein and contributes almost 37 percent (%) of the world's protein supply (Food Agriculture Organization (FAO), 2018). Nonetheless, agriculture is also predicted as the highest enhancer of methane (CH_4) pollution (International Energy Agency (IEA), 2022), with livestock, including ruminants, one of the primary sources of agricultural emissions (Frank, 2017; FAO, 2021). The ongoing climate change and livestock production make the increase in production while reducing greenhouse gases (GHGs) and climate impact emissions difficult (Cheng *et al.,* 2022). In other words, rising numbers directly related to increasing carbon dioxide (CO_2) and CH_4 emissions (Agossou and Koluman, 2022). Thus, an effort to increase livestock's productivity can lead to an enhance of emissions on earth (Beauchemin *et al.,* 2020). In this sense, livestock causes water eutrophication, as well as air pollution, such as ammonia (NH_4) and GHGs emissions, directly and indirectly (Chang *et al.,* 2019). In comparison with other livestocks, such as buffalo, swine, goat and chickens, cattle farm is a major contributor to pollution and GHGs (Scherer *et al.,* 2018). Furthermore, in the tropics, cattle and oilseed products account for almost half of the deforestation and carbon pollution that causes GHGs (Creutzig *et al.*, 2019), whereas cattle production increased 18% in 2019 (FAO, 2021), thereby reaching 978.68 million head and is projected to reach 1,9009.69 million head in 2022 (Statista, 2022). This increase occurred because to the livestock can play an important role in ensuring food security on earth (Chungchunlam *et al.*, 2020). Furthermore, in husbandry, pollution due to livestock farming in the form of water, air, and soil can disrupt the environmental balance, including the comfort of the surrounding community, which can threaten health. Water pollution caused by livestock waste is due to the fact that the liquid waste is disposed of without being processed or filtered first and then channeled into waterways around the environment, potentially causing an unpleasant odor. The smell from livestock waste is caused by NH_4 gas and other chemical compounds, including phosphate and nitrogen, which are quite dominant. Other research states that livestock waste that contain nitrogen and phosphorus causes eutrophication and the death of fishes in rivers (Biagini and Lazzaroni, 2018). Eutrophication causes the oxygen content in water to decrease, thereby making surviving difficult for biota in aquatic ecosystems. Moreover, manure management is responsible for almost 12% of emission sources in 2021 (Environmental Protection Agency (EPA), 2010). Nevertheless, the livestock sector can also make a significant contribution to reducing the global temperature increase that causes climate change (Intergovernmental Panel on Climate Change (IPCC), 2022; Reisinger *et al.*, 2021). In this sense, livestock is indicated as the main agricultural contributor of reducing almost 38% of excess CO_2 emissions (IPCC, 2022) and more than 60% of total emissions aside from CO_2 with proper management (Frank et *al.*, 2018). Livestock waste comes in various forms, namely, solid, liquid, and gas. The waste generated by livestock is in the form of solid, liquid and gaseous waste. Solid waste on cattle farms include solid animal manure, leftover feed, and livestock bones and bodies. Liquid waste includes animal urine, blood when animals are injured, and water used for washing slaughtered livestock. Overall, all livestock organic wastes, such as silage, animal feed residue, slaughterhouse bio waste, sewage sludge, molasses and others, can be processed further. A total of 34.7% of the potential amount of cow dung can be used for further processing (Priekulis *et al.*, 2021). Storage and management of slurry (a mixture of urine, feces, water, and sand bedding material) are critical factors to consider during livestock and rearing practices (Guo *et al.,* 2019) because GHGs are formed during storage. Nitrous oxide (N_2O) results from the improper storage of manure and the use of various types of fertilizers. N_2O is a compound that harms climate change and is 265–298 times higher than CO_2 (Grossi *et al.,* 2019).

Under anaerobic conditions, CH_4 emissions occur as a result of organic matter degradation. Methane, a gas emitted by animals primarily through enteric fermentation and the improper storage of manure, contributes to global warming by 25 to 28 times than CO_2 (Wang *et al.*, 2021). The nitrification of ammonium (NH_4+) and denitrification of nitrate (NO_3) processes to produce N_2O (Liebig *et al.*, 2021). Based on these facts, long-term solutions for improved manure storage management must be considered. Treatment of slurry can reduce N_2O emissions at 50% and methane emission at 36% to 63% (Ruiz, 2022). Moreover, the substrate that is converted into CH_4 during anaerobic digestion processes can be used as a renewable energy source. The higher the organic matter content in its composition is, the higher the biogas production if manure is used as a substrate or co-substrate in anaerobic digestion processes (Van den Oever *et al.*, 2021). The anaerobic digestion reduced the GHGs by relpacing the consumption of fossil fuel due to the decline in the use and production of fertilizer (Kaparaju and Rintala, 2011). Conversely, in Indonesia, livestock waste is most often only disposed of in sewers or human yards, causing pollution to the environment (Nugraha *et al.*, 2021). The total production in the country has been rising in recent years (Statistic of Indonesia, 2021). Moreover, in 2022, the Ministry of Agriculture of the Republic Indonesia has committed to make this year as the year of animal husbandry and promised to encourage more cattle production in the next year (DGLAH-RI, 2022). Hence, modifying industry management practices is essential to lessen the contribution of livestock production to climate change (Rojas-Downing *et al.*, 2017). Additionally, these efforts can also increase farm profitability and environmental sustainability by improving farm animal welfare (Dawkins *et al.*, 2017; Fernandes *et al.*, 2021). In this sense, farmers' involvement in the area's agricultural development is essential to ensure the success of agricultural development and mitigation plans (Yuniarsih *et al.*, 2021). Recognizing the characteristics of farmers is also crucial (Reddy *et al.*, 2022) because farmers are the first line of defense against climate change (Rockney, 2022). This information is essential for public decision-makers to encourage the adoption of mitigation measures (Calciolari *et al.*, 2021). The research question is, what are the correlation between the perception and awereness of livestock waste management in the Enrenkang and Barru Regencies? These data include the basic steps in formulating adequate program procedures for climate mitigation. Second, the data can be used for further research that could lead to new ideas for creating mitigation strategies. Third, the study could facilitate a proper understanding between field stakeholders in creating new solutions. This study will contribute relevant information for education. Hence, this study will elaborate on the research by interpreting the relationship between the perception or awareness of livestock waste management practices. The characteristics, perceptions, and awareness of livestock farmers toward the livestock waste management will be investifared. South Sulawesi was selected becaise it is the third highest cattle producer in Indonesia at 1.46 million heads in 2021 (Statistic of Indonesia, 2022). The current study aims to investigate climate change mitigation and adaptation in various ways. This study was carried out in Enrekang and Barru Regency in South Sulawesi in 2022.

MATERIALS AND METHODS

Description of the study area and context

The Enrekang and Barru Regencies are located in South Sulawesi, Indonesia. The coordinates of Enrekang Regency are 3° 33‘ 52” South, 119° 46’ 29” East, and Barru Regency is 3° 14’ 36” South, 119° 40’ 53” East (Fig. 1). According to the 2020 Census, Enrekang Regency has a total area of 1,786.01 square kilometer (km^2) and a population of 225.172 people, whereas Barru has population of 184.452 people and an area of 1,174.72 km^2.

Data collection

This study was conducted in 2022 using the primary data from 49 selected respondents from Barru Regency and 49 selected respondents from Enrekang Regency. The selection of 98 samples was conducted by paying attention to breeders who consistently raise cattle, not seasoned breeders. Information was gathered through observation and questionnaire-assisted interviews for the survey. The study used a qualitative survey methodology, and semi-structured questionnaires were used to collect from purposively selected interviews. In terms of adoption, farmer characteristics are important factors in the success of the farming business (Small *et al.*, 2022). Observable

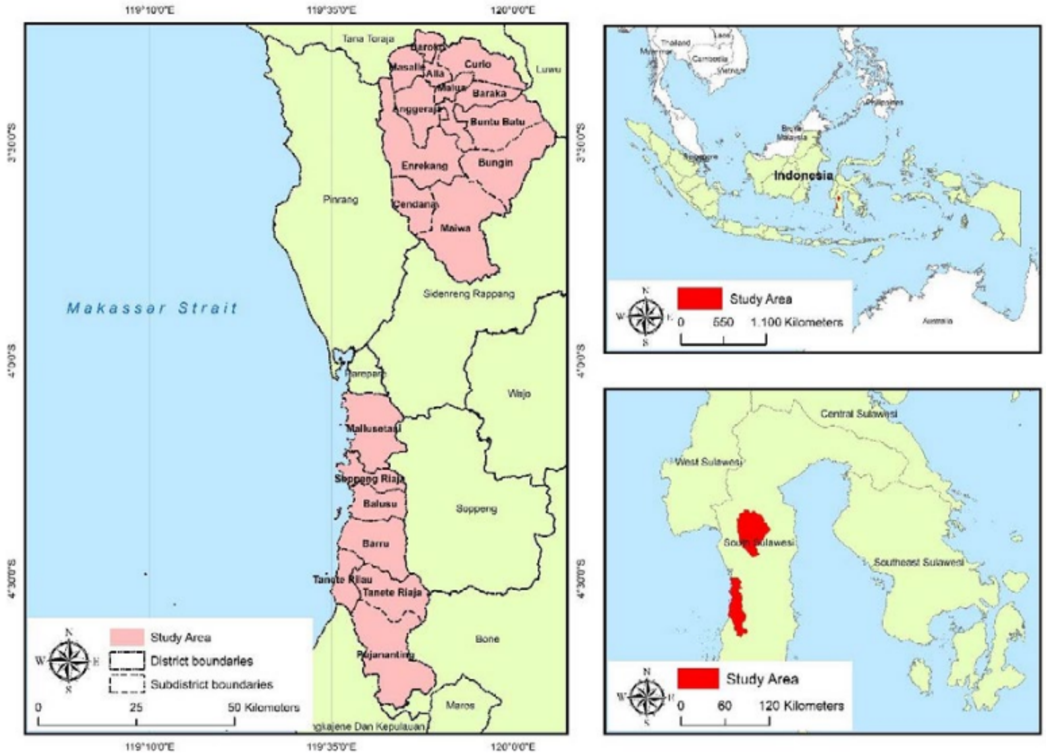

Fig. 1: Geographic location of the study area in Barru and Enrenkang, Indonesia

individual characteristics include age, education level, farming experience, side job, number of family dependents, and business scale (Etsay *et al*., 2019). A farmer's age affects his productivity when conducting business activities (Komba *et al.,* 2018). Good adaptation can be obtained through learning and education so that business activity will grow more rapidly with innovation that is driven by the ability to think creatively using that education (Ramesh *et al*., 2019). Continuous learning activities will also improve a person's experience and help them avoid mistakes in business management (Kolapo *et al*., 2022). The number of family dependents whose needs must be met is another factor that can motivate a person to grow his or her business. The existence of income from a side business will aid in increasing capital to scale up the main business (Maake and Antwi, 2022). The data collected include gender, age, education, primer job, farmer group participation status, farming status, and cattle ownership status. Moreover, data on type, perception, and knowledge on livestock manure management are also included in this study. In addition, liquid petroleum gas (LPG) or gas energy consumption is also an important variable to emphasize a point to develop livestock manure into biogas to minimize farmer's consumption expenditure. Previous studies that describe essential variables are shown in Table 1.

Furthermore, to recognize manure management condition in these two regencies, data on perception and knowledge about this management will also be collected. In addition, the willingness to adopt new management and original manure treatment practices is included.

Data analysis

The study used International business machines (IBM) - Statistical package for the social sciences

Table 1: Variables collected

No.	Variables collected	References
1	Age	Gebre *et al.*, 2022
2	Long husbandry experiences (year)	Masumi *et al.*, 2022
3	Number of family member	Hasan and Kumar, 2022
4	Number of farming assistant	Mairura *et al.*, 2022
5	Gender	Fadeyi *et al.*, 2022
6	Education	Ramesh *et al.*, 2019
7	Farmer group participation status	Goodwin *et al.*, 2022
8	Side job	Kayode *et al.*, 2017
9	Type of business	Dew *et al.*, 2022
10	Cattle ownership status	Rahman *et al.*, 2022
11	Number of cattle (head)	Aken *et al.*, 2022
12	Weight total of cattle's manure (kilogram per day: kg/day)	Setoguchi *et al.*, 2022
13	Age, long husbandry experiences, total of family member, total farming assistant, LPG consumption (in a month), education, gender, job, farmer group participation status, type of cattle farming, cattle farming characteristics, manure management condition, and practical livestock waste, knowledge and perception of farmers	This study

(SPSS)- 27 to analyze the collected factors. SPSS sowftware is selected because of its simplicity, simple command language, and well-documented user manual. In addition, SPSS has all the features needed for this research, such as descriptive and bivariate analyses. The result will be categorized into three main groups. First, farmer characteristics, which will describe the age, long husbandry experiences, number of family members and farming assistants, gender, LPG consumption, education level, address, and group participation. Second, cattle farming characteristics interpret the business type, cattle owning status, number of cattle and total manure produced, livestock waste management practices, willingness to manage livestock waste, knowledge level, and perception level of manure management. Livestock waste is assessed by collecting waste every day, which is collected in a certain container, and measuring the volume of waste produced. Then, it was calculated to the body weight of each livestock. So that results in the average size of waste per head per day. For knowledge and perception levels, the results will be explained based on median score. Scores of 16 or above will be categorized as adequate, whereas scores below 16 will be categorized as inadequate. Additionally, cattle types will be specified as adult cattle (more than 2 years), young cattle (young cows, 13 weeks to 2 years), and calf (newborn to 8 months). Cow was chosen as the object of research because of the dominant breed of cattle at the research location. Thus, the cow waste produced is quite a lot and worthy of being the object of research. Third, bivariate analysis is conducted to examine knowledge and perception variables with the practice of managing manure. A chi-square test and probability-value (p-value) analysis is used to compare the observed result from the experiments (perception and knowledge of livestock manure management) with livestock manure management practices. Moreover, descriptive statistics will be used to compile and examine the data, including mean, maximum, minimum, and percentages, qualitatively.

RESULTS AND DISCUSSION

Farmer's characteristic

Climate change adaptation is critical for achieving food security and sustainable agricultural development (Das *et al.,* 2022). Climate change is sparking new levels of global concern, shifting values, preferences, and behavior (Nezhyva and Mysiuk, 2022). However, the current set of personal farmer preferences, daily practices, and belief systems have a positive impact on decision-making in farming activities (Haberl *et al.,* 2021). Specifically, factors such as farmer group intervention (Crudeli *et al.,* 2022), and basic characteristic data (e.g., main job, experiences, total family's member, land ownership and education level) are massively useful in presenting new mitigation management due to farmer's willingness to adopt programs (Wang *et al.,* 2022). Moreover, Fernández-Habas *et al.,* (2022) in their study stated that proper management

Table 2: Farmer's characteristic (descriptive analysis)

No.	Variable	Data	Minimum	Maximum	Mean	Standard deviation (SD)
1	Age	98	20	83	45.69	13.126
2	Long experience husbandry (year) *Data missing*	95 3	0	43	11.29	9.680
3	Total family member	98	1	8	4	1.560
4	Total farming assistant	98	0	3	1	0.849
5	LPG consumption (a month)	98	1	6	3	1.037

Table 3: Specific farmer's characteristic

No	Variable	F	%
1	Farmer's address (Regency)		
	Barru	49	50
	Enrekang	49	50
2	Gender		
	Male	85	86.7
	Female	13	13.3
3	Education		
	No educational attainment	4	4.1
	Elementary level	35	35.7
	Junior high school level	20	20.4
	Senior high school level	28	28.6
	University	11	11.2
4	Job		
	Farmer	85	86.7
	Employee	4	4.1
	Housewife	9	9.2
5	Farmer group participation status		
	Yes	35	35.7
	No	63	64.3

programs is needed to guarantee farmer's survival and functionality. In other relevant studies, knowing the characteristics of farmers, especially age and job can affect their perceptions (Zhang *et al.,* 2022). In the case of agriculture, describing some information, such as education level, can benefit in designing suitable training programs.

The data presented in Table 2 describe the basic information of cattle farmers in Enrenkang and Barru Regencies. The age of cattle farmers range from 20 to 83 with a mean age of 45 years Wanga *et al.,* (2022) found that most farmers under 45 years old exhibit better productivity. This range of age is important to consider with the conditions that are found. Additionally, farmers in the active age with more than 22 years of experience are more likely to recognize the importance of new farming innovations (Shah *et al.,* 2022). The average farming experience of the respondents in this study was 11.29 years, although some farmers had more than 20 years of experience in cattle farming. As mentioned in the Methodology, the research was conducted in two regencies, namely, Barru Regency and Enrekang Regency, South Sulawesi. The respondents were studied comprised

Table 4: Type of cattle farming

No	Variable	F	%
1	Type of business		
	Profitable business	72	73.5
	Non-profitable business	26	26.5
2	Cattle ownership status		
	Not an owner	1	1
	Owner	97	99

86.7% male. Furthermore, most of the respondents had elementary school education (35.7%), while only 11.2% had university education. According to Table 3, 4.1% of farmers have primary job as employees, and more than 50% farmers did not join any farmer groups in Barru Regency nor in Enrekang Regency. Some studies, such as (Tong *et al.,* 2021), suggested that farmers' associations or groups and relevant government agencies must be proactive to achieve agricultural development through education. Moreover, participation and interaction among farmers through social networks (Pratiwi and Suzuki, 2017) and farmer groups (Zossou *et al.*, 2019) play an active role in exchanging information and acquiring knowledge. Additionally, education level is an important factor in motivating farmers to adopt new farming practices (Bai *et al.,* 2022). Another study suggests that training programs and experiences can be alternatives to reduce the education gap (Abebe *et al.,* 2022).

Cattle farming characteristics

The livestock business of the respondent is dominated by the profit livestock business type in both districts, accounting for 73.5% of the total, with 99% of livestock being privately owned. The data are shown in Table 4.

Indeed, data of business type and cattle owning status are used to identify restrictions and assess scenarios of mitigation (Arata *et al.,* 2022). Furthermore, a connection is observed between climate mitigation goals and selected rules as part of a mechanistic environmental modeling tool or mitigation model that fits the business conditions (Stoian *et al.*, 2022). A related study about cattle age was conducted by (Pence *et al.,* 2022). The study showed that knowledge about animal age can be used to predict the biogas amount, CO_2 emissions, coal, electricity-thermal energy, and CH_4 values that are all modeled. This study finds that the livestock business carried out by the respondents is divided into three types, namely, adult cattle, young cattle (e.g., young cows aged 13 weeks to 2 years), and calf (e.g., newborns to 8 months). On average, farmers keep three adult cows, one young cow, and one calf. The amount of cattle's manure produced by an adult cow ranges from appriximately 14 kg/day (average) to 125 kg/day (maximum). Meanwhile, the average manure produced by young cattle and calf is 2 kg/day. Of course, this, depends on the number of livestock kept. In addition, classifying animal age is used to create a mitigation formula that can adequately be adapted by farmers (Ghalandari *et al.*, 2021).

The husbandry business type in these regencies is small-scale farming, which, according to some studies, mean that it might restrict the professionalization of animal production (Pence *et al.,* 2022). Based on the data in Table 5, cattle farming generates enough manure to be processed productively, such as by composting and bio-energy. Biogas, which is a type of biomass, can be produced from the animal manure. Digested substrate or decay product residues can be used as a valuable fertilizer when the obtained biogas is used (Cheng *et al.* 2022). The upcycling of cattle manure has the potential to reduce greenhouse gas emissions significantly (Kim *et al.,* 2022). Based on Fig. 2, the contribution has grown slightly every year and has reached more than 2700 kilo-tonnes CO_2-equivalent (kt CO_2-eq).

Additionally, (Honorato *et al.,* 2022) described that cattle manure application in thyme farming could raise plant antioxidants. Further, (Carmo *et al.,* 2022) found that by using fertilizer from cow's manure, plants could possibly grow better based on their diameter and height. Moreover, cattle's manure application on farming system can significantly

Table 5: Cattle farming characteristics

No.	Variable	Data	Minimum	Maximum	Mean	SD
1	Total of adult cattle (head)	73	0	25	3	4,164
2	Total of adult cattle's manure (kg/day)	73	0	125	14	12,088
3	Total of young cattle (h)	73	0	7	1	1,414
4	Total of young cattle's manure (kg/day)	73	0	15	2	4,035
5	Total of calf (head)	73	0	5	1	1,279
6	Total of calf's manure (kg/day)	73	0	9	2	2,200

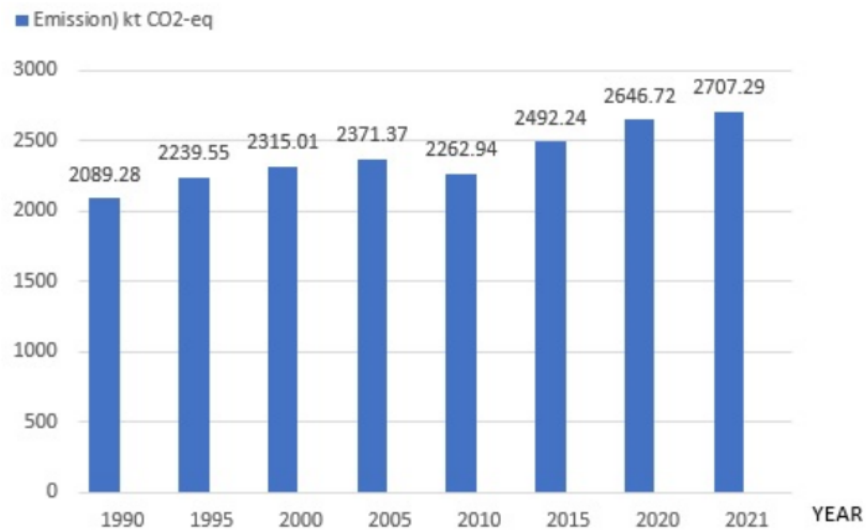

Fig. 2: Manure emission contribution to global GHGs (MLA, 2022)

6

reduce farming cost. Natural gas can be saved, and imports are reduced significantly if the potential of agricultural and animal waste is used effectively (Melikoglu and Menekse 2020).

Despite the potential benefits of cattle manure management in climate change mitigation, recognizing the percentage of livestock patterns that are already being used in local cattle husbandry is important. According to Table 6, only 14.3% of the respondents have already managed cattle's manure on their husbandry, whereas 85.7% have not yet applied these manure management practices. However, 50% of the respondents are willing to manage livestock manure, whereas the other 50% are not willing because of the potential costs and time involved. Notably, poor handling of waste is still being carried out by farmers in the regencies. Furthermore, only 51% of the respondents have adequate knowledge and perception of the processing and impact of livestock waste, whereas 49% have poor knowledge and perception. Nevertheless, when a large number of farmers adopt a particular practice, it may inspire others in the area to follow suit. In contrast, low participation may discourage other farmers from adopting the practices (Šūmane *et al.*, 2018). In fact, based on the data in Fig. 3, farmers are predicted to accumulate livestock waste in open spaces (63.3%), disposed of into rivers (10.2%), and stockpile it (3.1%). Only a small number of farmers manage their livestock waste by processing it into compost (10.2%)

Table 6: Manure management condition

No	Variable	F-value	%
1	Livestock management practical		
	Yes	14	14.3
	No	18	85.7
2	Willingness to manage livestock waste		
	Yes	49	50
	No	49	50
4	Respondent knowledge in livestock waste management and its impact		
	Adequate	50	51
	Inadequate	48	49
5	Respondent perception of livestock management and its impact		
	Adequate	50	51
	Inadequate	48	49

or using it as a medium for earthworms (13.3%).

Although the management of cattle's manure in these areas is extremely poor, the willingness of the farmers to manage the manure may positively attract the potential of implementing mitigation programs (Lambert *et al.*, 2022). Improving socio-economic conditions, such as intensifying government extension and study programs in the husbandry area, can also increase the willingness of farmers to adopt mitigation programs (Jan, 2021).

The chi-square test (X2) results suggest no significant relationship between the respondents' knowledge and the practice of managing animal manure (p-value: 0.837). Additionally, respondents' perceptions and the practice of managing animal manure have no significant relationship (p-value: 0.343). However, a relevant study found that perception and knowledge could affect farming management, particularly when farmers understand not only the climate impact but also the economic impact of their practices (Abdollahzadeh *et al.*, 2022). Using manure in anaerobic digestion reduces the release of carbon in the atmosphere and produces biogas. The manure in anaerobic digestion also produces organic fertilizer that is valuable in the marketplace (Awasthi *et al.*, 2022). Furthermore, peer groups and field experiences can encourage the development of knowledge and perception (Hazard *et al.*, 2022). This condition happened because of the realization of new ideas that need collaboration among the farmers or community and farming policy. The policy frameworks are needed to support the adaptation of climate-friendly livestock waste management practices in agriculture. For example, China's Zero Fertilizer Increase Input Policy aimed to replace 60%–75% more friendly synthetic fertilization (Awasthi *et al.*, 2022). To improve farmers' adaptive capacity and adoption of innovations, the government and other stakeholders must increase their access to socioeconomic resources and education (Asare-Nuamah *et al.*, 2022). Similarly, providing support from institutions and improving access to proper facilitation and technology are important for bringing perception and knowledge into practical action (Bui and Do, 2022). Adequate technology will encourage bioenergy production with appropriate livestock manure management and utilization as a feedstock. Additionally, the mutual trust level among stakeholders is a factor that can generate management action in agriculture (Erkkilä-Välimäki *et al.*, 2022). Perceptions and actions show different responses in the actualization of waste management in agriculture, even though livestock and waste are not optimally managed, farmers still have a sense of responsibility to maintain their livestock. The reason is that farmers know that the waste that they produce can pollute the environment. Nitrate waste in the form of nitrogen monoxide (NO) and nitrogen dioxide (NO_2) significantly affects climate change on earth, but farmers do not understand this concept of climate change because of their livestock activities. Therefore, managing livestock waste through a

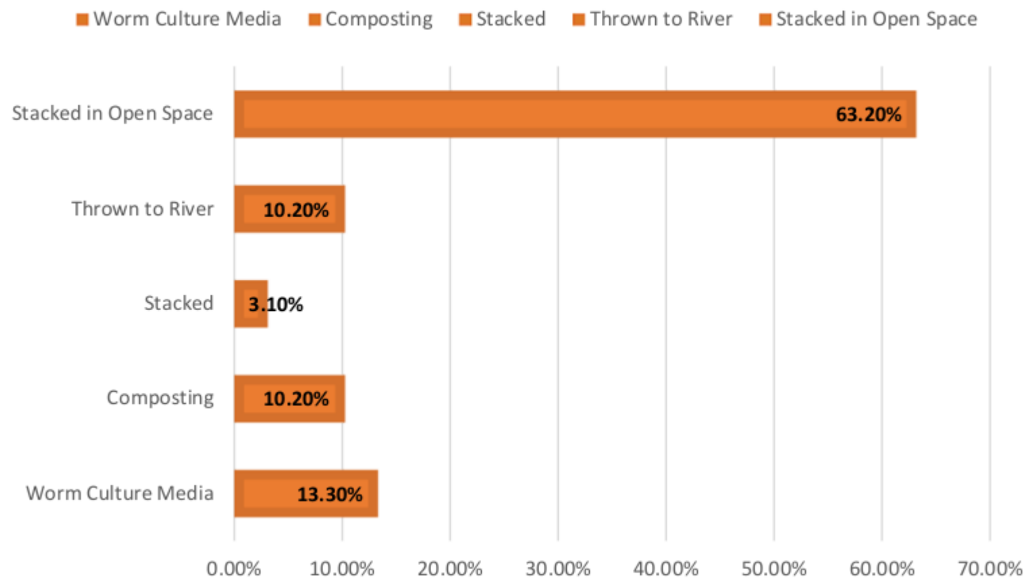

Fig. 3: Percentage of practical livestock waste

Table 7: Bivariate analysis of knowledge and perception variables with the practice of managing manure

Variable	Livestock management practical						Probability
	Yes		No		Total		
	Data	%	Data	%	Data	%	
Knowledge variable							
Adequate	8	16.0	42	84.0	50	100	0.837
Inadequate	6	12.5	42	87.5	48	100	
Perception variable							
Adequate	5	10.0	45	90.0	50	100	0.343
Inadequate	9	18.8	39	81.3	48	100	

conversion strategy into something useful is crucial to mitigate livestock waste and reduce greenhouse gas emissions. Management to achieve zero waste is focused on business owners who manage the whole process in the farm. The fact is that the conversion requires a high amount of waste, thereby giving large farmers more opportunities for development, in contrast to small farmers. However, a gap still exists in the management between small and large breeders. In industrial-scale livestock, management is more organized, thereby making business owners aware of to the importance of minimizing livestock product waste. On a small scale, farmers tend to produce minimal waste, hence, they may be reluctant to manage it because of considerations of time and cost inefficiency. However, other alternatives can be further studied through socialization and intensive assistance regarding the benefits of livestock waste management. Business owners, as leaders, have a significant influence in making decisions that greatly determine the goals of a farm (Fałkowski and Lewkowicz, 2022). Productivity should not only focus on production but also on feed yields through the concept of horizontal integration. This concept can motivate farmers because they benefit in saving costs by reducing fertilizer considering that livestock waste can be used as a substitute, leading to sustainable farming practices (Shortall, 2022). In addition, the local government's control over livestock waste management has been previously studied. Good relations between the government and the livestock private sector can contribute to socially and environmentally sound livestock management (Richards and Yabar, 2022). The public–private partnership will help the project of livestock management run productively, that is, the formulation of a firm and booming market for boosting the profit. This includes the disposal of livestock waste water, which should not be disposed directly into waterways. A strict approach to companies through government regulation is very important in regulating livestock waste contamination. With regulations in place, companies will be more disciplined in managing their wastes, because if the companies violate the regulations, their permits will be revoked. Further, if regulations are good but supervision, outreach, and assistance are weak, then it can be an opportunity for rogue companies to not manage their waste. Large-scale farmers can take advantage of this, whereas small-scale ones can lose motivation and willingness to manage their livestock wastes. Periodic inspections can help analyze the condition of large-level breeders.

CONCLUSION

This research expanded on previous studies by interpreting the relationship between perception and awareness of livestock waste management in South Sulawesi's Enrekang and Barru Regencies. Male farmer employees in these two regencies are found higher in comparison to female farmer employees, making up only 4.1% of them. According to the findings of this study, the respondents' livestock business is divided into three categories, namely, adult cattle, young cattle (young cows aged 13 weeks to 2 years), and calf (newborns to 8 months). On average, farmers keep three adult cows, one young cow, and one calf. An adult cow can produce manure at the rate of around 14 kg/day (average) to 125 kg/day (maximum). Meanwhile, young cattle and calves produce manure at average of 2 kg/day. However, manure management in these areas was not well developed. More than 63.2% of the manure was only stacked in open space. Nevertheless, other treatments, such as composting and worm culture media, were used by 23.5% cattle farmers, and 50% of the farmers are willing to manage livestock waste. The research found that more than 50% of the farmers have adequate knowledge about the impact of livestock waste. Furthermore, no significant relationship is observed between respondents' knowledge or perceptions of animal manure management practices. The results in this study contributes to the basic knowledge for stakeholders and other researchers to develop the appropriate intervention to improve livestock waste management, especially for farmers. The limitation of this study was the sole use of statistical analysis data. Furthermore, the researcher can determine the economic valuation of livestock waste management or even provide an intervention to enrich the perception and awareness toward livestock waste management. The public–private partership of the livestock waste management needs to be considered. Additional local government participation is recommended to develop good manure management in husbandry, especially centralized waste management, and to optimize biogas waste utilization.

AUTHOR CONTRIBUTIONS

E. Frimawaty performed conceptual and design, data acquisition, analysis, and interpretation of data, obtaining funding, supervision, and the corresponding author. A. Ilmika performed the data analysis and interpretation and drafted the manuscript. N. A Sakina performed the data analysis and interpretation, drafted the manuscript, and checked the article to guideline for author. J. Mustabi performed the statistical analysis and administrative, technical, or material support.

ACKNOWLEDGEMENT

This work was supported by the Hibah Publikasi Terindeks Internasional (PUTI) Q1 Directorate of Research and Development, Universitas Indonesia grant numbers [NKB-525/UN2.RST/HKP.05.00/2022]. The study was conducted according to the guidelines of the Declaration of Helsinki and approved by Research Ethics Committee, Faculty of Medicine, Universitas Sebelas Maret, Indonesia [protocol code 155/UN27.06.11/KEP/EC/2022] dated November 10, 2022).

CONFLICT OF INTEREST

The authors declare no potential conflict of interest regarding the publication of this work. In addition, the ethical issues including plagiarism, informed consent, misconduct, data fabrication and, or falsification, double publication and, or submission, and redundancy have been completely witnessed by the authors

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PUBLISHER'S NOTE

ABBREVIATIONS

%	Percent
CH_4	Methane
CO_2	Carbondioxide
FAO	Food and Agriculture Organization
GHGs	Green House Gasses
IBM	International business machines
IEA	International Energy Agency
IPCC	Intergovernmental Panel on Climate Change
kg	Kilogram
kg/Day	Kilogram per Day
KM	Kilometer
kt CO_2-eq	Kilo-ton CO_2-equivalent
LPG	Liquid Petroleum Gas
MLA	Meat and Livestock Australia
m^2	Meter square
NH_4	Ammonia
NH_4+	Ammonium
N_2O	Nitrogen oxide
NO	Nitrogen monoxide
NO_2	Nitrogen dioxide
NO_3	Nitrate
p-value	Probability-Value
RI	Republic Indonesia
SD	Standard deviation
SPSS	Statistical package for the social sciences
X2	Chi-square

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HOW TO CITE THIS ARTICLE

Frimawaty, E.; Ilmika, A.; Sakina, N.A; Mustabi. J., (2023). Climate change mitigation and adaptation through livestock waste management. Global J. Environ. Sci. Manage., 9(4): 1-16.

DOI: 10.22035/gjesm.2023.04.***

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