

# Small Holders Managed Manure Nutrient Losses and Their Implications on Environment

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**Abstract** Animal manure is rich in absorbable plant nutrients and an appropriate addition of manure into the soil respond to high crop productivity than use of commercial fertilizer. But volatilization of ammonia due to high temperature and leaching of nitrate, phosphorous and potassium into the soil due to rainfall results in the loss of manure nutrients. The objective of this study was to assess manure nutrient loss and gaseous emissions due to inappropriate manure management. The study was conducted in central Ethiopian highland, east of the capital Addis Ababa. The study included laboratory analysis for manure nutrients contents from sampled units and the manure management type was captured through focus group discussions. Storage age has impacted on nutrient losses as a result the highest loss of N, P and K occurred in 2 to 3 years at the rate of 84%, 19 % and 42 % , respectively. The analysis of variance showed that at  $P < 0.05$ , there was a significant difference in storage age for N and K, but there was no significant difference for P across different storage ages. Shade type and manure heap height has no significant impact on nutrient losses. The total carbon equivalent ( $\text{CO}_2\text{e}$ ) gas emitted per household per annum was estimated at 11, 276 kg  $\text{CO}_2\text{e}$  (i.e. 8 200 kg  $\text{CO}_2\text{e}$  came from methane directly released by livestock plus their manure, 2 694  $\text{CO}_2\text{e}$  came from  $\text{N}_2\text{O}$  emissions from manure management and 381.48 kg  $\text{CO}_2\text{e}$  came from  $\text{CO}_2$  released from manure burning) that is about 2 tons  $\text{CO}_2\text{e}$  per capita per year, twice the value reported for Ethiopia emission in 2005. The largest emissions were from methane (72.6%), nitrous oxide (24%) and carbon (3.4%), this result appeal for a need to improve livestock and manure management systems under smallholders' agriculture in order to curb the challenges of global carbon release.

**Keywords** Green House Gas Emission; Livestock; Manure; Nutrient Loss; Smallholders

Livestock production has several advantages under smallholder agriculture, but it is also the largest global source of methane emissions representing 20 to 25 % of all sources of methane. In addition livestock is the greatest generator of nitrous oxide which contributes to global warming [12,17]. In addition to pollution, poorly managed livestock keeping is blamed for soil degradation through overgrazing, trampling and compaction [3].

Animal manure is more efficiently utilized by plants than commercial fertilizer because a larger fraction of nutrients from manure is absorbed by the plants [2,6]. However, their negative environmental consequence is eminent during the storage of manure in the open fields. In the case of open field manure storage operation volatilization of ammonia occur due to the high temperature and nitrate, phosphorous and potassium leach down due to high rainfall. Volatilization and leaching results to loss of nutrients making them inaccessible to plant root absorption. Mode of manure application during farming is also important to nutrient losses. For example, surface spread of manure without working it into the soil during periods of high precipitation on fallow land may also lead to volatilization, leaching and surface runoff of manure [2]. Even when nutrient levels in animal manure adjusted to the level of nutrient removal by the crop, wrong application techniques can cause losses or emissions [2]. Thus implies that manure management is more important than manure production.

Although manure remains an important organic source of fertilizer and energy, its impact on the environment has never been given adequate research it deserves, particularly under mixed-crop livestock production system [25]. The purpose of this study was, therefore, to document the impact of storage type and age of stored manure on the local environment under mixed crop-livestock production system of smallholders farming.

Research on manure use and management in the highlands of Ethiopia were carried out by Tesfaye et al [25]; and these authors have explained about manure storage type, means of manure transportation and the level manure use as soil fertilizer in the highland agro-ecology. However their report

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## 1. Introduction

did not describe the impact of different manure management systems on the environment and their implication to local and global air pollution. Getente [7] reported the effect of manure and nitrogen fertilizer on the perennial grasses' establishment, herbage yield and seed production in that was conducted in the highland agro-ecology of Ethiopia. The National Meteorological Service Agency in Ethiopia [20] and Asres [1] undertook a greenhouse gas emissions inventory for all sources in Ethiopia based on the guideline of IPCC [13], including manure pollution at national level. However, these authors did not oversee the effect of different manure management systems on the local environment and did not scaled down the influence at household level.

Thus the current study attempted to assess the different manure management systems and their impacts on the environment. The current research also addressed the following issues: to explore the extent of nutrients losses due to manure storage type and storage age and to document the household level gaseous emissions due to inappropriate manure management.

Information on these research questions was captured through focus group discussions and manure sampling to evaluate their chemical content in laboratory analysis.

Objectives: to determine manure nutrient loss and gaseous emissions due to different manure management practices.

## 2. Materials and Methods

### 2.1. The Study Area

The study area Ada'a district has a high potential for livestock- crop production systems. Livestock and crop production are integrated farm activities at household farm level as animal draught power is used for plowing, threshing, and transporting of agricultural goods and services. Animal manure is used as a fuel for household energy source and also utilized to improve soil fertility. Manure also sold on market as a means to generate income to smallholder farmers.

The study district is one of the 12 districts in East Shoa zone in Oromia regional state of Ethiopia. It is located southeast of the capital Addis Ababa at 38°51' 43.63'' to 39°04' 58.59'' E and 8°46' 16.20'' to 8°59' 16.38'' N, on the western margin of the Great East African Rift Valley. The altitude ranges between 1500 to over 2 000 meters above sea level. There are two major agro climatic zones: the mountain zone located over 2 000 meters above sea level and that covers 150 km<sup>2</sup> (9 % of the area); and the highland zone that lies between 1500 to 2000 meters above sea level covers over 1 600 km<sup>2</sup> (91 % of the area). The average annual rainfall is 839 mm. Mean minimum and maximum temperature are 8°C and 28.0°C ; respectively. The mean temperature at the time of this study in 2009 was 18.5°C. The dominant soil is vertisol, which is fertile but poorly drained and difficult to

work on [14].

The district is best suited to diverse agricultural production systems, both for intensive and extensive agriculture. Teff (*Eragrostis tef*) and wheat are the two major crops growing in the district in addition to pulses. Most farmers rotate chickpeas with cereals for soil fertility and resting of the land. Livestock production is an integral part of the whole agricultural production system.

### 2.2. Research Design

The study conducted in May and June, 2009 as a part of PhD thesis research of this paper's corresponding author. The study focused both on biological and socio-economic data. The biological study used to target manure sampling to assess different nutrients lost due to manure storage and age, and their impact on the environment. The biological data were then compromised through the interview of the manure owners.

#### 2.2.1. Biological study

Heaps of manure were identified from farmers backyard visited during the study period and manure were classified according to the size, age and storage condition as described by Tadesse et al [24]. A total of 25 samples were taken. The storage condition was classified as shaded, open and fresh (without a heap) as shown in table 1 below. Sample manure was scooped from four random spots on each heap at different height of 0-50 cm, 50-100 cm and above 100 cm to a depth of about 30 cm. The four sub samples from each representative height( 0-50 cm, 50-100 cm and above 100 cm) of the manure heap were separately pooled and a sample of approximately 1 kg was taken and stored in plastic bags for each height before chemical analysis. The pooled samples for each height were air dried and ground to pass through a 2 mm screen ready for further analysis based on guidelines prepared by Tadesse et al [24].

**Table 1.** Sampled manur storage condition, heap height and storage age

Storage condition	Heap height (m)	Storage age (yrs)	Frequency	Feed management
Shaded	1.0 -1.5m	1.0-3.0	6	Indigenous animals with straw feeding and supplementation
Shaded	1.5-2.0 m	>3.0	4	as above
Open	0-0.50 m	0.5-1.0	1	as above
Open	0.50-1m	0.5- 1.0	9	as above
Open	1-1.5m	0.5-1.0	2	as above
Fresh	0	0	3	as above

Key: Storage condition: Shaded mean manure heap covered by grass, mud or plated by manure itself; Open mean uncovered or not protected from sun and rain. Fresh manure means those collected within 12 hours of dropping.

### 2.2.2. Manure Chemical Analysis

Total nitrogen was determined by the micro Kjeldahl digestion, distillation and titration method described in the manual of Tadesse et al [24]. Total phosphorus and potassium was determined by dry ash method as described by Tadesse et al [24]. Organic carbon was analyzed using method as described in the manual of the above authors [24]. The dry matter content of the manure was obtained by oven drying the 25 samples at the 105°C for 24 hrs. The carbon - nitrogen ratio was computed by dividing the amount of carbon by that of nitrogen. Calculations were made on dry matter basis.

Methane (CH<sub>4</sub>)

Methane emissions per household were calculated for cattle, sheep, goats, horses, mules and donkeys using the average number of animals owned by household; according to the inventory methodology from the IPCC [13].

$$\begin{aligned} ECH4 \text{ (kg/year)} \\ &= f \text{ CH4 (kg/head} \\ &\text{/year)} \times P \text{ (average number of animals)} \end{aligned}$$

**Where;** ECH4 (Gg/year) = Emissions,  
f CH4 (kg/head/year) = Emission factor, and  
P = Average number of animals. Owned by households

**Nitrous oxide emission:** The IPCC uses the emission factors of equines, sheep, goats, poultry and cattle, to calculate their N<sub>2</sub>O emissions as follows:

$$\text{Nitrous oxide} = N \times EF$$

**Where;** N<sub>2</sub>O = emissions from the animals (kg N/year),  
N = number of animals, and  
EF = N<sub>2</sub>O emission factor (kg N<sub>2</sub>O-N per animal).

**The emission factor (EF)** is a function of the nitrogen excretion from the animal [13] and the waste management system in the region [13]. The N<sub>2</sub>O emission factors of sheep and goats as well as equines were estimated by averaging them. The default values from the IPCC [13] were used to calculate the EF.

**Carbon release:** The amount of carbon released from manure burning per household was adapted from IPCC [13] a formula which was used to estimate carbon emission from burning of crop residues as follows:

**Carbon (kg emission per day) =**

$$\text{Manure carbon fraction} \times \text{manure DM fraction} \times \text{Total DM manure burnt per day}$$

### 2.3. Statistical and Mathematical Analysis

For both socioeconomic and chemical analyses SPSS Version 17.0.1 [23] was used for statistical interpretation. Greenhouse gas emissions from manure were estimated using mathematical formulae described by the IPCC [13]

indicated as follows.

## 3. Result and Discussion

### 3.1. Nutrient Losses and Manure Management

Comparisons were made for N (Nitrogen), P (Phosphorous), K (Potassium) and OM (Organic Matter) based on different manure management systems such as manure heaps based on the following criteria; manure heap covering, age of manure and height of manure heaps. According to Hansen et al [8] covering of manure in storage reduces the loss of carbon, ammonia N and production of greenhouse gases. However, in the current study manure heaps which were exposed to external environment had an average of 1.4 ± 0.3 % N content while covered manure had 1.2 ± 0.7 % N. In general, N, P and K values were higher for manure stored in the open than that was covered. The analysis of variance showed a significant (P<0.05) difference between covered and open manure heaps for N, P and K. The difference was due to age disparity between open and covered manure. The samples from open manure heaps were those between the age of 6 to 8 months, while covered manure heaps were above one year in storage. This indicated that the longer the storage age the higher the nutrient loss through emissions, leaching, decomposition and physical weathering [26].

Long storage periods of (slurry) manure and high temperatures increased C (carbon) and N losses, depending on storage conditions [6]. Harris and Yusuf [9] reported N losses of up to 59 % in Ghana during three months of storage of the manure. A comparison of manure based on the storage age that is shown in table 2 below indicated that with increasing age the nutrient depletion for N, P, K increased, particularly the N loss rate was higher than the other two nutrients due to the volatile nature of N [16,22].

In the current study the highest loss of N, P and K occurred in the years 2 to 3 at the rate of 84%, 19 % and 42 %; respectively. The analysis of variance at P<0.05, there was a significant difference in storage age for N and K, but there was no significant difference for P. The current findings agree with the results obtained elsewhere [18,26] who reported that N loss during (aerobic) composting varied from about 20 to 80 %. These authors also reported that losses were by far the highest for nitrogen, followed by potassium and phosphorus which agreed with the current findings. Therefore, storage of manure for more than two years has a serious environmental impact on nitrogen, which is lost in the form of ammonia, nitrates and nitrous oxide [2]. Refer to table 2 below.

**Table 2.** Chemical composition of different storage type, storage age and heap height

Composition	Manure shade		Storage age					Heap height			
	Covered	Uncovered	Fresh	6-12 mo	1-2yrs	2-3 yrs	>3yrs	0-0.5 m	0.5-1 .0m	1-1.5 m	1.5-2m
DM%	97.8±0.8	97.2	81.84±6.2	97.2±0.4	97.1±0.3	96.2	96.4±1.8	96.5	97.2	96.9	97.6
OM%Kg DM	36.3±10.3	36.6±10.5	76.2	36.6±10.5	32.1±7.6	30.8	45.0±2.1	55.1	50.4	49.0	33.2
N % Kg DM	1.2±0.7	1.4±0.3	1.9±0.07	1.4±0.3	1.4±0.9	0.3	1.2	1.7	1.4	1.9	1.6
P ppm	1.4±0.3	1.6±0.3	1.6±0.4	1.6±0.3	1.4±0.1	1.6	1.3±0.4	2.3	1.9	1.8	1.8
K % kg DM	0.56±0.2	0.56±2	0.72±0.01	0.56±0.2	0.71±0.12	0.59	0.41±0.1	0.49	0.19	0.58	0.69

Storage age showed significant differences in chemical composition like OM, too[18]. For example; the organic matter content was higher for fresh manure (76 %) compared to 6 to 12 months old manure (36 %). The difference of about 40% in organic matter between fresh manure and 6 to 12 months old manure could be attributed to weathering. This finding is in agreement with the review reported by Kulling et al [16] who said that average carbon losses of about 40% were suggested for solid cattle manure, but the value could vary as a result of storage conditions (aeration, storage period and temperature), and manure characteristics (degradability and moisture content), that strongly affected organic matter degradation and carbon loss. In the current study the losses in organic matter and other nutrients increased with increasing age of manure as shown in table 2.

The other argument of manure management that affected nutrient depletion was the height of the manure heaps. Petersen et al [21] reported that losses of K, OM and N were much higher for heap storage, with large differences for manure from rations with high protein content. In the current study most farmers (80 %) stored manure in heaps while 2 % of them used deep litter storage. Heap heights of up to 2 m were recorded in the study area. The analysis of variance for manure height at P<0.05 showed no significant difference in chemical composition because of heap height. This could be attributed due to the fact that the upper heap tips are well protected from weathering, whereas lower layers were enriched by nutrients leaching from the upper layers, which made the nutrient composition uniform across different heap heights, as shown on table 2.

### 3.2. Manure Management and Environment

Variations in nutrient loss during manure collection, storage or processing and application was high [16,22]. The most important processes involved in the loss of nutrients were: leaching of soluble nutrients from urine in particular N, K and S (Sulfur), and Gaseous losses during collection, storage and application in particular ammonia.

Manure management systems in the study area were affected by livestock husbandry practices. Only crossbred cattle (5% of total herd) were zero grazed. Indigenous cattle were taken out to grazing in the fields during the day and kept in kraals at night. Kraals were permanently kept near

homesteads to avoid theft. Therefore, there was a substantial loss of nutrients during the day as the animals goes out for grazing in the fields. The losses are very high through urine, because urine patches contained as much as 200 to 550 kg N/ha [26]. Volatilization of N might also be considerable (10 - 25%) since most of cattle dung was collected from the fields by poor farmers who did not have enough cattle to produce manure [18]. A nitrogen loss of 41 % from dung was reported other researchers during the collection of cattle dung for 144 days and composting [18].

Part of the nutrients in dung was also lost through leaching and surface runoff, due to trampling and poor drainage in the kraals [9]. Volatilization losses were dependent on the level of ventilation, depth of storage tanks and storage time [6] and often ranged between 5 and 35% of the total N excreted.

#### 3.2.1. Livestock greenhouse gas emissions in households

Estimates of methane emissions and manure from cattle, sheep, goats, horses, mules and donkeys and nitrous oxide emissions were calculated based on IPCC [13] green house gasses emission guidelines and average household livestock ownership in 2009 data which was obtained through socioeconomic survey ( Table 3 below). The emissions were calculated as: the emission factor per animal multiplied by the number of animals in a household. The emission factors were based on the IPCC data [13]. These emissions were important in evaluating the contribution of livestock to the greenhouse gases in the atmosphere. Table 3 below shows the concentration of methane and nitrogen contributed by an average household in the study area.

**Table 3.** Average methane and nitrogen emissions per household

Livestock species	Household average holding	Methane kg/yr			Nitrogen from manure (kg/yr)
		Emissions	Manure Produced	Total	
Cattle	8.3	265.6	8.3	273.9	318.72
Sheep and goats	4.3	21.5	0.73	11.2	46.44
Equines	2.1	29.4	2.67	32.1	83.16
Poultry	7.6	-	0.14	0.14	3.78
Total		316.5	11.84	328.3	452.1

(I). Methane (CH<sub>4</sub>)

The global atmospheric concentration of CH<sub>4</sub> has increased from a pre-industrial value of about 715 ppb to 1 732 ppb in the early 1990s, and 1 774 ppb in 2005 [11]. The growth rate has declined since the early 1990s, consistent with total emissions (sum of anthropogenic and natural sources) and nearly constant during that period. One of the most important sources of anthropogenic methane is ruminants. They produce methane during the normal enteric fermentation process. In the 1990s, the ruminants were thought to be responsible for about 28% of all anthropogenic CH<sub>4</sub> emissions [17,19].

In the current study the amount of CH<sub>4</sub> produced was estimated at 328.3 kg per year per household and depending on the type of animal. The most important ruminants in terms of CH<sub>4</sub> emissions were cattle which produced 82% of the household emissions. The emissions of 1 million metric tons of CH<sub>4</sub> are equivalent to the emissions of 25 million metric tons of carbon dioxide called “*equivalent carbon dioxide*” (CO<sub>2</sub>e). This is the concentration of CO<sub>2</sub> that could cause the same level of radioactive force and concentration of greenhouse gases. Therefore, the current amount of CH<sub>4</sub> produced per household was estimated at 8.2 tons CO<sub>2</sub>e per household per annum. The reference value adopted the emission factor per animal were taken from IPCC [13] which has an uncertainty of 20% in these values. The average household size in the current study was 6.2, thus the amount of CO<sub>2</sub>e methane emission per capita per year was 1.3 tons. This rate alone was 30% higher than the total CO<sub>2</sub>e for all GHG emissions reported in Ethiopia, 1 ton per capita reported in 2005 [27].

(II). Nitrous oxide (N<sub>2</sub>O)

It was estimated that the global atmospheric concentration of N<sub>2</sub>O increased from pre-industrial value of about 270 ppb to 319 ppb in 2005 [11]. In 1998 the N<sub>2</sub>O emissions from manure management systems were responsible for 26% of the total anthropogenic emissions of N<sub>2</sub>O [10,15]. The study area N<sub>2</sub>O emissions from domestic livestock were calculated using the average livestock ownership of respondent households, and the inventory data obtained by IPCC [13].

Therefore, the N<sub>2</sub>O released per household was estimated as  $452.1(N) \times 0.02 (EF) = 9.04 \text{ kg N}_2\text{O emissions/annum/household}$ . The emissions of 1 million metric tons of N<sub>2</sub>O were equivalent to the emissions of 298 million metric tons of carbon dioxide. In the current study, the CO<sub>2</sub> equivalent of N<sub>2</sub>O emitted through various manure inappropriate management systems was 2 694 kg/annum/household or 0.4 ton per capita per year..

## (iii) Carbon (C)

About 94% of the respondents in the current study used manure for cooking fuel as shown in table 1 above. When manure was burnt directly, most of the organic compounds such as C, N and S were lost to the atmosphere, which contributed to greenhouse gas emissions [5] and other

nutrients were recycled on arable land through the application of the ashes in the fields.

Eighty percent (80%) of the respondents said that they used manure aged between 6 to 12 months for cooking. Therefore, the carbon fraction of 6 to 12 months old manure was 36.6 % OM. Assuming there was 55 % C in the OM manure [8] and at carbon factor of 0.2013 the DM fraction was 0.972.. The average amount of manure burnt per day for 3 years as reported in the current study was 1.57 kg/day/household. Thus, the annual carbon emitted per household due to manure burning was calculated as:

$$\begin{aligned} \text{C (kg emissions/household/year)} &= \\ 0.2013 \times 0.972 \times 1.57 \text{ kg/day} \times 365.25 \text{ days} \\ &= 112.20 \text{ kg carbon emitted /household/year} \end{aligned}$$

It was also estimated that the global atmospheric concentration of CO<sub>2</sub> increased from a pre-industrial value of about 280 ppm to 379 ppm in 2005. The annual CO<sub>2</sub> concentration growth rate was larger from 1995 to 2005, (an average of 1.9 ppm/year) than it has been since the beginning of the continuous direct atmospheric measurements from 1960 to 2005, (an average of 1.4 ppm/year), with year-to-year variability in the growth rates [27]. To convert carbon to carbon dioxide, a factor of 3.67 (i.e. 44/12) was used [13]. Therefore, the amount of carbon dioxide released per household from burning of manure was 122.20 kg C x 3.67 = 381.48 kg CO<sub>2</sub>/household. The world CO<sub>2</sub> emissions per capita per annum in 2006 were estimated at 4 180 kg CO<sub>2</sub> [11].

Thus, with an average of 6.2 family size of in the current study area per capita CO<sub>2</sub> emission was estimated at 61.50 kg CO<sub>2</sub>. In the USA, which is the highest carbon emitter, CO<sub>2</sub> emissions per capita from human activities in 2006 was estimated at 18 600 kg CO<sub>2</sub> [11]. The comparison showed that the use of manure as fuel in the study area had no significant effect on CO<sub>2</sub> emissions per capita, but they had a negative impact in terms of nutrient cycling, soil carbon sequestration and soil fertility. Therefore, for improved yield and healthy eco-systems balance, manure burning has to be substituted by other alternative energy sources such as bio-gas [6].

In general, livestock and manure management systems contributed a lot to greenhouse gas emissions. The total carbon equivalent (CO<sub>2</sub>e) gas emitted per household per annum by livestock, manure management and burning was estimated at 11, 276 kg CO<sub>2</sub>e (i.e. 8 200 kg CO<sub>2</sub>e from methane and manure plus 2 694 CO<sub>2</sub>e from N<sub>2</sub>O emissions from manure management and 381.48 kg CO<sub>2</sub>e from CO<sub>2</sub> from manure burning) that is about 2 tons CO<sub>2</sub>e per capita per year, twice reported by Wikipedia [27] for Ethiopia emission in 2005. Had other anthropogenic and natural greenhouse gases emitted by household been added to the current carbon equivalent value, the amount of carbon equivalent gases released per household in Ethiopia would be more alarming. This calls for more research to estimate greenhouse gas emissions at household level under the

smallholder production systems. The largest carbon equivalent emissions were from methane (72.6%), nitrous oxide (24%) and Carbon dioxide (3.4%) which showed that there is an urgent need to improve livestock and manure management systems under smallholders' agriculture.

In 1998, Ethiopia ranked 18<sup>th</sup> globally in terms of CH<sub>4</sub> emissions from livestock and 10<sup>th</sup> in N<sub>2</sub>O emissions from manure management. The ranking in N<sub>2</sub>O emissions went down from 13<sup>th</sup> in 1980s to 10<sup>th</sup> in 1998 [28]. This evidence showed that due attention should be given to reduce N<sub>2</sub>O emissions by improving manure management at local level particularly at farm level.

#### 4. Conclusions

Manure management systems in the study area were affected by the livestock husbandry practices. Only crossbred cattle (5% of total herd) were zero-grazed. Indigenous cattle grazed out in the fields during the day and at night they were kept in kraals established near homesteads. There was a substantial loss of nutrients during the day when animals were grazing in the fields through leaching and trampling of dung and urine patches. Therefore, indoor or zero grazing of livestock could reduce nutrient losses.

Comparisons showed that the use of manure as fuel in the study area had no significant effect on CO<sub>2</sub> emissions at household and local level, but had a negative impact on soil carbon storage and soil fertility. Therefore, for improved yield and healthy eco-systems balance manure burning has to be substituted by other alternative energy sources such as bio-gas, firewood and kerosene.

The largest carbon equivalent emissions were from methane (72.6%), nitrous oxide (24%) and carbon dioxide (3.4%) which indicated the need to improve livestock and manure management systems under smallholder agriculture. Existing mitigation strategies for methane emissions for dairy, e.g., the addition of ionophores, fats, use of high quality forages, and increased use of grains were the recommended management practices to be exercised to reduce emission. Recently a new dietary strategy was proposed in the developed world to reduce CH<sub>4</sub> emissions from ruminants such as by manipulating ruminant fermentation directly by inhibiting methanogens and protozoa or by diverting hydrogen ions away from methanogens. In developing world; change in feeding systems, breed selection, good animal husbandry and improved take-off were identified as viable options to reduce greenhouse gas emissions.

#### Conflict of Interest

The authors declare that there are no conflicts of Interest.

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