

Livestock manure management practices in rural households in Tapanuli Utara reGENCY of North Sumatra

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Abstract. Livestock manure management is a big challenge for low income economies including the region of North Sumatra, Indonesia. Currently, low percentages of manure managed cause illegal disposals, and negative impacts on public health and environment. Therefore, the objective of this study was to assess the current trends among livestock manure management practices in rural households and to recognize potential problems with it. The questionnaire survey using randomly selected households (n = 196) was administered in the province of North Sumatra, Tapanuli Utara reGENCY, from July to August 2014; then followed by several field visits from August to September 2016. Data obtained in the survey were analysed with descriptive statistics and cross tabulation. Majority (81%) of rural households handle manure in the process of either composting (75%) or sun-drying (6%). Remaining 6% of the respondents does not handle manure at all. Manure could represent valuable energy and plant nutrition resource, if used appropriately. However, if not handled at all or handled inappropriately, it can lead to the environmental problems. Our results revealed that current ways of stabling of livestock are inappropriate from the environmental perspective. The stabling has got only dusty earthen floor, which makes difficult for farmers wash out the excrements and pollution. Hence, there is a need to improve manure management practice to eliminate potential threats as current practices do not protect either humans, animals or environment against the risk of contamination with potential zoonotic pathogens.

Key words: manure management, waste management, Indonesia, livestock sector, rural household, Sumatra.

INTRODUCTION

Livestock plays an important role in global food production and in agricultural and rural economies in many developing countries. It also plays an important role in socio-economic development of rural households within improving wellbeing of the family

household. Livestock is helping with food supply, improves family income and nutrition, improves soil productivity, agricultural diversification, and sustainable agricultural production, as well as it enhances family and community employment and in some cases also social status and ritual purposes (Bettencourt et al., 2014).

It is one of the fastest growing subsectors of agriculture worldwide. During the last decades, global production of meat, milk and eggs has rapidly expanded in response to a rapid growth in the consumption of livestock products (Thornton, 2010). A doubling of demand for animal food source is expected for developing countries by 2050 (Teenstra et al., 2014) and 70% increase for the world (Belete & Ayza, 2015).

In the early 1970's, beef was the main meat source in Indonesia, however, with the introduction of modern poultry systems, both for broiler and eggs in the 1970's, poultry meat production increased significantly. In 1995, Indonesia had 11 million heads of beef cattle and almost 12 million of goats and approximately 330,000 of dairy cattle. Over the period of 1941 to 1997 the number of pigs increased more than seven times from 1,296,000 to over 9,000,000. Beef and buffalo meat are not favoured by Indonesians because, compared to poultry both meats are expensive. The main livestock species nowadays include poultry, pigs, cattle and buffaloes. Also, it is important to notice, that 46.3% of population in 2015 were settled in rural areas (FAOSTAT, 2017) where majority of livestock production is concentrated. Currently, livestock production in rural Indonesia is mainly integrated into the way of life of rural families and communities.

The livestock sector also contributes towards conservation of environment, supplements income from crop production and other sources, and absorbs income shocks due to crop failures (Ali, 2007). Further, it can generate continuous income and employment and reduce seasonality in livelihood patterns particularly of the rural poor (BIRTHAL & Ali, 2005). It is important to realize that rural poverty is largely concentrated among the landless (Ali, 2007) and several empirical studies indicate importance of livestock in terms of rearing positively on equity in terms of income and employment and poverty reduction in rural areas (Lefroy et al., 2000; Thornton et al., 2002; Ali, 2007; Valešová et al., 2017). Livestock breeding is also important for many of the poor in the developing countries. It does often contribute to multiple livelihood objectives and offers pathway out of poverty as it also affects and indispensable assets of the poor, their human capital and through all of it positively impacts their own nutrition and health (Randolph et al., 2007; Valešová et al., 2017). Furthermore, the livestock species play very important economic, social, and cultural functions for rural households in developing countries, as improving income and wellbeing of the family household (Bettencourt et al., 2014). Livestock is helping with food supply, improves family income and nutrition, improves soil productivity, agricultural diversification, and sustainable agricultural production, as well as it enhances family and community employment and in some cases also social status and ritual purposes (Bettencourt et al., 2014). The importance of livestock goes beyond its food production function as it provides also draught power, organic manure for fertilizing, and other products as bones, skin and blood or fibres to industrial sector and further use. When considering classification of livestock functions, according to FAO (ILRI, 1995) two classifications widely used are based on the kinds of output produced (food, cropping inputs, and raw materials) or in the uses (household consumption, supply of inputs, cash income, savings and investment, and social and ritual roles) in which these outputs are put on. Different classification divides livestock functions in economic (source of cash income, mean of savings accumulation and

investment, economic status), household use (feeding, transportation, fertilizer and draught animals), socio-cultural (social status, paying bride wealth, providing animals for communal feasts or sacrifices) and leisure (horse racing, cock fighting, bullfight, hunting). Regarding cattle ownership, 97.91% smallholder farmers keep between 2–3 heads, however with high ownership disparity. In addition, total of 5.1 million farmers keep their livestock as a ‘saving’, not as a ‘commodity’ (DLBP, 2015).

When focusing on the target area, most of the population of region of North Sumatra professes the Christian religion (unlike other provinces that are predominantly Muslim), hence, there is enlarged pig production in the target area. Another important domesticated species of animal for locals are water buffaloes (which are also the symbol of the local Batak culture) and poultry. There are also significant numbers of cattle (meat and dairy breed; over 666,000 and over 1,100, respectively in 2015 in North Sumatra). However, they are not commonly kept in the rural households in the target area (as they are mainly in the large-scale farms). Numbers of livestock in 2014 and 2015 are given in Table 1.

Table 1. Total livestock in North Sumatra

Type of livestock (<i>local name</i>)	2014	2015
buffalo (<i>kerbau</i>)	116,008	117,200
cow – meat breed (<i>sapi</i>)	646,749	666,496
cow – dairy breed (<i>sapiperah</i>)	1,088	1,147
pigs (<i>babi</i>)	1,118,909	1,159,027
broiler chicken (<i>pedagingbroiler</i>)	47,179,814	47,659,709
local chicken (<i>ayamkampung</i>)	14,037,817	14,190,165

Source: Adapted from BPS (2015) with latest available data.

Manure management and housing of livestock

Considering numbers of livestock populations, it is undeniable that there is a great necessity of proper livestock manure management including proper treatment of high volumes of livestock excreta. Manure, if managed properly, can be used for multiple purposes (Roubík et al., 2016), such as fertilizer for crop production (Mieldažys et al., 2016), energy source (Roubík et al., 2017), or sometimes as basis for construction materials (Teestra et al., 2014; Belete & Ayza, 2015; Holman et al., 2016). However, if manure is not managed at all or inappropriately (disposing to rivers and other water sources etcetera), it can lead to the environmental consequences and further problems. The negative impacts of the livestock sector include degradation of land, soil and water, reduction of the biodiversity and the air pollution (Moula et al., 2015; Sarkwa et al., 2016). Therefore, proper manure management is crucial in terms of sustainable livestock production. It is important to realize that disposal and storage of raw manure has become an environmental problem (Ghaly & Alhattab, 2013; Sarkwa et al., 2016). Manure is largely composed of animal excreta (faeces and urine) that is mixed up with other substances such as water, dirt, mammary glands and others. Recovery of pathogenic bacteria in freshly voided animal faeces shows that manure is a potential source of zoonotic pathogens contaminating the environment and represents a risk for further transmission to human (Kruska et al., 2003; Ali, 2007; Randolph et al., 2007; Lupindu et al., 2012). Several studies have also reported cases of human gastroenteritis due to bacteria entero-pathogens of animal origin following consumption of contaminated food

or water or direct contact with infected animals in farms (Ali, 2007; Hoelzer et al., 2011; Lupindu et al., 2012; Cantas & Suer, 2014).

Housing of cattle is an important aspect of manure management, as it is essential for animals' optimisation of both housing and manure management. This optimisation includes factors such as feeding facilitation, hygiene, animal health and facilitation of manure collection and nutrient conservation as well as to save labour force. Poultry manure begins to decompose immediately after excretion giving off ammonia which, in high concentrations, can have adverse effects on health as well as on the productivity of birds and health of people living in the household (Ghaly & Alhattab, 2013). More frequent collection and/or cleaning of pens/stables can contribute to reducing of nitrogen losses.

In practice, manure is stored in heaps varying in their dimensions, management and occurring processes (aerobic and/or anaerobic). When water-tight floors are used, nitrogen losses decrease. On the other hand, the larger surface area of collection and storage facility of manure is, the higher risks for ammonia volatilisation occur. Among others, manure is an important contributor to anthropogenic greenhouse gas emissions, in which manure and manure management account for 10% of total livestock emissions. Agricultural practices, environment and human health are intrinsically linked (Międzażyński et al., 2016).

Liquid manure (urine and slurry) is obviously more difficult to collect and therefore is mostly flushed into the environment. However, such practices are resulting in emitting large amounts of methane (CH₄) and nitrous oxide (N₂O) into the atmosphere (Lupindu et al., 2012). Furthermore, it emits nutrients, which can contribute to public health risks such as waterborne diseases, to biodiversity losses as well as economic losses due to the increase of water treatment costs (Teenstra et al., 2014). Without proper implementation of adequate manure management practices, these negative impacts of manure are poised to increase. For example, if drying of poultry manure were practiced (to the dry matter content of 50% at least) it would substantially reduce the risk of nitrogen loss (Ghaly & Alhattab, 2013).

As can be found in FAOSTAT data (2017) livestock production accounts for 7.1 Giga tonnes of CO₂ equivalent per year, representing 14.5 percent of all anthropogenic GHG emissions involved in climate change and global warming. The majority of emitters from livestock sector are from cattle (both dairy and non-dairy) and from poultry and pig production.

This study was conducted to improve understanding of livestock manure management practices in rural households in North Sumatra, focused on Tapanuli Utara regency, in order to reveal current practices for improving livestock manure management and health within the regency.

MATERIALS AND METHODS

Description of the study area

The survey was conducted in the province of North Sumatra, Tapanuli Utara regency (Fig. 1). The population of North Sumatra consists of over 13.9 million inhabitants, which represent around 5.4% of the population of Indonesia (currently 255,461,700 inhabitants; with prediction of around 305,652,000 inhabitants in 2035 (BPS, 2015)). North Sumatra is fourth most populous province in the country. The

population of Tapanuli Utara regency, according to the latest data from 2014, is over 290,000 inhabitants.



Figure 1. Target area (Tapanuli Utara regency) of North Sumatra.
Adjusted from: Wikimedia Commons.

Data collection and analysis

The survey was conducted using randomly selected households ($n = 196$) (on the confidence level of 95% giving margin error less than 7%) from July to August 2014 and followed by several field visits from August to September 2016. The methods of data collection consisted of 1-hour semi-structured personal interviews. Main categories of the questionnaire are given in Table 2. The results of interviews were compared with observations of the target groups. The questionnaire was designed to determine the current situation about the issue of manure management for the target area in rural households. The questionnaire included different types of questions such as open, closed, semi-open, evaluation and multiple choice questions. The questionnaire was subject to pilot testing and was subsequently adjusted and translated before final distribution. Data obtained in the survey were analysed with descriptive statistics and cross tabulation.

Secondary quantitative data regarding total livestock population and regarding total emissions from livestock sector were obtained from available statistical databases such as FAOSTAT and BPS (Badan Pusat Statistik/Central Bureau of Statistics Indonesia).

Table 2. Main categories of the questionnaire

Category	Variable
Livestock farming	Number of livestock
	Stabling of livestock
	Feeding of livestock
Manure management practices	Amount of available excrement from livestock
	Manure management practices

Estimation of methane emission from manure management

For estimation of methane emission from manure management, IPCC (2006) methods was applied using the following Eq. 1:

$$E_{CH_4} = EF_{(T)} \cdot N_{(T)} \cdot 10^6 \quad (1)$$

where E_{CH_4} are methane emissions from manure management, [Gg CH₄ y⁻¹]; EF_T is emission factor for the defined livestock population, [kg CH₄ head⁻¹ y⁻¹]; N_T is the number of head of livestock species / category T in the country.

We used the emission factors for selected livestock according to the IPCC (2006) (Table 3).

Table 3. Emission factors for selected livestock

Livestock species	Manure management emission factor
Buffalo	2.00
Cow – meat breed	1.00
Cow – dairy breed	31.00
Pig	7.00
Broiler chicken	0.02
Local chicken	0.02

Source: IPCC (2006).

RESULTS AND DISCUSSION

General characteristics of livestock farming in the study area

Majority of interviewed farmers in the study area are facing harsh weather, the adverse weather effects and pests that affect quality and quantity of production, and consequently household incomes. According to the respondents, prolonged drought (96%), presence of pests (66%), earthquakes and floods (7% and 3% respectively) were the main problems. As stated in the SNV report (2009,) in years 1997–1999 prolonged drought caused food shortages in many provinces in Indonesia and numerous fires that devastated large areas of forests and human settlements. Earthquakes, as mentioned by farmers, appears only once a year and it is only small tremors, which does not have devastating effects.

Over the last decade, the livestock sector has grown at an annual rate of 13% (US\$4.5bn) of the overall agriculture. This increase corresponds to an annual average growth of 4.6%, which is higher than the overall growth of agricultural sector (3.5%). This suggests that livestock is likely to emerge as an engine of agricultural growth in the coming decades. As shown in Figs 2 and 3, all categories except buffaloes have growing number of livestock.

This is in accordance with the continuous growing trend in meat consumption (1.1 billion tons in 2014; meaning +1.4% growth in volume since 2013 and +3.2% since 2010) (BPS, 2015). As shown in Fig. 3, by 2014, poultry production reached 47 million heads of broiler chicken, while cattle (meat breed – Fig. 2) number was approximately 0.6 million of heads. The reason for the importance of chicken meat is that it is generally fast and accessible source of proteins – the least expensive to produce and to purchase.

In Fig. 3, there is a growing trend in broiler chicken production and slowly decreasing trend of local chicken. Even though it is still demanded, especially by domestic consumers. Currently, the government policy is aimed at increasing efficiency and productivity to enable poultry producers to compete in the market through better quality products, competitive prices and good delivery systems.

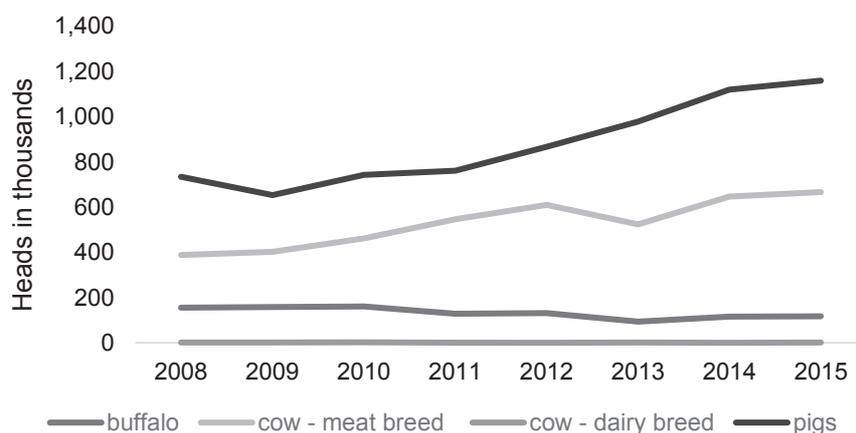


Figure 2. Development of livestock in the period 2008–2015 in North Sumatra.
Source: BPS, 2015.

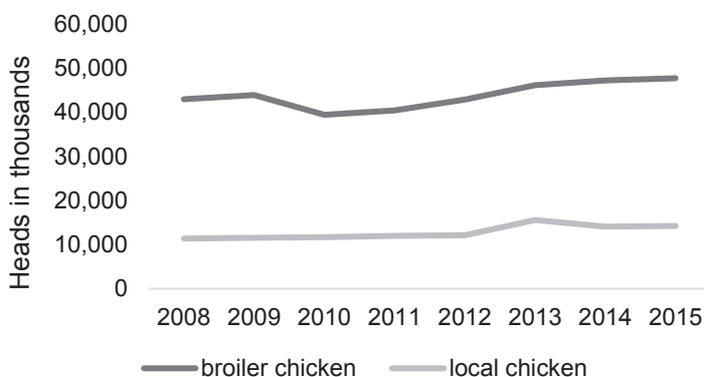


Figure 3. Development of poultry in the period 2008–2015 in North Sumatra.

The average size of farm was 1.1 (\pm 0.7) hectare. The farm is either located directly behind their household or in the distance reached by a motorbike in maximum 15 minutes. As shown in Table 4, the composition of livestock in small-scale farmers differs in nature.

Table 4. Livestock numbers in the interviewed households (n = 196)

	No of household	Average heads of animals	Min/Max of heads of animals
Buffalo	54	3.3	1 / 20
Pigs	73	6.4	1 / 120
Cattle	4	1.8	1 / 3
Poultry	69	56.3	2 / 40

Stabling and Feeding of livestock in the target area

Throughout much of the developing world livestock are raised in mixed farming systems, where animals have very often different functions. Livestock activities are normally integrated into the existing farming systems: animals graze on fallow land and browse on hedges, utilise crop residues as feedstuffs and produce milk and meat, manure for biogas and power for traction (Teenstra et al., 2014).

The two main methods for housing pigs in the target area are using of bamboo structures called *kandang* (majority of cases) or tethering the pigs with a rope. In both cases, it is common to keep pigs close to the household. *Kandang* is a bamboo structure often with partially open sides and usually built off the ground allowing so appropriate ventilation and waste to fall below the pen (Leslie et al., 2015). Pigs are mostly fed with local agricultural products including vegetable products (such as corn, sweet potatoes leaves, cassava and taro), fruit products (such as papaya, coconut and banana) and kitchen food waste. The quantities of feed follow seasonality – lower availability during the dry season. Such findings are in accordance with the study by Leslie et al. (2015).

Small-scale farmers keep cattle outside during the day and in open or roofed stables for night. Generally, in Sumatra it is common to collect cattle excreta when at least medium-scale production of animals (minimum 10 heads) is kept (not in the household small-scale production), then collection of excreta is executed below cattle stables.

Similarities are found in the case of buffaloes, as they are also mainly kept outside and they are taken to their housing (open or roofed) for nights. Regarding feeding practice, it can be divided into dry and wet feeding systems. Grazing is gradually changed to cut-and-carry feeding systems in the growing period of paddy and secondary crops when less grazing land is available. Low feed availability may force farmers to sell the mature animals and replace them with young ones. Smallholders tether their animals in grazing areas during the day and confine them at night. One can still see children or older people herding the animals during the day. In some areas, cattle are permitted to run free in designated areas during the cropping season and are permitted to graze crop residues during the dry season. Since recycling of crop residues is an important function of cattle, keeping them tethered eases manure collection. Allowing the cattle free range requires close supervision to maintain the security of the animals.

Poultry is most commonly kept free in the surrounding of the household or in the backyards. Therefore, its manure is usually not collected at all. However, if poultry were kept on a raised wired or slatted floor, it would allow easy collection of excreta below the floor (for example in a pit) and for further use.

As stated in Teenstra et al. (2014) between 60% and 95% of the animal's nutrient intake via feed is excreted via dung and urine containing undigested carbon and nutrients. Manure, in case of our respondents, was either disposed of as an effluent, or collected, or stored and used. In practice, management and dimensions of manure heaps vary, and processed inside heaps may be partly aerobic and/or partly anaerobic. When

water-tight floors are used, nitrogen losses are also lower, but again a larger surface area for the (collection) and storage facility of manure increases the risks for ammonia volatilisation.

Therefore, it can be stated that majority of observed stabling was identified as inappropriate. Almost 2/3 of the respondents use only stabling on dusty earthen floor, which is difficult to be washed out in the way to use excrements for other purposes (such as biogas production etc.). Only less than 1/3 of the respondents keep pigs in simple stabling pens, occasionally equipped with a concrete floor.

Current livestock manure management practices in the target area

Agricultural operations generate large quantities of manure which must be eliminated in a manner that is consistent with public health guidelines (Holman et al., 2016; Wasserbauer & Herák, 2016).

Majority (81%) of rural households process manure in the way of either composting (75%) to get fertilizer or sun-drying (6%) to get fuel. Remaining 19% does not manage manure at all (meaning not collecting and leaving on the site). In the target area, amounts of excrement per each animal for buffaloes, cattle, pigs and poultry were in average 13.3 (\pm 8.0) kg per night, 15.2 (\pm 6.0) kg per night, 12.8 (\pm 13.5) kg per day and 4.5 (\pm 5.4) kg per day, respectively according to the respondents. High variances may be caused by feeding, stabling and age of animals. In case of buffaloes and cattle, the amounts of excrements were considered only for night time as they are mainly stabled only during the night time. If we focus on each of the manure management by each livestock category, the general practice in the target area is to collect only pig manure and dairy cow fully for further manure management. In case of buffaloes and cows for meat breed, it is common to wash the excreta out or collect it after night housing. In case of poultry it is common not to collect manure at all.

In the target area, traditional composting was the most common way of handling manure (when manure was managed). Such a method consists of trenches or pits about 1 m deep; the size of the trenches can vary according to the availability of land and the type of material to be composted, organic residues and night soil are put in alternate layers. After filling, the pit is covered with a layer of organic residues of approximately 15–20 cm. The materials are allowed to remain in the pit without turning and watering for three months. During this period, the material settles owing to reduction in biomass volume. Additional night soil and refuse are placed on top in alternate layers and plastered or covered with mud or earth to prevent loss of moisture and breeding of flies. After the initial aerobic composting (about eight to ten days), the material undergoes anaerobic decomposition at a very slow rate. It takes about six to eight months to obtain the finished product. Therefore, the total time used is being reported to about 1 year.

Implications from current manure management practices

In Fig. 4, methane emissions calculated from manure management in North Sumatra are clearly visible. Majority of methane emission is originating from pig production (8.11 Gg CH₄ y⁻¹ in 2015) followed by that of broiler chicken (0.95 Gg CH₄ y⁻¹) and cow production for meat (0.67 Gg CH₄ y⁻¹). Methane emissions from stored solid manure can be reduced by two completely different strategies (Table 5) aiming at either promoting or preventing anaerobic conditions (Chadwick et al., 2011).

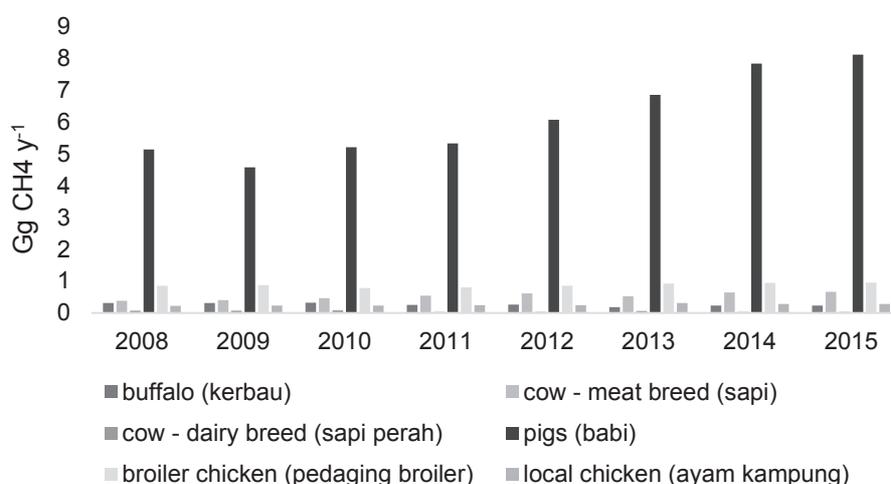


Figure 4. Methane emissions from manure management in North Sumatra, Indonesia.

Reducing the organic matter content of slurry through separation or fermentation of slurry in a biogas digester may prove to be the most efficient way of reducing CH₄ emissions during outside storage (Chadwick et al., 2011; Roubik et al., 2017).

Table 5. Potential methane reduction methods drawn from current manure management

	Reduction methods	Reference
Animal housing	Modified feeding strategy	Jordan et al., 2006; Beauchemin et al., 2008; Leytem et al., 2010; Chadwick et al., 2011
	Removal of slurry	Chadwick et al., 2011
	Cooling the slurry (in more sophisticated housing)	Chadwick et al., 2011
Manure storage	Modified feeding strategy	Beauchemin et al., 2008; Leytem et al., 2010; Chadwick et al., 2011
	Removal of slurry	Chadwick et al., 2011
	Cooling the slurry (in more sophisticated housing)	Chadwick et al., 2011
	Composting of manure	Leytem et al., 2010; Chadwick et al., 2011
	Anaerobic digestion of slurry (use of biogas plants)	Leytem et al., 2010; Chadwick et al., 2011; Roubik et al., 2016; Roubik et al., 2017

FUTURE CHALLENGES

As the production volume of the livestock sector in Indonesia is still far from meeting consumer's needs, there is expected growing trend to continue. For example, in 2008 domestic beef production was only able to satisfy 24% of the national demand and 31% in 2012. In pig sector, considering over 33 million non-Muslim Indonesians and growing number of tourists visiting the country every year, with annual average import

of swine meat increased by 25% and the growing trend will continue. As livestock contributes in sustaining agricultural production and meeting needs of consumers, it can also have disastrous environmental consequences, especially if manure is not managed properly.

Currently, manure management systems, with a special emphasis on environmental protection, are increasingly being incorporated into animal production systems (Belete & Ayza, 2015). It is important to consolidate approaches that involve biophysical, technological and human considerations across space and time to optimize livestock production systems in which manure management systems are integrated.

CONCLUSIONS

This study revealed that there is a need to improve manure management practice in order to eliminate potential threats coming from inappropriate practices. Almost 1/5 of the rural households do not manage manure at all (commonly leaving it on the site), which can lead to the environmental consequences and further problems. The current manure management practices do not protect either humans, animals or environment against the risk of contamination with potential zoonotic pathogens and therefore there is a need for the formulation of guidelines on safe manure management practices. There is need to improve the quality of human resources and maximize the use of natural and agricultural resources and supply. The construction and development of facilities and infrastructure, in addition to the development of farmer institutions are intended to ensure efficient and effective use of all development resources.

This research extends our knowledge of livestock manure management practices in rural households in Tapanuli Utara regency and therefore provides insight into current trends and proves to be particularly valuable for further consideration of implications from current practices. Future research and development in livestock manure management must focus more on strategies, techniques and systems allowing to maximize the benefits of manure while minimizing negative impacts (on the natural resources, humans, livestock and ecosystems).

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