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Cattle dung production, management and utilization practices in the smallholding dairy farming systems of East Africa: A situational analysis in Lushoto District, Tanzania

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Abstract

This focus review aims to update the dung and manure production, management and utilization in the East African countries and its associated challenges particularly in the case of Lushoto district, in northern Tanzania. Attention and efforts are continuously being made to promote the use of cattle dung though the challenges still exist. Majority of smallholder farmers in the East Africa poorly manage cattle dung such that its quality is impaired. Such practices include exposing the dung uncovered in a heap and applying directly to the crops. A survey conducted at Lushoto district in the smallholder dairy farmers observed poor management from collection of dung, processing or storage to utilization causing losses of potential nutrients when it's used as manure. Additionally, the knowledge on other uses of cow dung such as for biogas production is not adequately known. This review, therefore, revealed the need for training farmers on issues related to dung management and utilization such as the nutrient recycling at the farm scale. Cattle dung has been for a long time used as manure in agricultural production and recommendations especially on the applications and users have been generalized to a wide range of areas. There is a need to establish area specific recommendation on dung management from production to the final use. For sustainability of the knowledge, readable materials, an appropriate intervention of biogas plant, manure storage (shade structure) and decomposition process that will create awareness from production to farm application are required.

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Introduction

Cow dung is defined as the undigested residue of consumed food material being excreted by bovine animal species in particular cattle and buffalo (Gupta *et al.,* 2016). Nutrient concentration in cow dung varies with diet, water intake, genetic, health and feed conversion efficiency of a specific bovine animal especially for indoor systems whereby diet selection by animals is replaced by human perceptions of animal needs (Powel, 1994). Cow dung has many uses including; used as building materials, as fuel (Jahnke, 1982; Saadullah, 2002) and as fertilizer when processed from the biogas plant (Islam, 2006). In general, cow dung is perceived as plenty resource in the majority of the smallholding dairy farming in East Africa and thus can be used for soil fertility improvement to enhance crop production (Scoones, 1992). Therefore, manure from smallholder dairy keepers contributes to food security by increasing crop output and income in the poor households (Lekasi *et al.,* 2001).

It has been reported by Snijders *et al.,* 2009 that the major benefits obtained from the use of cow dung as manure include the increase of crop yields by 52.5% and disease reduction by 30%. Moreover, maize yields from improved cattle manure applied at a rate of 2.5 t ha^{-1} increase production by 50% in Uganda as reported by Zake *et al.* 2010. At Vihiga, western Kenya, it has been reported that manure use is more important to the production of food crops than of cash crops, and this is critical to low-income households (Waithaka *et al.,* 2007). Also, in Kenya, manure create income by 75% through selling to individual traders or brokers by 20% through selling directly to farmers, and by 5% through selling directly to large and small horticultural farms (Njoka *et al.,* 2013).

Despite those benefits cow dung is still given less emphasis by smallholder farmers who are primary producers of agriculture products (Kiratu *et al.,* 2011). Recently, smallholder farmers have been experiencing a decline in agricultural productivity, mostly due to soil fertility depletion that leads to food insecurity (Ngetich *et al.,* 2012).

Such deterioration in productivity is considered to be among the major constraints to economic development in Sub-Saharan Africa (Lunge, 2002). Soil fertility depletion or soil nutrient mining in Sub-Saharan Africa and many tropical cropping systems is contributed by traditionally cleared land while giving nothing back to the soil (Zake *et al.*, 2005; Henao *et al.,* 2006; Baitilwake *et al.*, 2011). Soil nutrient mining is also contributed by the majority of smallholder dairy farmers who do not allow cattle to graze in the maize fields after harvest as a way of adding manure to the field (Materechera, 2010). Therefore, there is a need for cow dung management from excretion to utilization as manure for replenishment of the lost nutrients from agricultural fields.

Many mixed farming systems in Sub-Saharan Africa rely upon organic matter recycling to maintain soil productivity (Lekasi and Kimani, 2003). It has been reported that un-affordability of mineral/inorganic fertilizers due to escalating prices, anticipates more smallholder farmers in Sub-Sahara Africa to turn to the use of organic sources that are not only available but also affordable for low-cost for enhancing crop productivity and improves soil water holding capacity, cation exchange capacity, and soil structure (Harris *et al.,* 2001; Achieng *et al.,* 2010). Currently, the human population is exponentially growing and most of the smallholder dairy farmers live in peri-urban areas, so farmers are encouraged to maximize crop yields per unit area through intensive cultivation (Henao *et al.,* 2006; Muhmood *et al.,* 2015).

Information on nutrient losses between excretion and application of manure is still limited under smallholder conditions in the tropics, due to the wide variation in farming conditions and variation in livestock and manure management (Snijders *et al.,* 2009). Therefore, in order to maintain the consistency of dung and manure quality, it is important to disseminate proper knowledge on dung collection, management, storage, and utilization that would minimize nutrient loss and allow the nutrients to be readily available to the plants for maximizing crop yield.

Cow dung production

Dung production from a cow is influenced much by the amount of feed intake related to fodder resources which in smallholder systems especially in tropics depend on rainfall that is extremely variable in amount and distribution over the season. The estimated dung production for cattle is 4 to 5 and 2 to 2.5kg DM day^{-1} for crossbred and local cattle respectively according to Raussen, 1997 as was cited by Jackson *et al.,* 2005 and the average value of moisture content of dung is 60% (Aggarwal *et al.,* 1984). Other study reported in Zimbabwe indicated that; daily production of fresh wet dung averaged 4.8% (range 3.3-6.5%) of the live body weight (Vale *et al*., 2004). El-Mashad and Zhang, 2010 reported that 1800 cows produce 83.1 ton of wet manure daily in the USA, which is an average of 46.26kg^{-1} cow while Jackson *et al.,* 2005 reported that in an average of two herds of cattle per household, farmers are likely to produce 2 to 3 tons DM of manure per year. The significant differences could be influenced by body weight and food as reported by Vale *et al.,* (2004). It was reported in another study of estimating manure production in 15 households whereby 1300kg ha^{-1} and 3800kg ha^{-1} was collected during dry and wet season with an approximately of 22kg N ha^{-1}, 2.7kg P ha^{-1} and 45kg N ha^{-1} and 5.7kg P ha^{-1} for dry and wet season respectively (Powell and Williams, 1993). This means manure production depends much on the availability of fodder which is perceived to be plenty at wet season than in dry season.

In West Africa for instance, palatable crop residues are harvested at the end of the cropping season and stored for consumption at a later period to reduce the fodder shortage as well as to maintain dung production (Harris, 2002). Weiss *et al.,* 2007 pointed out that dung excretion increased on average with increasing milk production although this is not necessary due to increased milk is the result of adequate feed which may contribute to dung excreted. The total amount of dung that needs to be removed from the cowshed is affected by on stocking rate, digestibility of the diet, moisture content, frequency of cleaning and techniques.

Indoor rearing system of dung collection is also affected by floor type. Cattle house made by concrete floor rather than soil floors results in not only higher quality but also quantity of dung (Bationo *et al.,* 2004) which provide maximum opportunity for dung collection compared to traditional "kraal" which have poor drainage (Lekasi *et al.,* 2001; Snijders *et al.,* 2009). Lenkaitis, 2014 reported techniques for dung collections in USA that *flush system* involve dilution of the solid content of the available materials which can vary from 10:1 to 2:1 parts of water to dung while *Scrape Systems* does not use any additional liquid for dung collection. Dung is collected as close to as excreted solids concentrations as possible, but depending on the amount of bedding and the amount of water used in cow and collection is accomplished by mechanical means and the last is *Cross Gutter* Collection Systems whereby collection system requires an additional transfer system to move dung from each alley across the barn to pit outside of the animal housing system. Majority of farmers in East Africa practice the same way as *scraping system* as reported by Kim *et al.,* 2013; Lupindu *et al.,* 2012 probably due to water shortage or lack of knowledge but also the rest two systems need an investment of facilities for storage of slurry of which many smallholder farmers cannot afford. Introducing an affordable, cheap and efficient system for dung collection to enhance manure collection after dung production is important in the smallholder dairy systems especially in Sub-Saharan Africa.

Cow dung management and utilization practices

Cow dung handling

Cattle dung is the primary on-farm manure resource and is generally of low quality due to poor management practices in Sub-Saharan Africa (Zake *et al.,* 2010). Cow dung management encompasses all activities associated with management of dung and urine; from excretion, collection, housing, and storage (Teenstra *et al.,* 2014). The practice of management determines the usefulness of dung. Dung can be used for biogas production and as well as fertilizer or manure. Management strategies identified in some areas of Kenya include covering, turning and adding ash or water.

Only the small and medium farmers practice a single strategy, the most notable being covering (Lekasi *et al.,* 2001) and the nutrient composition is highly influenced by the way the dung was stored (Bayu *et al.,* 2005). In Kenyan highlands, manure is stored for about 6 months (Tittonell *et al.,* 2010). The longer manure remains in the housing or storage area before removal, the more chances for nitrogen loss (Barker *et al.,* 2002).

Covering of manure heaps influences all microbial changes and biochemical reactions during the decomposition process (Dewes, 1995) if well covered. According to the experiment reported by Dewes *et al.,* 1991, 24.8 to 44.4% of nitrogen was lost through NH_3 emission compared to 2.5 to 3.4% of nitrogen content leached with liquids. Other study in Kenya reported that the amount of N lost from manures that were covered was lower than that of uncovered manures and the N loss was equivalent to 19.23% with cover and 46.13% without cover, respectively (Gichangi *et al.,* 2006). From that finding covering of heap manure is important for minimizing loss of nutrients. However, many farmers leave manure uncovered in a heap as the most common storage method while others apply the manure directly as fresh (dung) to crops (Lupindu *et al.,* 2012; Muhereza *et al.,* 2014). Lindgren, 2013 reported that one methods of preventing ammonia emissions from storage facilities is to change a system that generates solid manure to a system that gives liquid manure because the ammonia emissions can be decreased since liquid manure is stored under anaerobic conditions. Biogas plant is working under anaerobic condition so efforts are required to smallholder farmers to invest in this technology to reduce the loss of ammonium which is the product of nitrogen nutrients.

In central Uganda, as reported by Zake *et al.* 2010 manure was delayed and irregularly collected ranging between 1 to 2 weeks after deposition by cattle. Formally, in Uganda storing of the manure collected in roofed stacks gave the best results in terms of their fertilizing qualities; however, this technique was found to encourage the breeding of flies and had the possibility of carrying human disease (Wejui *et al.,* 2002).

In Morogoro Tanzania, Lupindu *et al.,* 2012 had reported that, after collection into a heap, manure was moved to storage area either by bare hands or water splash using utensils such as spade, bucket, wheelbarrow, plastic bag or rawhide. Kim *et al.,* 2013 observed that farmers at Garinka, Rwanda; primarily used tridents, hoes, and baskets to facilitate manure handling and transportation and over 60% of farmers used their hands, often with banana leaves to collect cow dung. Significantly more female farmers were observed to practice in this local collection method than men.

Some practice of leaving manure uncovered in a heap has also reported by Muhereza *et al.,* 2014 in Central Uganda as the most common storage method although some farmers are providing shade to heaped manure, others applying it directly to crops while in the mixed systems most manure is not returned to grazing land (Herrero *et al.,* 2013). The recommended method for making farmyard manure in Uganda was to store the manure under the cattle until required and cattle be kept in a covered shed, darkened as much as possible to reduce the breeding of flies, and bedded down daily. It is further reported that little labor was involved in this process before the final transportation to the field and was suitable for use by the native farmer (Wejuli *et al.,* 2002). On contrary, Zake, 2005 in his study reported that covering cattle manure is not widely adopted practice by farmers the main reason being lack of covering materials. However, still there could be undiscovered alternative covering ways to reduce volatilization loss of nutrients. From these reports, it is therefore evident that the knowledge and skills on cow dung collection and manure handling is undoubtedly limited which then calls for a need to invest on practical training especially to smallholder systems.

Cow dung utilization

Cow dung is composed of feces and urine while manure consists feces, urine and materials used for bedding/left over-feeds (Tisdale and Nelson, 1958) which can be used manure as fertilizer and dung for biogas production.

The by-product from the biogas plant (bio-slurry) used as organic fertilizer to enhance agricultural productions and 50% use bio-slurry for their production in rural Bangladesh (Khan and Martin, 2016) while 68 and 52% use manure in rural and urban areas respectively (Saadullah, 2002). Bio-slurry maintains soil fertility and can be applied directly to crops without prior composting; this is evident from adopters in Arusha, Tanzania as reported by Laramee and Davis, 2013. Therefore, instead of composting manure for six months, farmers could use this technology to increase the value of their manure.

Cow dung as manure

Dung can be used as manure by providing nutrients for crops and positive effects to plant growth when directly applied to the soil. However, Dung may inhabit some harmful as well as beneficial insects (Halling-Sorensen *et al*., 1998), may have relatively high temperatures that could harm the plant and may contain weed seeds that could germinate when applied in the farm (Pleasant and Schlather, 1994.) The reasons above justify the need for complete decomposition of the cow dung before applying in the crop fields. Manure releases nutrients (from composted dung) (Aggarwal and Singh, 1984) and has the ability to increase soil productivity by improving organic matter content and soil physical properties (Bayu *et al.,* 2012). Manure has also been found to reduce the population densities of *Heterodera rostochiensis* in potato roots (Van der Laan, 1956). Manure contains all the nutrients needed for plant growth including trace elements and has the potential for improving soil fertility (Achieng *et al.,* 2010; Ngetich *et al.,* 2012). In most farms, animal manure used is mainly from cattle (65%) with the rest coming from diverse sources such as sheep and goats (6%) and 4% poultry (Lekasi *et al.,* 2001).

In Kenya more than 95% of smallholder farmers growing maize use animal manure (Ngetich *et al.,* 2012). Most cattle keepers dispose the manure either as fertilizer or waste within a radius of 10 m from their residential house (Lupindu *et al.,* 2012). Manure is mostly used in maize fields (Jackson and Mtengeti, 2015) and due to transportation need, its use decreases with an increase in steepness of the land (Ketema and Bauer, 2011).

The efficiency of manure utilization by a crop is determined by the method of application, time of incorporation and rate of decomposition in the soil (Achieng *et al.,* 2010). Efficiency also determined by the right amount of the composition of manure and an accurate estimate of crop requirements (Schröder, 2005). If manure is spread on the ground without being mixed into the soil then a large portion of the ammonia nitrogen can be lost to the atmosphere (Chastain *et al.,* 2004). Repeated applications of manure can result in their building to detrimental levels (Kuepper, 2000). A study done in South Africa showed that the majority (78%) of the farmers broadcast the manure and plows it under with a hoe or tractor before planting. The second most used method was applying manure in open fallows either as a continuous line (63%) or spot application and 7% farmers were mixing the manure with water and applied the solution to the soil around the root zone of the plant (Materechera, 2010). To ensure maximum utilization of manure contents and to reduce any environmental effects, therefore, proper application rate, time and application methods should be adhered to by farmers.

In Africa, the average nutrient losses of nitrogen (N), phosphorus (P) and potassium (K) in soils range from 9 to 88kg of NPK/ha per year (Henao and Baanante, 2006). In Tanzania, the amount of nitrogen and phosphorus removed from the soil every year by the main crops was estimated to be 251,448 tons N, and 115,112 tons P_2O_5 by the year 2000, only 21% and 14% of N and P removed respectively was projected to be replaced through fertilization (Kaihura, 2001). Other losses were reported from Kenya, Uganda, Rwanda, and Burundi for the rate of 68, 66, 77 and 77 respectively of NPK kg/ha/year (Henao and Baanante, 2006). The fact that many smallholder dairy farmers have small plots and if the manure produced per cattle could be managed properly, it will suffice the respective farmers' plots for enhanced land/soil productivity. It's approximated that farmers could use 6,000 kg ha^{-1} $year^{-1}$ of manure on their fields as reported at Garinka, Ngoma district in Rwanda (Kim *et al.,* 2013).

According to Materechera, 2010 high ranges in values of most of manure are reflected by differences in management such as feeding, housing, application method, rate and frequency of application of manure at the household/farm level. Harris, 2002 reported that the quality of manure produced by livestock varies according to their diet. The manure from improved management practices performed considerably better than the farmers' manure management practice in terms of cattle manure quality (Zake *et al.,* 2010). Tethering system of livestock has also been reported to affect the collection of good quality manure (Waithaka *et al.,* 2007). Animals fed on high levels of concentrates produce excreta with larger amounts of N (Lekasi and Kimani, 2003). The use of cattle concentrate feeds would be a way of improving the levels of phosphorous in manures and because of the economic aspects, this is only feasible in areas where milk production is intensive (Waithaka *et al.,* 2007). According to Lekasi *et al.,* 2003 roofing offered protection from the leaching effect of rain, from high temperatures and the loss of phosphorus thus increasing the quality of the manure. It is therefore evident that the qualities of animal feeds and animal housing are essential for improving the manure quality.

Cow dung as energy sources

Cow dung can be used for producing energy as biogas (Teenstra *et al.,* 2014). Cow dung from 3–5 cattle/day can run a simple 8–10m^3 biogas plant which is able to produce 1.5–2m^3 biogas per day sufficient for the family of 6–8 persons for cooking 2-3 times/meal or may light two lamps for 3 hours (Werner *et al.,* 1989). The biogas produced can also be fed into biogas generators to provide lights and run other types of equipments on the farm (Amankwah, 2011). In Tanzania, energy access is about 2% in rural areas (Uisso, 2009) and more than 80% of energy delivered from biomass is consumed in rural areas.

Heavy dependence on biomass as the main energy source contributes to deforestation (Msyani, 2013). In Kenya, wood fuel is accounting up to 95% of total energy consumption in rural households and nearly 60% of urban dwellings (Wamuyu, 2014) while few using charcoal occasionally and rarely gas (Ngetich *et al.,* 2009). Although the technology is more advantageous, there are constraints facing smallholder dairy farmers. Some factors that reported from Rungwe district by Mwakaje, 2012 are the relative too high installation costs, lack of credit facilities, lack of expertise and inadequate water to run the plants. Most of the plants in Africa have only operated for a short period due to poor technical quality (Amigun *et al.,* 2012) and management. Capacitating technical skill to local members who are easily available within the community would help to maintain the plants in case of minor problems at a reduced cost. Teenstra *et al.,* 2014 reported using cow dung for producing biogas as one way of reducing climate emissions partly by minimizing or eliminating the dependence of wood-fuel among smallholder farmers.

Nonconventional uses of cow dung

In African traditions, cow dung has been used since time in memory for various purposes. For instance, smoke from burning cow dung has been used to drive away or kill insects and other pests when burnt in clay pots or on the open ground and the smokes engulf the sick animal or the entire herd (Dharani *et al*., 2015). In Addis Ababa, cow dung is used as plastering material for houses and can also be used as fuel in form of dried cow dung cakes which are also sold for income earning (Desjeux, 2001; Guendel and Richards, 2002; Taddesse *et al.,* 2003). Cow dung is often applied to the floors of rural homes in India and may be applied to the walls as well (Udayani *et al.,* 2008). However, Taddesse *et al*., 2003 cited in Girma, 2001 reported that the practice reduces soil fertility and nutrient recycling in grazing land. The Maasai people of sub-Saharan Africa traditionally apply cow dung to the umbilical stump of a baby born to underline the close connection (Meegan *et al.,* 2001).

Therefore, cattle dung act as one of the traditional assets passed from one generation to another explaining way of living from ancestors.

Situation Analysis on Cow Dung Management and Utilization Practices in Lushoto District, Tanzania

Preamble

Lushoto district is found in Tanga region, in the North Eastern corner of Tanzania with an altitude of 1000 – 2100m above sea level and is famous for horticultural products. The district had a number of projects such as SECAP (1980-2000), TDDP (1991-2005) and Heifer International (1986-2006) that implemented developmental and research activities mainly on milk production, dairy cattle management, and agricultural production. The manure produced by the same animals has not been significantly investigated by such research activities in terms of its management and utilization to explore its potential in this area.

The current Community Action Research Project (CARP) conducted a household survey through direct observation and interviewing three households per village to assess cow dung production and the consequent manure handling and utilization. It was generally observed that poor manure management and utilization practices are common in Lushoto Districts and that there is a need to undertake a detailed study.

Cow dung production

Lushoto has a total of 90929 cattle; indigenous cattle 68197 and cross breed 22,732 and the surveyed villages comprise a total cross breed of 2159 (summarized in Table 1) that if fed well could produce an average of 25908kg day^{-1} of dung. With this dung production, respective farmers could have sufficient cow dung for manure, energy source and other uses.

Table 1. Dairy cattle population in surveyed villages in Lushoto district.

Village	Number of Household keeping dairy cow	Dairy cow population	Estimated cow dung production (fresh weight kg day^{-1})**
Ngulwi	134	402	4824
Bombo	89	267	3204
Viti	167	501	6012
Hambalawei	129	388	4656
Ubiri	96	428	5136
Mbuzii	65	173	2076
Total	680	2159	25908

**Fresh dung was estimated by taking the average production 4.8% (Vale *et al.*, 2004) per day times average Tropical Live body weight per dairy animal (250kgLBW) (Thornton and Herrero, 2010).

Cow Dung Management and Utilization

It was observed that dung is collected from the cattle pen and piled outside the pen for an average of six months until the pile is big enough to be shifted to the farm or into a pit. However, some farmers reported that the manure is gathered into large pits for about 12 months before being transferred and spread to the crop fields, particularly the nearby banana, maize and beans farms. For all that period, the manure is left uncovered (Fig. 1) resulting in accelerated loss of nutrients such as nitrogen and phosphorus through leaching and volatilization and might pose environmental risks. Majority of cowshed had poor quality with no concrete floor which might contribute to low manure collection and of poor quality.

Manure application is normally done 2 to 4 times a year depending on the type of crop grown and seasons, this is the evidence that manure is much used in the area and farmers require high quality manure for soil nutrient improvement. Another improper practice observed was the time and rates of application whereby there was an unknown amount of manure applied per area in which farmers could use the rate that may lead to negative effects on either plant or soil. Farmers point out that, the majority has 0.25–1.5 acre for their agriculture activities implying that if the manure produced in a household was applied at average rates of 2.5 t dry matter ha^{-1} with 50kg of nitrogen and 9kg of phosphorus (Probert *et al.*, 1995) could suffice the need for such a small farm.

The ratio of 2.5t ha^{-1} could replenish the average annual loss of 22kg N and 2.5kg of phosphorus (Sanchez, 2002). Therefore, there is a need for further study to know the available amount nutrients in soil and in manure so that the study could recommend the proper application rate for manure per land size.

Fig. 1. Uncovered cattle manure heaped behind cowshed indicated poor storage that poses environmental pollution risks and nutrient loss, Ubiri village.

As for the alternative dung utilization especially for domestic biogas, out of eighteen households that were surveyed in the six villages, only one household owned a biogas plant. The biogas plants were no longer function due to poor management (Fig. 2). Moreover, when was function, was underutilized and the use of bio-slurry was rather limited or completely unused. Observations and farmers opinion depicted the need for interventions by practical training on manure management techniques and promotion of biogas production from dung, especially at the household level. Every interviewed/visited household was excited with the biogas idea.

Fig. 2. Biogas plant at Viti village indicates poor management that lead to low gas production and destruction of the plant system.

Conclusion and recommendations

According to various literatures proper cow dung handling could lead to the production of manure which when appropriately used among smallholder farmers, it evidently increases crop production and securing sustainability in smallholding farming system. The major challenges identified to be facing farmers include limited knowledge and skills of cow dung handling and its benefits- from excretion to collection (e.g. importance of urine for nitrogen), manure handling and awareness of the associated losses of available nutrients due to poor handling, storage practice/duration, manure utilization especially in terms of application rates and cow dung alternative uses such as biogas production. Similar challenges were observed in the surveyed villages of Lushoto. Further to the poor management of cow dung and the manure, farm production is not up to the level is supposed to be when using manure. Farmers need to be practically trained on appropriate cow dung collection and proper manure handling and utilization as well as the alternative use of cow dung, especially on biogas production. Due to the potential of the area for agriculture activities, farmers could be trained on the importance of nutrient recycling to reduce nutrient mining as a factor for nutrient depletion which is predominant to farms that are at the hill where maize is produced but the return of nutrients through fertilization is very minimal. This focused review and the situational analysis in the smallholder dairy systems of Lushoto reveals the need to investigate on cow dung production, handling practices and the ultimate uses with emphasis on manure and biogas production. Proper recommendation on manure or biogas slurry application to the farms requires establishing the quality of the manure and characterizing soil from the intended farms. The appropriate farm-level cow dung management practices and manure/slurry uses could be documented for all-time use and for sustainability of the adequate practices.

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