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Waste Management Practices of Dairy Buffalo Farmers in Nueva Ecija, Philippines

ABSTRACT

Effective waste management in dairy buffalo farming is vital to ensure the health and productivity of a farm and its farmers, as well as to minimize negative environmental impacts. This study examined the waste management practices of dairy buffalo farmers in Nueva Ecija, Philippines in relation to their socio-economic status and farm profile. Fifty-nine dairy buffalo farmers were interviewed face-to-face using pre-tested semi-structured questionnaires to gather data on their socio-demographic and economic profiles, farm profiles, and waste management system. Principal Component Analysis and binary regression were used to determine correlation between socio-economic status and farm profile with their manure management systems. Eighty percent of the respondents practiced stockpiling while 12% practiced vermi-composting. The liquid waste is disposed of via open channels going to rice fields, rivers, creeks, irrigation canals, forage areas, or vacant lots. The non-biodegradable farm waste is either buried, burned, thrown in a vacant area, reused, sold or given to garbage collectors. The regression model revealed that the significant determinant of manure management system was animal holding ($p<0.05$) which indicates that as the animal holding of the dairy farmers increased by 1 unit, there was a .23 increase in the probability that the dairy farmers will practice stockpiling. The agencies concerned need to intensify efforts to disseminate suitable, cost-effective, efficient and sustainable interventions related to waste management for dairy buffalo farms.

Keywords: *Dairy buffalo farms, waste management, stockpiling, vermi-composting*

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INTRODUCTION

Livestock waste and how they are managed contribute to different and most often interconnected environmental issues such as air pollution and water pollution. Wastes from livestock farms such as manure contribute to the production of greenhouse gases (GHG) like methane (CH_4) and nitrous oxide (N2O) (*Chadwick et al. 2011*). The nutrients in dairy manure especially Nitrogen (*Faugno et al. 2012*); and other contaminants like microorganisms including pathogens and virus (*Avery et al. 2004; Hakhoe et al. 2011*); veterinary pharmaceuticals, heavy metals and steroids (*Liu et al. 2012*) may pose risk to the environment, to the farmers and to their animals if not properly managed. However, if managed properly, manure from dairy animals is a valuable source of nutrients that can improve physico-chemical and microbial condition of soil (*Rayne and Aula 2020*).

The amount of waste generated in a dairy farm depends on herd size and herd composition (*Powell et al. 2005*). Daily manure production of a dairy animal is estimated to be 7-8% of its body weight (*Yeck 2010*). Thus, a caracow with a body weight of 400 kg generates 28-32 kg of manure daily. This is close to the findings of *Karthik* (*2014*) that tropical dairy murrah buffaloes with an average body weight of 400 ±50 kg, produce an average of 25 kg of manure per day. The urine production of dairy buffaloes can be similar to the 13-20 L urine production per day of dairy cows (*Misslebrook et al. 2011*). This means that if a farmer owns five dairy murrah buffaloes, then he has to manage 125 kg of manure and 65-100 L of urine daily. These numbers indicate that farm waste management is an immense concern of any dairy farm that is often overlooked especially in developing countries like the Philippines.

In the province of Nueva Ecija, Philippines– the National Impact Zone (NIZ) of the Carabao Development Program of the Philippine Carabao Center (PCC), the dairy buffalo farmers traditionally pile buffalo manure near their animal sheds and leave it to decompose naturally. Very few farmers apply rapid composting with the use of either vermi (African Night

Crawlers) or effective microorganisms. Some farmers even throw their animal waste in nearby creeks, ponds, or water canals. These waste management practices may result to interconnected issues that can eventually affect sustainability and productivity of dairy farms (*Sarabia et al. 2009*). However, extensive review of related literature showed that studies about waste management practices of dairy buffalo farms, characteristics of dairy buffalo farm wastes and factors influencing waste management practices among buffalo farmers have not yet been conducted in the Philippines.

This study aims to assess the waste management practices of dairy buffalo farmers in Nueva Ecija, Philippines in relation to their socio-economic conditions, farm characteristics, and environmental awareness. Baseline information on the current waste management patterns, and practices of dairy buffalo farmers will serve as important input in coming up with comprehensive plans or policies toward attaining sustainable dairy buffalo enterprise in the country. It can also provide understanding on how these waste management practices affect the immediate environment and overall farm productivity. Recognizing the factors that influence the decision of farmers to adopt certain waste management practices is also essential for directing and redirecting research, and institutional efforts to formulate, develop, and implement holistic programs toward attaining environmentally sustainable buffalo-based enterprise that will benefit the producers and the society.

MATERIALS AND METHODS

Study site

This study was conducted from November 2019 to August 2020 in the two cities of Nueva Ecija with the greatest number of dairy buffalo farms, namely, San Jose City and the Science City of Muñoz (**Figure 1**). San Jose City and Science City of Muñoz are neighboring component cities of the landlocked province of Nueva Ecija; thus, they have almost similar geophysical characteristics. San Jose City has a land area of 185.99 km^2, while Science City of Muñoz is 163.05 km^2 wide which constitute 3.23% and 2.83%, respectively, of Nueva Ecija's total area. Both cities are situated along a level to a very gently sloping topography with slope of 0-30%. Five soil types exist in these cities, namely, Maligaya Silt loam, Maligaya clay loam, Annam clay loam, Umingan silt loam and Quingua silt loam. San Jose and Science City of Muñoz fall under the type I climate classification, which is characterized by two pronounced seasons- wet and dry (*PhilAtlas.com 2020*). The average ambient temperature of these two neighboring cities is 27.8^{o}C (*PAGASA 2019*).

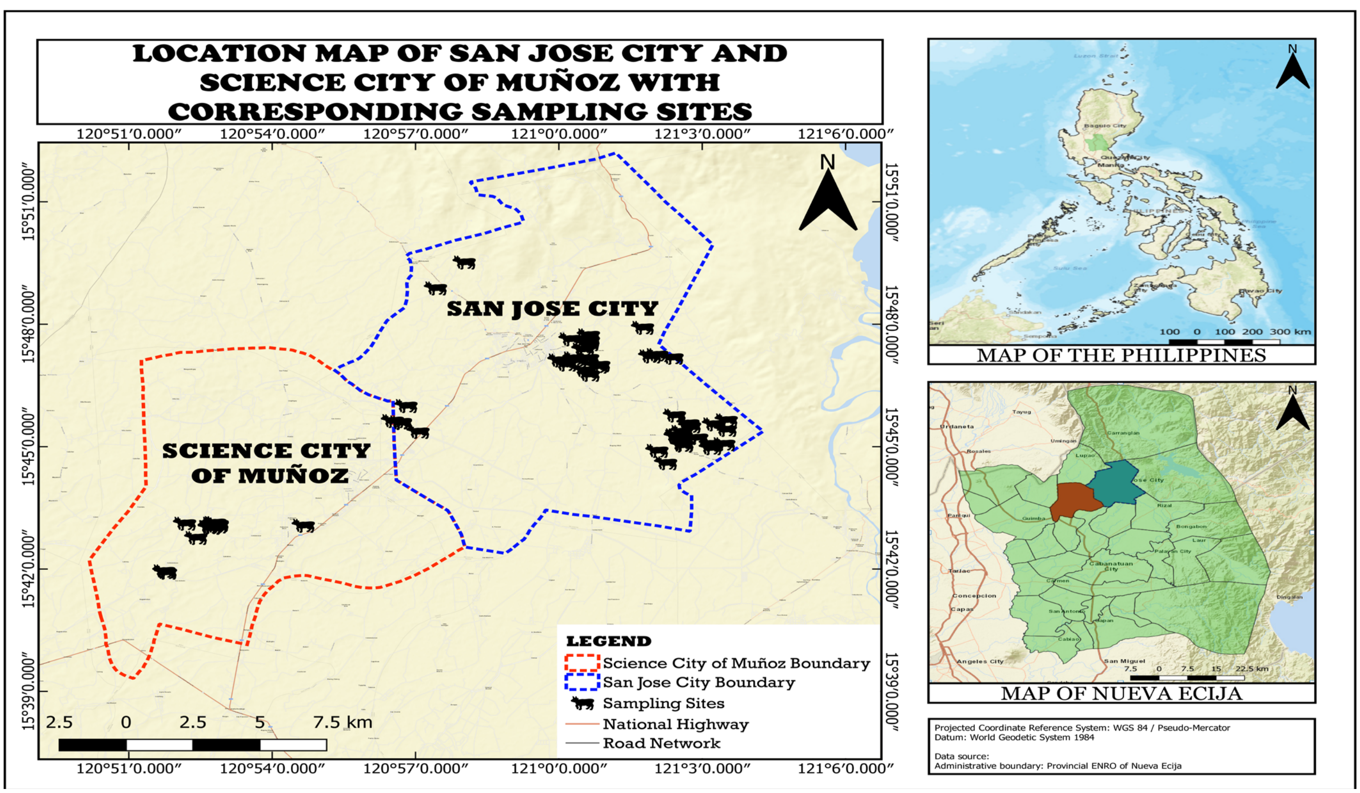

Figure 1. Location map of San Jose City and Science City of Muñoz, Nueva Ecija, Philippines with corresponding sampling sites.

Data Collection

Face-to-face interviews using a pre-tested, semi-structured questionnaire were done to collect data on the kinds and volume of waste generated in the dairy farms and how these wastes are managed by the respondents. Both biodegradable, non-biodegradable and liquid wastes generated in the dairy buffalo farms of the respondents were considered in this study. Biodegradable wastes include buffalo manure, feed refuse and animal carcasses. The gloves and semen sheets used for artificial insemination; sacks; rope and medicine containers compose non-biodegradable wastes assessed in this study. On the other hand, the liquid waste that was measured came from the wastewater generated when bathing the buffaloes, cleaning the pens, and washing milk pails.

The respondents' socio-demographic profiles, trainings attended and environmental awareness were also collected using the same questionnaire. The socio-demographic information collected included the sex, civil status, age and household size. The number of years in formal school, number of studying family members, number of years in buffalo production, and membership in organizations such as cooperatives or associations were also included. The respondents' annual household gross income and gross income from dairy buffalo production were also gathered.

The level of awareness and knowledge of the respondents were measured by asking six awareness questions and six knowledge questions. These awareness questions were answerable by yes or no while the knowledge questions were answerable by "true", "false", or "I don't know". Before the assessment, it was explained to the respondents that they should not hesitate to answer "I don't know or not sure" if they have not heard or do not have any idea about the stated topic because not everyone has heard about the environmental issues related to dairy farming that were included in the questionnaire. This was done to ensure that their true answers were provided since there are instances in similar studies where some respondents were uncomfortable in admitting that they did not know the topic (*Ciochetto et al. 2016*). The awareness score of the respondents was computed by counting their "yes" answers to the six awareness questions whereas the knowledge score was computed by counting the correct answer to the six knowledge questions provided to them. For the level of awareness, a score of 0-2 meant low awareness; a score of 3-4 meant moderate awareness and a score of 5-6 meant high awareness. The same adjectival equivalent was applied to the knowledge score.

In every interview, the objective of the study was first explained to the respondent. It was also expressed to them that the information they will provide will be treated with utmost confidentiality in compliance with the Data Privacy Act of 2012. Afterwards, their permission to be interviewed was asked before moving on to the interview. At the end of the interview, the respondents were requested to sign an informed consent statement found in the last part of the questionnaire which stated, "I consent to the information I have provided in this interview being used for research purposes".

A separate semi-structured questionnaire was used in gathering information from key-informants such as the chief of City Environment and Natural Resources Office (CENRO), Chief of the City Agriculture Office (CAO) and Philippine Carabao Center personnel regarding environmental programs and policies implemented in the dairy industry level and study site.

Farm Selection and Respondents

The respondents were dairy farmers who are duly registered members of a cooperative that was at the time of the study, being assisted by the Philippine Carabao Center (PCC). As per the PCC classification, the buffalo farms they own are classified according to the number of dams or caracows (female buffalo that have already produced an offspring or a pregnant heifer) being raised. A farm raising 1-5 caracows was considered as a smallhold dairy farm; 6-10 caracows as a family module; 11-25 caracows as semi-commercial; and 26 caracows and above as a commercial farm. There were 84 smallholds, 21 family modules, nine semi-commercials and one commercial farm in the area totalling 115 dairy farms.

The sample size was computed using the sample size calculator of *Creative Research Systems* (*2016*). Using a 95% level of confidence, the computed total sample size was 59. Thirty-five survey respondents from the smallhold and 16 survey respondents from the family module dairy farms were randomly selected. On the other hand, eight semi-commercial and one commercial farm were purposely chosen to make sure that these farm categories were represented since there were so few of them. If they were included in the random sampling, they might not have been selected and represented.

Data Analysis

Descriptive and inferential statistics were used in analyzing the data gathered. Count or frequency, percentage, and means were utilized in summarizing the socio-demographic profile as well as the waste management practices of the dairy farmers. Principal Component Analysis (PCA) which is a data exploratory tool was employed using the software Past, to determine the significant quantitative variables that were used for the regression. Binary regression using Stata software version 13.1 was applied to identify the significant factors that influenced waste management practices of the participating dairy farmers. The results were then presented in tables.

RESULTS AND DISCUSSION

Socio-demographic Characteristics of the Farmer-Respondents

Generally, dairy buffalo farming in Nueva Ecija is a family enterprise as majority of a family's members are often involved in the different activities in dairying (i.e. feeding, milking, cleaning of animal pens, bathing of buffaloes, gathering of forage feeds, washing of milking paraphernalia, and selling). Nevertheless, the male parents for the most part are the main actors in this enterprise since raising dairy buffaloes requires much physical activity. Hence, the majority of the respondents (99%) were males (**Table 1**). About 97% of the respondents were married with an average age of 47 years (with age range of 23-68 years).

The household size of the farmer-respondents ranged from 2 to 8 members with an average of 5 members per family, which is marginally higher than the national average household size of 4. Most of them finished 10 years of formal schooling (high school level) members of their organization for an average of 12 years and have 11 years of experience in dairy buffalo farming. As members of their organization for considerable years, they attended various trainings related to dairy buffalo farming like social preparation, basic buffalo management, animal health care, feeding of buffaloes at different physiological stages, breeding management, and others.

Most of the farmer-respondents practice mixed farming systems, with dairy buffalo production as their major source of income, followed by rice farming and vegetable production, among others. Their average household income in 2019 ranged from PhP 60,000.00 to PhP 4,410,260.32 or an average of PhP 476,970.00 wherein 62.55% (PhP 298,337) was from dairy buffalo production. They earned on average, as much as PhP 24,861.00 per month in buffalo dairy farming which they claim to have helped elevate their economic status.

Environmental Awareness and Knowledge

Generally, dairy farmers have a high awareness and knowledge score on the stated environmental issues related to dairy farming and waste management (**Table 2**). The mean score for knowledge was 5 points which is slightly lower than the awareness score of 5.3. It was expected that the awareness score would be higher than the knowledge score because it is easier to become aware of a certain topic than gaining full knowledge about it. It is noticeable that for the awareness level, many (80%) of the respondents scored 5-6 with an adjectival equivalent of high awareness. Same is true with the knowledge level, 71% of the respondents garnered scores of 5-6 indicating high knowledge on the environmental issues related to dairy buffalo farms. Some (14%) scored 3-4 points for awareness and 22% for knowledge indicating a moderate

Table 1. Socio-demographic characteristics of the dairy bufallo farmer-respondents in San Jose City and Science City of Muñoz, Nueva Ecija, Philippines, 2021.

Particular	San Jose City (n=39)	Science City of Muñoz (n=20)	Total (n=59)
Sex (%)			
Male	99	80	90
Female	1	20	10
Civil Status (%)			
Married	99	100	99
Single	1	0	1
Age in years (ave.)	48	48	48
Household size (ave.)	5	4	5
Number of years in school (ave.)	11	10	11
Number of studying family members (ave.)	2	1	2
Years of membership in organization (ave.)	11	12	12
Years of experience in dairy buffalo production	11	11	11
Annual household income [Philippine Peso (PhP)]	541,534	354,300	476,970
Annual gross income from dairy buffalo production (PhP)	321,348	254,618	303,572

Table 2. Awareness and knowledge score on proper farm waste management of the dairy buffalo farmer- respondents in San Jose City and Science City of Muñoz, Nueva Ecija, Philippines, 2021.

Score	Adjectival equivalent (n=58)	Awareness		Knowledge	
		Frequency	%	Frequency	%
5-6	high	48	83	41	71
3-4	moderate	8	14	13	22
0-2	poor	2	3	4	7
Average Score		5		5.3	

level of awareness and knowledge, respectively on environmental issues related to buffalo farming. A low percentage of the respondents showed a poor score (0-2) on the level of awareness (3%) and level of knowledge (7%).

The high awareness and knowledge score among the respondents can be attributed to their considerable years as dairy farmers and members of their organization. Majority (74%) of the respondents claimed that they learned about the asked topics through trainings or seminars provided by different government and non-government agencies like the PCC, Philippine Rice Institute, Central Luzon State University, LGU, NGOs, and their respective cooperatives. Most of the respondents (72%) also claimed that they were able to learn about the given topics through years of observation and experience in buffalo farming. Some farmers (24%) also said that printed material and relevant television programs aided in providing additional awareness and knowledge in these areas. They also mentioned that the sharing of knowledge and experiences with fellow dairy farmers gave them additional knowledge and awareness on different aspects of dairy farming. Nevertheless, the majority (95%) claimed that they still need additional knowledge on farm waste management and other related environmental knowledge for them to improve their overall dairy farm management capabilities.

Dairy Buffalo Farm Classification and Characteristics

The smallhold dairy farms have an average housing area of 59 m^2 which can house at least four caracows. The area of housing for family module dairy farms was twice the area for smallhold measuring 137.5 m^2 which can house 11 caracows. For the semi-commercial farms, the housing area is 163.75 m^2 that can house 13 caracows which is the average animal holding of these farms. The housing of the commercial farm measures 400 m^2 and can accommodate 33 caracows (**Table 3**).

Seventy-six percent (76%) of the dairy farms under the smallhold and all the farms under the family module, semi-commercial, and commercial farms have their own forage area planted with Napier grass and some legumes which serve as source of feed for their dairy animals especially for the farms that practice total confinement. Based on the recommendations of the PCC, 1000 m^2 of forage area should be established for every 1 caracow, however, the average forage area of all the study dairy farms does not meet the recommendations. Nevertheless, they are able to provide the feed requirements of their buffaloes by sourcing additional feedstuff such as rice straw, cut mixed native grass, sweet potato vines, corn stover, lactating feeds, rice bran, etc. from different places. Almost all the dairy farms, get their forage from

Table 3. Characteristics of each dairy farm classification in San Jose City and Science City of Muñoz, Nueva Ecija, Philippines.

Particular	Farm Classification			
	Smallhold	Family Module	Semi-commercial	Commercial
Farm Size				
Housing (m^2)	59	138	164	400
Forage area (m^2)	1,159	3,739	4,000	5,000
Source of forage (%)				
Own forage and	76	100	100	100
communal area	24	0	0	0
Communal only				
Feeding System (%)	21	31	50	100
Total confinement	58	69	50	0
Seasonal confinement	21	0	0	0
Grazing				
Average Total Milk Production in 2019 (L)	1,965.82	6,319.48	7,414.90	25,590.27

both their own forage area and from a communal forage area. Only 24% of the dairy farmers who do not have their own forage area gather native grasses or let their animals graze in a communal forage or grassland area.

The feeding system differs depending on the number of buffaloes. Total grazing is practiced by dairy farms under the smallhold category, especially farmers with only one caracow (21%). Pure confinement, a practice wherein the animals are confined in their pen throughout the year and provided with different feed materials is practiced by commercial farms as well as 50% of the semi-commercial dairy farms, 31% of the family module dairy farms and 21% of the smallhold dairy farms. On the other hand, 50-69% of the smallhold, family module and semi-commercial farms practice seasonal confinement wherein the animals are confined during the rice season (January-April and July-October) and allowed to graze throughout the months when the rice or vegetables are already harvested, and the soil is left to rest (May-June and November-December).

Majority of the respondents provide Napier grass, forage and rice straw as major feedstuff of their dairy animals. Other in-season feedstuff such as corn stover and sweet potato vines are offered as alternatives to Napier, forage, and rice straw. On the other hand, rice bran, commercial feeds, molasses, salt, and di-calcium phosphate are provided as feed supplements.

Volume of Dairy Farm Wastes

The biodegradable waste in the surveyed dairy buffalo farms was composed generally of buffalo manure (solid and semi-solid state), feed refuse and buffalo carcasses. On the other hand, the non-biodegradable waste generated were veterinary wastes like medicine containers, artificial insemination (AI) gloves and semen straw. Sacks used as containers of commercial feed and ropes used for tethering the buffaloes are also non-biodegradable wastes that were generated from these farms. The volume of waste generated varies depending on the scale of the farm (**Table 4**). It tends to increase with the size of the farm which is expected because more input is needed as the farm scales up. This is however not true with feed refuse and rope which are discussed in the following discussions.

According to the respondents, the volume and texture of manure excretion of the buffaloes depend on the diet of the animals. During the dry season when the feed ration is mostly composed of rice straw due to limited source of fresh forage, the buffaloes excrete manure about three to four times a day and the texture is solid. Whereas, during the abundance of fresh forage in the wet season, the buffaloes excrete about four to five times a day and the manure excretion is semi-solid. Based on their estimate, on average, a caracow and a bull with body weight of 350-600 kg excretes eight kg of fresh manure per excretion or a total of 32 kg manure per day or 6.7% of the animal's body weight. This is close to the record of *Yeck* (*2010*) that the volume of manure excretion of buffaloes is 7 to 8% of their body weight.

The volume of manure generated in the different farms according to classification was computed by multiplying the average number of dairy buffaloes in each farm with the daily excretion of each buffalo relative to status. The volume of fresh manure generated in a smallhold, family module, semi-commercial and commercial dairy farms were computed at 123 kg, 342 kg, 588 kg and 975 kg per day, respectively. With this huge volume of manure generated daily, the implementation of strategic, effective, and efficient farm waste management is crucial.

Feed refuse is composed of feeds that were left over by the dairy animals. These are usually stalks of Napier grass or corn that are too hard for the animals to chew and rice straw that were spilled and stamped on by the animals thus,

Table 4. Kinds and volume of solid wastes generated in the surveyed dairy buffalo farms in San Jose City and Science City of Muñoz, Nueva Ecija, Philippines for the year 2019.

Kinds of waste	Volume			
	Smallhold	Family Module	Semi-Commercial	Commercial
Manure (kg day^{-1})	123	342	588	975
Feed Refusals (kg month^{-1})	28	60	67	20
Animal Carcass (count yr^{-1})	1	3	4	5
Non-Biodegradables (volume yr^{-1})				
Artificial Insemination sheet, Semen Straw (kg)	0.06	0.16	0.19	2.3
Sacks (kg)	3.5	9.8	11.6	25.2
Rope (kg)	1.5	1.8	1.5	3.6
Artificial Insemination Gloves (g)	21	49	35	448
Medicine Containers (kg)	0.30	0.50	1.6	1.90

are no longer palatable. The commercial farm has the lowest volume of feed refuse (20 kg $month^{-1}$). As claimed by the owners, with the considerable number of their buffaloes, they are able to provide just enough or sometimes inadequate amount of feed to their buffaloes. Thus, it is very rare for their buffaloes to leave leftovers.

Each farm classification had case/s of unwanted mortality of buffaloes in 2019 giving the dairy farms carcasses to manage. The smallhold dairy farms incurred an average of one mortality each year while three mortalities were experienced by the family module farm. Meanwhile, four and five mortalities were encountered by the semi-commercial and commercial dairy farms, respectively.

For non-biodegradable waste, minimal volume was noted from the smallhold dairy farms. Only an average of 3 pieces (0.30 kg) of medicine bottle or containers, 3 pieces of AI gloves (21 g), and 6 semen straws and AI sheets (0.06 kg) were disposed by the smallholds in a year because the technicians who provided the health or breeding-related services took back with them the used medicine containers and AI gloves after providing technical services. The smallhold dairy farms utilized 2-3 sacks of commercial feed per month; thus, only 25 pieces (3.5 kg) of sacks were generated from these farms per year. However, it is notable that the volume of rope used by smallhold farms is at par with the family module and semi-commercial farms (63 m or 1.5 kg of rope with 2.54 cm diameter). This is because many small hold dairy farmers practice grazing or seasonal grazing wherein they use rope about 15-meter long to tether each caracow and 8-meter long rope for each calf. As claimed by the farmers who practice total grazing, they replace the tether of their buffaloes twice a year. Nevertheless, the highest volume of non-biodegradable waste was generated by the commercial farm followed by the semi-commercial and family module dairy farms.

Aside from solid wastes, considerable volume of liquid waste is also produced in the dairy buffalo farms. Aside from the urine excretion of the buffaloes, liquid waste is generated from the daily activities of bathing the buffaloes, cleaning the animal sheds as well as washing of the milk pails and milk-strainer cloths (**Table 5**). There was no milk waste because the farmers usually feed the foremilk (first three to five strips of milk which must be discarded because it has high number of bacteria) to their cats or dogs. The volume of water used for bathing and cleaning (which later become liquid waste) is generally higher during the dry season because the dairy farmers bathe their buffaloes (accompanied with cleaning the pens) two to three times a day to keep the animals cool. During the rainy season, they bathe their buffaloes only once or twice a day. As expected, the lowest volume of liquid waste was produced by the smallhold dairy farms (552 L day^{-1}) while the highest volume was generated by the commercial farm (21,580 L day^{-1}). These liquid wastes are mixed with some amount of manure that results to the formation of slurry.

Management Practices on Biodegradable Farm Wastes

Majority (80%) of the dairy buffalo farms regardless of their classification, practice stock piling of manure (**Table 6**). It is the routine of the farmers to manually scrape the manure excretions using a shovel and pile it near the animal shed every morning before milking. Once the manure is scraped, the remaining excretions are flushed towards a canal leading to a crop field, forage area, or a water body.

Stockpiling may be traditional and the most convenient way of disposing dairy manure however, it poses environmental and social repercussions especially if the dairy farm is located near a residential area. Problems associated with flies and rodents as well as unwanted odor of the manure may offend nearby residents that may result in complaints. Some (24%) respondents admitted that they have received complaints from neighbors about the foul smell of their buffalo manure affecting their social relationships. These farms are usually located near residential areas. In the Science City of Muñoz, a complaint against a dairy farmer in 2019 was settled in the level of the City Environment and

Table 5. Daily volume of liquid wastes (in liters) generated in the surveyed dairy buffalo farms in San Jose City and Science City of Muñoz, Nueva Ecija, Philippines.

Particular	Small-hold		Family module		Semi-commercial		Commercial	
	RS	DS	RS	DS	RS	DS	RS	DS
Bathing	330	463	1,149	1,464	840	1,230	7,680	14,000
Cleaning	190	251	238	303	435	688	4,500	7,500
Washing of milk pails	32	35	45	47	46	46	80	80
Total	552	749	1,432	1,814	1,321	1,964	12,260	21,580

RS stands for rainy season, DS for dry season

Table 6. Management practices on the different kinds of farm-biodegradable wastes in San Jose City and Science City of Muñoz, Nueva Ecija, Philippines.

Kinds of waste and management practice	San Jose City		Science City of Muñoz		All (n=59)	
	Frequency	%	Frequency	%	Frequency	%
Manure*						
Stock piling	32	84	15	71	47	80
Vermi-composting	2	5	5	24	7	12
Left on the field (grazing)	4	11	1	5	5	8
Feed refusals*						
Piled with manure	18	47	15	71	33	56
No feed refusals	12	32	1	5	13	22
Burned	3	8	7	33	10	17
Piled near the shed	2	5	2	10	4	7
Animal Carcass*						
Buried	23	61	13	62	36	61
Butchered	3	8	5	24	8	14
Sold	4	11	3	14	7	12
Never had animal mortality	14	37	7	33	21	36

*multiple response

Natural Resources Office (CENRO) and village leaders by transferring the dairy farm away from the residential area but these farms stopped operation later on. In San Jose City, some dairy farmers were warned with cease-and-desist orders during the on-the-spot monitoring of the City Sanitation Department in October 2019 due to the absence of proper disposal facilities especially for commercial and semi-commercial farms (*M. Alfonso, Pers. comm., November 2019*). With the urbanization of many rural areas, sustainability of dairy farming may be compromised if improper dairy farm waste management causing social problems will not be addressed by the concerned private and public entities.

Moreover, buffalo manure contributes to the production of greenhouse gases (GHG) such as methane (CH_4) and nitrous oxide (N_2O). Methane is released from the anaerobic decomposition of organic matter in slurries while N_2O is released from the stacks of animal manure in the form of Ammonia (NH_3) that is then transformed into N_2O (*Hanigan et al. 2011*). Manure is the second largest contributor of GHG emissions from dairy farms following enteric CH_4 emissions (*FAO 2006*). The practice of storing slurry for long periods of time without processing generates the most GHG emissions (*Aguirre-Villegas and Larson 2017*).

Vermi-composting using African Night Crawlers (a more environment-friendly practice) in contrast, is adopted by some (24%) respondents in Science City of Muñoz and a few (5%) in San Jose City. Vermi-composting is viewed as a clean and sustainable method of managing organic wastes which uses earthworms and microorganisms that convert organic materials into humus-like material known as vermi-compost (*Sharma and Garg 2019*). Vermi-compost is regarded as non-toxic material and a good soil conditioner (*Sanchez-Hernandez and Dominguez 2019*). Thus, it can be a viable source of additional income (*Lim et al. 2016*). However, the absence of a market for vermi-compost is one of the reasons for some dairy farmers for not adopting or for not continuing the practice of vermi-composting.

The feed refuse is piled with the stockpiled manure by most of the respondents (56%) while some of them (17%) burn it to drive away mosquitoes or mix it with burned non-biodegradable waste. Only a few of them (7%) pile it near the shed and let it decompose while 22% claim that they barely experience feed leftovers. For animal carcasses, a majority of the respondents mentioned that they bury the carcasses of their buffaloes because they know that it is the protocol of the PCC. But some (14%) testified that they butcher and either sell or give the meat to their neighbors for free if they know that the animal was not administered with so much veterinary drugs. Alarmingly, there were 12% who admitted that they sell the carcass of their buffalo to buyers who then sell the meat to the public market. Some mentioned that those buyers mix the double dead meat to good meat that is then sold in the market.

Section 14 of the Comprehensive Solid Waste Management Code of Science City of Muñoz and San Jose City stipulates that agricultural wastes such as rice straws and corn cobs shall not be burned and that animal manure shall be stockpiled in a proper location and composted or utilized for bio-gas production. The CENRO is the primary unit tasked to lead the implementation of the provisions of the said ordinance. However, the CENRO Chief stated that they do not include dairy farms in their periodic monitoring unless a complaint is filed in their office. Correspondingly, the CENRO in San Jose City does not monitor livestock industries because they assume that the City Veterinary Office and Sanitation Department are the units responsible for monitoring dairy buffalo farms.

Management Practice on Composted or Stockpiled Manure

The piled manure is allowed to accumulate and stocked for three to four months especially during the rainy season. The stocked piled manure naturally decomposes which is later hauled and applied to the crop field and forage areas. Half of the respondents (50%) apply about 56 sacks (2,805 kg) of manure to their forage area having an average area of 2,212 m^2 four times a year (**Table 7**). For the rice field with an average area of 1.1 ha, about 83 sacks (4,150 kg) of composted manure were used for two cropping seasons. Composted buffalo manure is also well utilized in vegetable farms, especially in onion production. An average of 4, 652 kg (93 sacks) of compost were applied during the seedling and mature stage of most vegetables. The farmers attested that application of compost results to good vegetable production such as healthy growth and high yield of their crop. In addition, it reduces the cost of fertilizer input.

Dairy manure is rich in Nitrogen (N), Phosphorus (P) and Potassium (K). Nitrogen in dairy manure occurs in the form of ammonium (NH_4^+), urea and solid, organic N. Ammonium and urea are readily available for plant uptake. However, these are easily converted into NH_3 gas when applied to the agricultural field which leads to rapid loss due to volatilization (*Hanigan et al. 2011*). Volatized NH_3 then reacts with other air particulates contributing to the formation of particles with diameter less than 2.5 μm called particulate matter 2.5 (PM 2.5) (*Campbell et al. 2009*). Long-term exposure to PM 2.5 can lead to premature death in people with heart or lung diseases, non-fatal heart attacks, irregular heartbeat, aggravated asthma, decreased lung function, and increased respiratory symptoms, such as irritation of the airways, coughing or difficulty in breathing (*WHO 2013a*). To avoid N losses through volatilization, liquid manure injection or incorporating the manure into the soil as soon as it is applied is recommended (*Hernandez and Schmitt 2012; Webb et al. 2013*).

The nutrients in dairy manure, especially N, when not managed properly, can also result to water contamination (*Chen and Pandey 2021*). Nitrogen that is not lost from volatilization is eventually converted to nitrite (NO_2) and then to nitrate (NO_3) in the process called nitrification (*Ward 2011*). This form of N is highly soluble but is chemically unreactive in aqueous solution (*WHO 2011b*) making it readily and easily taken up by plants, but is also easily lost through leaching, percolation or surface run-off (*Rotz 2004*) ending up in water bodies.

The stockpiled or composted manure will be of more value to the farmers if they can convert it into cash. However, they mentioned that they do not have a market for their manure compost, thus, most of them (98%) just give it for free to anyone who asks for it, especially friends and neighbors. On the contrary, only 22% have a market for their composted wastes but are unstable and are bought at a very minimal price (average of PhP 37.00 per 50 kg). According to them, their buyers are mostly farmers or entrepreneurs who are engaged in onion production, vermi-compost production or in ornamental plant production. If only a centralized, regulated market for compost can be established, a continuous source of additional income for dairy farmers can be generated.

Article 5, section 34 of Republic Act 9003 (Ecological Solid Waste Management Act of 2001) stipulates that there should be an updated inventory of existing markets and demand for composts published by the Department of Agriculture (DA). Nevertheless, according to the head of the DA of each respective covered municipality, they do not have a record or list of potential markets for composts. They deem that

Table 7. Management practices of dairy buffalo farms on the composted or stockpiled buffalo manure in San Jose City and Science City of Muñoz, Nueva Ecija, Philippines.

Management Practice	Count*	%	Freq/year	Ave Qty/application (kg)	Total qty/year (kg)	Area (m^2)
Applied in:						
Forage area	27	50	4	2, 805	5, 787	2, 212
Rice farm	32	59	2	4, 150	6, 181	11, 887
Vegetable farm	19	35	3	4, 652	8, 179	5, 628
Sold	12	22	4	6, 823	40, 708	
Given to neighbors	53	98	16	1, 228	10, 889	

*- multiple response Freq –frequency Ave –average Qty -quantity

there is no problem in the marketing of compost in their municipality and that demand for it is not significant because farmers in their jurisdiction prefer commercial fertilizers.

Management Practices on Liquid Wastes

Urine and wastewater are the main components of liquid wastes in the surveyed dairy buffalo farms. Some amount of the solid manure mixed with liquid wastes and become slurry (semi-liquid). Many of the respondents (37%) dispose the liquid wastes and slurry in their rice farm near their animal shed (**Table 8**). They mentioned that the liquid waste serves as additional fertilizer for their crops. However, the convenience of disposal is possibly the main reason for such practice more than nutrient recovery.

Some respondents (12%), with dairy farms located near a water body dispose of their liquid waste into the nearby water body most often a creek or river. This disposal practice is unacceptable because it contaminates the water resource that can imperil human health. Bacterial content and nutrient level of the receiving water body can also be increased which can impact aquatic organisms.

Furthermore, some of the dairy farmers (20%) dispose their liquid waste to their forage area which they claim makes their forage grow more robustly. This can be true because the leachate from the buffalo manure and urine contains a high percentage of nitrogen, but it also contains a high coliform count. On the other hand, 14% direct their liquid waste through an open channel to a vacant area near their dairy farm while 5% direct it to an irrigation canal. Only one dairy farmer, who is acknowledged by the PCC as a progressive farmer, has a septic tank for liquid waste from his dairy farm.

Chapter 3, section 50 of the Philippine Environment Code (PD 1152) stipulates that wastewater from different sources shall be treated either physically, biologically, or chemically prior to disposal. However, interview with the CENRO Chief of Science City of Muñoz revealed that the septage and sewerage ordinance for the municipality was just submitted in 2018 and has not yet been approved until the time of the study. Thus, there is no ordinance to regulate the disposal of liquid wastes of Science City of Muñoz. In San Jose City, City Ordinance 17-022 - an ordinance on proper septage management system of the City was established in 2017. However, the scope and application of the ordinance is for residential structures only. The CENRO of both municipalities also do not include dairy farms in their monitoring. The absence of concrete policies and clear delineations of the functions and roles of the regulatory bodies in this aspect will allow unsustainable disposal practices among the public that may result in interconnected environmental and social issues.

Management Practices on Non-Biodegradable Farm Wastes

The non-biodegradable wastes that were generated in the surveyed dairy buffalo farms were containers of veterinary drugs, artificial insemination (AI) gloves, semen straws, sacks, and rope (**Table 9**). A considerable percentage of the respondents (45%) usually sell used veterinary drug containers which are reusable, but this also depends on the presence of a buyer. Without a market and or a garbage collector, 47% of the respondents choose to either bury, burn, or just throw it away in a convenient area. Only 36% indicated that those wastes are collected by the technician who provided animal health services or by a garbage collector. Correspondingly, semen straws, AI gloves and rope which are all made up of plastic are disposed of by some respondents (33%) by burying, burning, or throwing it in a vacant area. According to them, there is no regular garbage collector in their area thus, they resort to such practices to avoid accumulation of non-biodegradable wastes in their respective farms and or residential area.

Burying, burning, or throwing plastic waste in improper areas is not an acceptable waste management practice. Buried or scattered plastic waste, overtime,

Table 8. Dairy buffalo farms' liquid wastes disposal by location in San Jose City and Science City of Muñoz, Nueva Ecija, Philippines.

Disposal Site	San Jose City (n=38)	%	Science City of Muñoz (n=21)	%	All (n=59)	%
Rice Farm	8	21	4	19	22	37
River or Creek	6	16	7	33	13	22
Forage Area	10	26	1	5	12	20
Vacant Lot	8	21	1	5	8	14
Irrigation	2	5	1	5	3	5
Septic Tank	0	0	1	5	1	2

Table 9. Disposal practices of surveyed dairy buffalo farms on non-biodegradable farm wastes in San Jose City and Science City of Muñoz, Nueva Ecija, Philippines.

Kinds of Non-biodegradable waste	Buried/burned/thrown in a vacant area*	%	Stored/reused/ sold*	%	Collected by garbage collector/service provider/neighbor*	%
Medicine Containers	27	47	26	45	21	36
AI Gloves	36	62	17	29	21	36
Semen Straw	35	60	6	10	24	41
Rope	36	62	44	76	6	10
Sacks	0	0	59	100	0	0

*Multiple response

oxidize and produce copper salt which may pollute the surrounding soil and leach into the groundwater aquifer (*Gewert et al. 2015*). Correspondingly, when plastics are burned, the residuals contain persistent organic pollutants (POPs) such as mercury, polychlorinated biphenyls (PCBs), dioxins and furan (*Wu et al. 2021*) which are then transported by wind or water action into land or bodies of water that may enter the food chain and bio accumulate especially on the top predators causing cancer, deformed offspring, reproductive failure, immune diseases, and subtle neurobehavioral effects (*WHO 2008c*). The smoke of burning plastics also contains air pollutants like carbon monoxide, carbon dioxide, sulfur oxides, etc. that can affect human health. Exposure to the smoke of burning plastics can cause eye and nose irritation, breathing difficulty, coughing, headaches and can aggravate health problems of people with lung infections, pneumonia, bronchiolitis, heart disease, asthma, emphysema or other respiratory diseases and allergies (*Nagy and Kuti 2016*).

The Chief of CENRO of both municipalities claimed that garbage collection is regularly done only in the town proper while the rest of the villages have their own material recovery facility (MRF) where residual waste should be disposed. The accumulated waste in the MRF is then transferred by the village-based waste collection committee to the Municipal waste transfer station. Both the Science City of Muñoz and San Jose City deputized village officials to take charge in the enforcement and monitoring of the implementation of the Ecological Solid Waste Management (ESWM) ordinances of their respective municipalities. However, only orientation seminars were provided to the village-based environmental enforcers or eco-police before transferring to them this obligation. They are also obliged to submit quarterly reports regarding the implementation of ESWM Ordinance in their respective villages (*Noel Busine, Pers. comm. August 5, 2020*).

Furthermore, some dairy farmers (29%) especially the trained village-based AI technicians reuse AI gloves by washing and drying it. The washed gloves are then reused when they conduct pregnancy diagnosis for their animals. They mentioned that they reuse the gloves as long as it is still usable. The used ropes were reused as laundry clothesline, hammock halters and used to tie other materials in their dairy farm or in their house. Empty sacks of commercial feed were stored then reused to contain rice straw, forage, unmilled rice, vermi-cast, harvested crops like corn, onions, vegetables, etc.; or sold by all the respondents.

Drivers of Waste Management Practices of Dairy Buffalo Farmers

Principal component analysis (PCA) was first employed to the identified 15 quantitative variables related to waste management practices to detect the most significant predictor of waste management practices of the participating dairy farmers. The result of the PCA showed that a form of income is what contributes most to the variability in the data related to waste management. However, household income, gross and net income from dairy were correlated; thus, only household income which has the highest absolute score in Principal Component 1 (PC1) was considered as an independent variable (quantitative) in running the binary regression. The number of buffaloes raised by the dairy farmers was also considered as an independent variable because it is highly regarded by the authors as an important predictor of waste management. Other nominal variables such as gender, feeding system and awareness score were also included as independent variables.

After several runs of the binary regression, number of buffaloes, and seasonal confinement type of feeding system came out as the most significant variables among the independent variables used. However, seasonal confinement shows ambiguity in its confidence interval thus was omitted leaving only the number of mature buffaloes being raised as the significant predictor variable (**Table 10**).

Table 10. Predictor variable of manure management practices of dairy buffalo farmers in San Jose City and Science City of Muñoz, Nueva Ecija, Philippines.

Predictors	Coefficient	Standard error	z	P>[t]	[95% confidence interval]	
Number of buffaloes (mature)	0.23	0.1	2.21	0.027**	0.026	0.432
Constant	-0.05	0.64	-0.08	0.934	-1.311	1.203

** - significant at the α = 5% level Prob>chi² =.005 Log likelihood = -24.18

The number of mature buffaloes (3 years old and up) being raised by the farmers (animal holding) is significant at $P<.05$. The positive relationship between manure management and animal holding indicates that as the animal holding of the dairy farmers increases by 1 unit, there is a 0.23 increase in the probability that the dairy farmers will practice stock piling. Stockpiling is the traditional, cheapest, and most convenient practice of managing dairy animal manure but has a host of negative environmental implications. An increase in the number of dairy animals means an increase in the bulk of work (i.e., bathing, feeding, gathering of forage, etc.) as well as an increase in the volume of manure to manage. With the bulk of work in their farm, the dairy farmers tend to pile the manure of their dairy buffaloes to finish their work easier and faster.

This is evident in the number of semi-commercial farms who are practicing vermi-composting. Only one semi-commercial farm practiced vermi-composting while the rest tried but stopped and did not continue. According to them, vermi-composting is laborious and that they cannot allot time for it since their whole day is already devoted for milking, collecting forage, feeding the buffaloes, bathing the buffaloes, and cleaning the pen and so they resort to just piling the manure of their buffaloes near the animal pen.

CONCLUSION AND RECOMMENDATIONS

Most of the dairy buffalo farmers in San Jose City and Science City of Munoz, Nueva Ecija, Philippines are male who are married and are middle-aged. They attended formal education for 11 years, on average, and currently have 1-2 members of the family who are studying. They are members of an agricultural organization and have engaged in buffalo farming for more than a decade. Their hands-on experience and connections provided them with learnings. These, along with the various training courses they attended over the years contribute to their high awareness and knowledge of environmental issues related to buffalo farming. Dairy buffalo farms are categorized as smallhold, family module, semi-commercial and commercial dependent on the number of caracows being raised. There are commonalities but more differences on the characteristics of the assessed buffalo farms per farm category in terms of housing area, forage area, and management system. The volume of waste differs by each farm category with the smallhold having the least volume of waste and the commercial with the highest volume of waste produced which includes both biodegradable and non-biodegradable waste.

The waste generated in the buffalo farms is managed depending on the kind of the waste produced. Manure is stockpiled by a majority of the farmers and allowed to naturally decompose for several months which are then applied in their forage areas, rice farms or vegetable farms. Some are able to sell it but at a minimal price and in an unstable market, thus many of the farmers just give it for free to requesting neighbors. Only a few practices vermicomposting because it is laborious as claimed by the respondents while those who practice full grazing of their animals just leave the manure in the grazing area to decompose and to be incorporated into the soil.

For non-biodegradable wastes such as medicine containers, AI gloves, semen straws, and rope, many of the respondents bury, burn or throw in vacant areas because of the absence of a garbage collector. Some of the respondents store, sell or reuse the medicine containers while a majority reuse the rope and sacks. On the other hand, the liquid waste generated in the dairy buffalo farms is disposed by some farmers into their rice farms or forage areas to serve as additional fertilizer while some dispose it directly into rivers, creeks or irrigation canals.

The identified significant driver of waste management particularly on manure management is the number of mature animals being raised. The result of the binary regression showed that as the animal holding of the dairy farmers increased by 1 unit, there is a 0.23 increase in the probability that the dairy farmers will practice stockpiling.

Based on the findings of the study, several recommendations are suggested towards a more sustainable dairy buffalo enterprise in Nueva Ecija, Philippines. The Philippine Carabao Center (PCC), in partnership with other concerned agencies needs to co-develop a basket of options on waste management of dairy buffalo farms taking into consideration socio-economic status and farm characteristics of buffalo farmers. To encourage dairy farmers, adopt rapid composting and boost the businesses of vermi-compost practitioners, promotion, and establishment of a centralized market for composts should be established in each Local Govenment Unit (LGU). Stricter implementation of RA 9003 should also be observed in order to address burning, burying or improper throwing of non-biodegradable wastes. Each LGU should improve and intensify systems on garbage collection, monitoring, information education campaigns and training of deputized village-based environmental enforcers.

Fresh manure or slurry has higher fecal coliform content; thus, farmers should be discouraged to directly dispose of wastewater or slurry into their farms or other disposal sites to prevent contamination. A wastewater treatment pond is needed in this matter which imposes an additional cost to the farmers. However, protection of the environment is the best first step to attaining sustainable buffalo enterprise. Collaboration with other agencies to develop or showcase suitable, affordable and less labor-intensive technologies on dairy farm waste management such as odor minimizers, biogas digesters, septic tanks, constructed wetlands or wastewater treatment ponds, etc. must then be undertaken. Credit windows and technical support should be offered to the farmers in order to facilitate a faster and higher adoption of such technologies. A feasibility or operational study on the best wastewater treatment technology applicable to each classification of dairy farm should also be undertaken. Studies on innovations to improve, maximize, or diversify the usefulness of farm waste particularly animal manure and liquid waste must also be carried out by the concerned agencies (Department of Agriculture, Department of Environment and Natural Resources, PCC and academe).

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