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Assessment of GHG Emission from Dairy Cattle Manure Management Practices in Rural and Urban Dairy Production in Enderta District and Mekelle City, Northern Ethiopia

Amanuel Berhe[1]*, Mulubrhan Balehegn[1,2], Solomon Abera Bariagabre[1], Daniel Kiros Woldegebriel[1], and Gebremedhn Beyene[1]

[1]Mekelle University, Department of Animal Range and Wildlife Science, Mekelle, Ethiopia.
[2]World Resource Institute, Gainesville, Florida, United States.

Abstract: This study was aimed at the assessment of greenhouse gas emissions (GHG) from manure management in rural and urban dairy cattle production in Enderta and Mekelle, northern Ethiopia. Data was collected through a semi-structured questionnaire and greenhouse gas emission was estimated using IPCC Tier II methodology. Dairy herd structure, feed resources, and manure management practices significantly differed ($p<0.05$) between urban and rural dairy production. Urban dairy production had greater methane emissions from manure management practices. The mean methane emissions from manure management practice were 4.96± (±.28) kg of CH_4/head of dairy cattle/year in rural dairy production and 8.30 (±.55) kg of CH_4/head of dairy cattle/year in urban dairy production. Both direct and indirect nitrous oxide emissions from manure management practices did not significantly ($P>0.05$) differ between the dairy cattle production. The mean direct nitrous oxide emissions were 0.11 (±.011) kg of N_2O/head of dairy cattle/year in rural dairy production and 0.11 (±0.011) kg of N_2O/head of dairy cattle/year in urban dairy production, while the mean indirect nitrous oxide emissions were 0.067 (±.006) kg of N_2O/head of dairy cattle/year in rural dairy production and 0.07 (±.006) kg of N_2O/head of dairy cattle/year in urban dairy production. This study indicated that variations in dairy cattle herd structure, feed resources and manure management practices producing higher methane emissions from dairy manure management in urban dairy production.

Keywords: *Dairy cattle, Greenhouse gas, Methane, Manure management, Nitrous oxide*

Introduction

Livestock farming is a major contributor to global greenhouse gas (GHG) emissions accounting from 18% (Steinfeld *et al*., 2006) and livestock-derived food contributed 57% of anthropogenic GHG emissions (Xu *et al*., 2021). Cattle, which provide significant benefits to smallholder farmers, are responsible for 80% of agricultural GHG emissions (Gerber *et al*., 2007; Homeier, 2011). The primary GHGs emitted from livestock manure are methane (CH_4) and nitrous oxide (N_2O), both of which have a much higher global warming potential than carbon dioxide (CO_2) (Gerber *et al*., 2013). Livestock manure includes both dung and urine from livestock.

The present manure management practices lead to potential hazards to human and livestock health, especially in urban dairy cattle production, where livestock is not integrated with crop production (Aektasaeng, 2015; Christophe *et al.,* 2023). Improperly stored manure raises environmental concerns due to underutilized nutrients, zoonotic pathogens, antibiotic and hormone residues, odors, ammonia, dust, CH_4, and hydrogen sulfide (Tadesse *et al*., 2021; Qi *et al*., 2023). Conversely, manure management practices in rural dairy production may not be a problem because of the integration of crop-livestock production. Nearly 50% of nitrogen is lost during the handling and storage of livestock manure, contributing to environmental issues such as acid rain, water eutrophication and biodiversity loss (Steinfeld *et al*., 2006).

Integrated manure management involves various activities related to dung and urine management, from excretion to application. Approximately 60% and 95% of the animal's nutrient intake via feed is excreted via dung and urine containing undigested carbon and nutrients respectively (Aektasaeng, 2015).

In Ethiopia, livestock emissions were expected to double in a business-as-usual scenario (CRGE, 2011). Ethiopian dairy production contributed 14.4 million tonnes of CO2 eq to GHG emissions from stored manure management (FAO and NZAGRC, 2017). The increasing demand for animal products has led to an increase in livestock population. This exacerbates the environmental impact of livestock from manure management particularly in urban dairy production (Shapiro *et al*., 2017).

The present study differed from the research conducted by Habtamu *et al.* (2021), who used highly aggregated data from the Central Statistical Agency that does not accurately represent local manure management practices. In contrast, it was similar to the study by Feyissa *et al.* (2022) and Berhe *et al.* (2020), which emphasized on local dairy manure management practices. However, this study employed a different methodology from the previously mentioned research, specifically employing the IPCC tier 2 approach. This methodological difference resulted in considerable

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*Corresponding Author. E-mail: amanuelberhe3@gmail.com

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differences in GHG emissions from dairy manure management practices. Moreover, the diversity in dairy production and variations in manure management practices need to be assessed on the environmental effect of manure management practices in urban and rural dairy production. Therefore, this study aimed to assess greenhouse gas emissions from dairy cattle manure management practices in two dairy production settings; namely urban and rural dairy cattle production in Mekelle and Enderta, respectively.

Materials and Methods

Description of the Study Areas

Enderta district and Mekelle city, which are located at an altitude ranging from 1500 to 2300 meters above sea level, having an annual rainfall between 450 and 700 mm. In these areas, average minimum and maximum annual temperature ranges from 11.5 to 27 °C (Kibrom, 2005; Gebrehiwot and Veen, 2014). In Enderta, farmers are engaged in mixed crop-livestock production, utilizing local livestock breeds to support crop cultivation and livestock uses byproduct of crops. On the other hand, Mekelle specializes in livestock production for milk, meat and income generation, with animals being fed crop residues and industrial byproducts due to limited grazing areas. The livestock population in the study areas is presented in Table 1.

Sample Size

According to Louangrath (2017), a novel method, known as n* (n-Star), employing Monte Carlo iteration, was utilized to determine the minimum sample size in questionnaire surveys. This method enables up to 95% accuracy when inferring from the sample to the population, resulting in an estimated minimum sample size of 31 for survey scales. For the purpose of this study, a total of one hundred twenty dairy cow owners from both study sites (sixty from each) were interviewed.

Sampling Procedures

Multistage sampling procedure was used to select target households. Initially, two productions, rural and urban dairy, were purposely selected. Following this, three *kebeles* (the smallest administrative unit) from each dairy production were chosen based on the criteria of the number of dairy cows and milk production potential. Finally, farmers were selected using a systematic random approach from the list provided by local administrators.

Data Collection Methods

Semi-structured questionnaire surveys were used to collect data on the demographic characteristics of dairy cattle owners and dairy management aspects such as feed resources and feeding practices, milk production, and manure management practices. The survey was conducted among dairy owners in both dairy production systems. Furthermore, existing data from producer surveys were analyzed to characterize the production environment and cattle performance. Additional insights were obtained through direct communication with various governmental organizations. Lastly, secondary data were used for calculating GHG emissions from dairy manure management practices as shown in Table 2.

Table 1. Livestock population in the study areas.

Livestock species	Study site		Source of data
	Enderta	Mekelle	
Cattle	79,858	24,419	EARDO (2023)
Sheep	10,726	4,935	
Goat	50,210	3,372	
Chicken	89,155	93,656	
Camel	874	293	MUADO (2023)
Donkey	23,157	2,164	
Mules and horses	1,173	5,296	

Table 2. The assumptions for calculating GHG emission from manure management.

Assumptions	Unit	Reference
Live weight of indigenous dairy cattle	225 kg	IPCC (2006) Vol 4 Ch 10 Table 1 0.5
Live weight of cross dairy cattle	460 kg	Own survey using heart girth
Live weight of indigenous calve	96.4	Haile (2011) and Tesfa *et al.* (2016)
Live weight of crossbreed calve	116 kg	Tadesse *et al.* (2022)
Live weight of indigenous bull	236.5	Tadesse *et al.* (2022)
Live weight of crossbreed bull	350 kg	Tadesse *et al.* (2022)
Milk fat	4 %	Own laboratory analysis
Milk protein	3.6%	Own laboratory analysis
CP in diet	12%	Tadesse *et al.* (2022)
Weight gain for calves	0.04 kg/day	Tadesse *et al.* (2022)
Working hours of dairy cattle	0 hr	Own survey
Digestible energy (DE)	60 %	
Bo (kgCH$_4$ per kg VS) of dairy cattle	0.13	IPCC (2006) Vol 4 Ch 10 Equation 10.24
Bo (kgCH$_4$ per kg VS) of nondairy cattle	0.10	
Ash content of manure	0.08	
Urinary Energy as a fraction of GE	0.04	

Method for Calculating GHG Emissions from Manure Management

Methane emissions: Methane emissions from manure management were calculated from livestock population, activity and manure management data. CH_4 emissions from cattle manure management were calculated using the Tier 2 approach as follows:

$$CH_4emissions_{(mm)} = \mathrm{N}_{(\mathrm{T})} * \Sigma \frac{(\mathrm{MCF}_{(\mathrm{S,K})} * \mathrm{MS})}{(100)} * \ \mathrm{EF}_{(\mathrm{T})}(\mathrm{CH}_4 \text{ head}^{-1}\text{year}^{-1})$$

Where: CH_4 emission $_{(mm)}$= methane emissions from manure management (kg CH_4/year); $N_{(T)}$= the number of head of livestock species/category T; $MCF_{(S,\ k)}$= methane conversion factor for each manure management S by climate region k, in %; $MS_{(T,S,k)}$= fraction of livestock category T's manure handled using manure management S in climate region k, dimensionless; $EF_{(T)}$ = annual CH_4 emission factor for livestock category T, kg CH_4 animal^{-1} year^{-1}; T= species/category of livestock.

$$\mathrm{EF}_T = (VS_T * 365) * [B_{o(T)} * 0.67 * \Sigma_{S,K} \frac{\mathrm{MCF}_{S,K}}{100} * MS_{T,S,K}]$$

Where: EF_T = annual CH_4 emission factor for livestock category T [kg CH_4 animal-1 yr-1]; VS_T = daily volatile solid excreted from livestock category T [kg dry matter animal-1 day-1]; 365 = conversion factor for calculating annual VS production; B_O = maximum CH_4 production capacity for manure produced by livestock category T [m3 CH4 kg-1 VS]; 0.67 = density of CH_4 gas to convert from m3 to kg (kg m-3); $MCF_{S,k}$ = methane conversion factor for manure management system S by climate region k [%]; $MS_{T,S,k}$ = fraction of the manure from livestock category T that is handled using manure management systems S in climate region k.

$$VS = \left[\mathrm{GE} * \left(1 - \frac{\mathrm{DE\%}}{100}\right) + (\mathrm{UE} * \mathrm{GE})\right] * [\frac{1 - \mathrm{Ash}}{18.45}]$$

Where: VS = volatile solid excreted per animal per day based on gross energy intake and feed digestibility [kg dry matter day-1]; GE = gross energy intake [MJ day-1]; DE% = digestibility of the feed [%], which should be assessed for each season depending on the dry matter digestibility of the feed basket, which is determined by the "Protocol for cattle enteric methane emissions"; UE*GE = urinary energy expressed as fraction of GE (for most ruminants, urinary energy excretion is 0.04*GE, while it is 0.02*GE for ruminants fed with >85% grain); ASH = ash content of manure calculated as fraction of dry matter feed intake (0.08 for cattle, IPCC 2006); 18.45 = conversion factor for dietary GE per kg of dry matter [MJ kg-1].

Nitrous oxide: Nitrous oxide emissions from manure management were calculated from animal population, activity and manure management data. N_2O emissions from cattle manure management were calculated using the Tier 2 approach as follows:

$$N_2O_{D(MM)} = \left[\Sigma_S\left[\Sigma_T(N_T * Nex_T * MS_{T,S})\right] * EF_{3,S}\right] * \frac{44}{28}$$

Where: $N_2O_{D(mm)}$ = direct N_2O emissions from manure management, kg N_2O per year; $N_{(T)}$ = number of head of livestock species/subcategory *T;* $N_{ex(t)}$ = annual average nitrogen (N) excretion per head of cattle subcategory *T*, kg N per animal per year; MS(t, s) = fraction of total annual nitrogen excretion for each livestock/subcategory *T* that is managed in manure management *S*, dimensionless; $EF_{3,S}$ = emission factor for direct N_2O emissions from manure management *S*, kg N_2O-N/kg (N in manure management *S,* S = manure management, T = Sub-category of livestock); 44/28 = conversion of (N_2O-N)(mm) emissions to N_2O(mm) emissions.

Nex is calculated based on animal N intake via feed (Nintake) and N retained for growth and milk production (Nretention) as follows:

$$N_{\mathrm{exT}} = N_{\mathrm{intake(T)}} * (1 - N_{\mathrm{retention(T)}})$$

Where: Nex_T = annual N excretion for livestock category *T* [kg N animal-1 yr-1]; $N_{intake(T)}$ = annual N intake per head of animal of category *T* [kg N kg animal-1 yr-1]; $N_{retention(T)}$ = fraction of annual N intake retained by animal of category *T*.

Total N intake (N_{intake}) is estimated based on dry matter intake (DMI) and nitrogen content (%N) of the feed as follows:

$$\mathrm{N}_{intake(T)} = \mathrm{DMI} * \frac{\mathrm{N\%}}{100}$$

Where: DMI = dry matter intake of the animal [kg animal-1 day-1]; N% = N content of the feed basket in percent.

Total nitrogen retention ($N_{retention}$) for growth and milk production can be estimated as follows:

$$N_{retention(T)} = \left[\frac{Milk * \frac{Milk\ CP\%}{100}}{6.38}\right] + \left[\frac{LWG * \left[268 - \left(\frac{7.03 * NE_g}{LWG}\right)\right]}{6.25}\right]$$

Where: Nretention(T) = daily N retained per animal of category *T* [kg N animal-1 yr-1]; Milk = milk production [kg animal-1 day-1] (applicable to lactating cows only and the information is derived from farm milk records (see "Protocol for cattle enteric methane emissions"); Milk CP% = percent of crude protein in milk; 6.38 = conversion from milk protein to milk N [kg protein kg-1 N]; LWG = live weight gain per animal and season for each livestock category *T* [kg day-1]; NEg = net energy for growth, based on current weight, mature weight, live weight gain, and IPCC constants; 6.25 = conversion from kg dietary protein to kg dietary N [kg protein (kg N)-1].

Net energy for growth for cattle (NEg) can be estimated as follows:

$$\mathrm{NE}_g = 22.02 * \left(\frac{\mathrm{LWmean}}{\mathrm{C} * \mathrm{MW}}\right)^{0.75} * WG^{1.097}$$

Where: NE_g = net energy needed for growth [MJ day-1]; LWmean = mean live weight of the animals in the population for each season [kg], calculated from seasonal animal LW measurements; C = coefficient with a value of 0.8 for females, 1.0 for castrates, and 1.2 for bulls (NRC, 1996); MW = mature live body weight of an adult female in moderate condition (BCS = 3) [kg]; WG = average daily weight gain of the animals in the population for each season [kg day-1].

Indirect nitrous oxide (N_2O): Indirect nitrous oxide emissions from livestock manure management were calculated using the IPCC Tier 2 method as follows:

$$N_2O_{G(MM)} = (N_{Volatilization-MMS} * EF_4) * \frac{44}{28}$$

Where: $N_2O_{G(mm)}$ = indirect N_2O emissions due to volatilization of N from Manure management, kg N_2O yr-1; $N_{(T)}$ = number of head of livestock species/sub-category *T;* EF4 = emission factor for N_2O emissions from atmospheric deposition of nitrogen on soils and water surfaces, kg N_2O-N (kg NH_3-N + NOx-N volatilised)-1; 44/28 = Conversion of (N_2O-N)(mm) emissions to N_2O(mm) emissions.

Data Analysis

The data was analyzed using Statistical Package for Social Sciences (SPSS) version 23 (SPSS, 2011) to examine the information gathered from the survey questionnaire. Demographic characteristics were presented using descriptive statistics such as averages, percentages, and frequencies. Furthermore, data on greenhouse gas (GHG) emissions resulting from manure management were precisely recorded in an Excel spreadsheet, facilitating the quantification of GHG emissions in accordance with the guidelines described by the Intergovernmental Panel on Climate Change (Hung *et al.,* 2022). The GHG emission data were compared between the two dairy production systems for their means using an independent t-test.

Results

Demographic Characteristics of Dairy Owners

Among the total 120 dairy owners, 31% were females and 69% were males across both productions, indicating a greater representation of males in dairy production (Table 3). The average age of dairy owners were 41 years, with 43 years in rural dairy production and 39 years in urban dairy production. In rural dairy production, approximately half of the dairy owners (48.3%) were illiterate, while the remaining half (50%) had completed primary school. In contrast, in urban dairy production, more than 80% of the dairy owners (45% and 43.3%) had completed primary and secondary school education, respectively. Small percentages (11.7%) of urban dairy owners were classified as illiterate. The average family size was 6 in rural dairy production and 3.9 in urban dairy production.

Table 3. Demographic characteristics of the dairy owners at the study sites.

Attributes	Rural dairy production		Urban dairy production	
	Frequency	%	Frequency	%
Sex:				
Male	45	75	38	63.3
Female	15	25	22	36.7
Total	60	100	60	100
Age category:				
< 35	9	15	23	38.3
>35	51	85	37	61.7
Total	60	100	60	100
Level of education:				
Illiterate	29	48.3	7	11.7
Primary and above	31	51.7	53	88.3
Total	60	100	60	100
Family size:				
≤ 5	28	46.7	43[a]	71.7
> 5	32	53.3	17	26.7
Total (N)	60	100	60	100

Dairy Herd Structure

The dairy herd structure per household in the study areas is presented in Table 4. The average number of dairy holdings per household was 2.19 in rural and 4.44 in urban dairy production. The primary dairy cattle breeds in both rural and urban dairy production were predominantly local and crossbred (local x Holstein-Friesian) dairy cattle. Statistical analysis revealed a significantly higher number ($p<0.05$) of heifers, lactating cows, pregnant cows, and dry cows in urban production than in rural production. There were no statistically significant differences in the number of calves or bulls between the two productions.

Table 4. Dairy herd structure in the study areas.

Dairy herd structure	Mean±SE		*P-value*
	Rural production	Urban dairy production	
Heifers	0.51±.07	1.15±.13	0.000
Lactating cow	0.86±.05	1.4±.10	0.000
Pregnant	0.13±.04	0.78±.07	0.000
Dry cows	0.63±.06	0.98±.04	0.000
Calves	0.06±.04	0.13±.05	0.267
Bull	0.06±.03	0.15±.04	0.144

Dairy Cattle Feed Resources

In the study areas, the primary roughage feed sources included straw, natural pasture, grass hay, cactus, improved forages, and *hatela* (local brewery byproduct) (Table 5). The key feed resources for dairy cattle were wheat and barley straw, as well as *hatela*, in both productions. There were no significant differences *(P>0.05)* in the quantities of straw or *hatela* between the two dairy productions. Straw and natural pasture were the predominant dairy feeds in both dairy production systems, with significantly greater (P<0.05) amounts of natural pasture in rural compared to urban dairy production. Cactus was a commonly used feed resource in rural dairy cattle production, while improved forages such as alfalfa were used in urban dairy cattle production.

Regarding dairy concentrate feeds, the main sources in the study areas were wheat bran, grain, noug seed cake and commercial dairy feeds (as shown in Table 5). There were significantly greater (P<0.05) amounts of wheat bran, grain, noug seed cake, and commercial dairy cattle feeds in urban than in rural dairy production.

Table 5. Dairy cattle feed resources in the study areas.

Feed type	Dairy production		*P-value*
	Rural (Mean±SE)	Urban (Mean±SE)	
Roughage (%):			
Straw	53.05±2.42	57.83±1.99	0.13
Natural pasture	27.25 ±2.35	10.68±1.54	0.00
Hay	6.28±.96	0.08±.08	0.00
Cactus	2.53±.75	0.00	0.00
Improved forages	0.00	0.88±.27	0.00
Hatela	3.65±.57	3.63±.81	0.98
Concentrate feed (%):			
Grain	0.00	2.83±.80	0.00
Wheat bran	7.07±.81	17.08±1.46	0.00
Noug seed cake	0.17±.16	1.25±.49	0.04
Commercial dairy feed (%)	0.00	4.22±1.36	0.00

Manure Management Practices

This study revealed that there were various manure management practices and their corresponding percentages were presented in Table 6. Range/pasture utilization was common in rural dairy production, with a significant difference (p<0.05) between the two dairy production. Solid manure management and manure as a source of fuel were common practices in rural and urban dairy production. In contrast, the adoption of slurry or liquid manure management practices was significantly greater (p<0.05) in urban than in rural dairy production.

Greenhouse Gas from Manure Management

Methane emissions from manure management from dairy cattle were significantly greater *(p<0.05)* in the urban dairy production than in rural dairy production. However, there were no statistically significant differences in both direct or indirect nitrous oxide emissions from dairy cattle manure management between the two productions, as shown in Table 7. Moreover, there were no statistically significant (p>0.05) differences in methane emissions, both direct and indirect nitrous oxide emissions from non-dairy cattle manure management between the two dairy production (Table 7). The standardized greenhouse gas emissions, specifically the kilograms of methane and nitrous oxide, converted into carbon dioxide equivalents, resulting from manure management practices in two dairy production (Table 7).

Discussion

Demographic Characteristics

The current finding on male predominance (69%) could be attributed to the labor-intensive nature and high initial investment costs associated with dairy farming. The average age of dairy owners across both production was 41 years, suggesting that this age group was commonly involved in dairy farming due to the labor demands of the activity.

In the rural dairy production, approximately half of the dairy owners were illiterate, while the other half had only completed primary school. On the contrary, in urban dairy production, more than eighty percent (45% and 43.3%) of dairy owners had received primary and secondary education. Education plays an important role in making informed decisions and adopting new technologies related to manure management (IFPRI, 2010).

The average family size per production was higher in rural dairy production (6) compared to urban dairy production (3.9), indicating a greater labor availability in rural dairy production. The smaller family size in urban dairy production may lead to limited labor availability, resulting in inadequate manure management. This limitation could hinder the proper disposal of manure onto crop lands, leading to the accumulation of manure and potential environmental pollution in urban dairy production. This finding aligns with the earlier study by Ndambi *et al.* (2019), which highlighted that limited labor resources led to poor manure management practices.

Table 6. Manure management practices in rural and urban dairy production.

Manure management practice	Dairy production		*P-value*
	Rural	Urban	
Range/pasture (%)	4.83±1.35	0.00	0.00
Solid storage (%)	45.65±4.61	49.82±5.34	0.067
Fuel (%)	49.49±4.72	37.24±4.93	0.183
Slurry (%)	0.00	12.93±1.76	0.000

Table 7. GHG emissions from manure management using Tier 2 for dairy and non-dairy cattle and converting into CO_2 equivalence.

GHG emissions	Dairy production		*P-value*
	Rural (Mean±SE)	Urban (Mean±SE)	
Methane in dairy cow (Kg of CH_4/head/year)	4.96 ± 0.28^{b}	$8.30\ \pm.55^{a}$	0.00
Methane in non dairy (Kg of CH_4/head/year)	5.75±0.50	8.39 ±1.44	0.147
Methane in dairy cow (Kg of CO_{2eq}/head/year)	168.64±9.52	282.2±18.7	
Methane in non dairy (Kg of CO_{2eq}/head/year)	195.5±17	285.26±48.96	
Direct N_2O in dairy cow (Kg of N_2O/head/year)	0.11±0.011	0.11±0.011	0.712
Direct N_2O in non dairy (Kg of N_2O/head/year)	0.06±0.01	0.25±0.08	0.100
Direct N_2O in dairy cow (Kg of CO_{2eq}/head/year)	32.78±3.27	32.78±3.27	
Direct N_2O in non dairy (Kg of CO_{2eq}/head/year)	17.88±2.98	74.5±23.84	
In direct N_2O in dairy cow (Kg of N_2O/head/year)	0.067±.006	0.07±.006	0.315
In direct N_2O in non dairy (Kg of N_2O/head/year)	0.04±0.01	0.16±0.05	0.093
indirect N_2O in dairy cow (Kg of CO_{2eq}/head/year)	19.9632.78± 1.78	20.86 ± 1.78	
indirect N_2O in non dairy (Kg of CO_{2eq}/head/year)	11.92± 2.98	47.68± 14.9	

*To converter in to CO_2 equivalent: 1 Kg CH4/Kg= 34 kg CO2eq; Kg N2O/Kg CO2=298 (Source: FAO, 2017); * indicates statistical significance.*

Dairy Herd Structure and Feeding

The average dairy cow holdings per household varied between rural and urban dairy production, with lower dairy cows in the rural households than in the urban. The lower number of dairy cows in the rural households could be due to the implementation of zero-grazing systems and encroachment of grazing lands by croplands (Hirata *et al.*, 2018). In contrast, urban dairy production focuses on expanding their herds and implementing improved management practices to enhance milk production and financial returns.

There was a variation in dairy feeding between the two dairy production and this could be attributed to the limited availability of extensive grazing lands in urban dairy production, leading to a greater reliance on various crop residues and commercially purchased concentrate feeds for dairy nutrition. This could result in variations in milk yield and manure production and quality.

Manure Management Practices and Greenhouse Gas Production

The average manure management in range/pasture manure management in the rural dairy production was lower than the average value (47%) of sub-Saharan Africa (Petersen *et al.*, 2013). This could be due to the fact that there was adoption of zero grazing in rural dairy production. Such practices were known to produce lower levels of greenhouse gases like methane and nitrous oxide compared to other manure management practice (FAO and NZAGRC, 2017).

Solid manure management practices, along with utilizing manure as a fuel source, were more common in both rural and urban dairy production. This was similar with findings of Ndambi *et al.* (2019) where it is practiced commonly in Ethiopia. In the current study, solid manure management was higher than the average Sub-Saharan Africa solid manure management (32%) (Petersen *et al.*, 2013). This could be due to the fact that the manure that was stored would be used for further use in crop production. Solid manure management is known to result in lower greenhouse gas emissions (Gerber *et al.*, 2013).

Significant amount of manure was made as dung cake and utilized as an alternative source of fuel to fire wood (Aektasaeng, 2015). Due to the deforestation problems, there was inaccessibility to use fire wood as fuel sources and converting manure in to dung cake.

In urban dairy production, livestock are often housed indoors in zero-grazing which leads to dung accumulation near the barns. As a result, solid storage emerged as a common manure management practice in urban production. Despite little integration of livestock with crop cultivation in urban dairy production, solid manure could still be utilized for crop fertilization or sold for additional benefits, as indicated by previous studies (Yan *et al.*, 2017; Tadesse *et al.*, 2021). This type of manure management generates lower greenhouse gas emissions, particularly in terms of nitrous oxide, compared to liquid or slurry manure management (Gerber *et al.*, 2013).

The slurry or liquid manure management was practiced in urban compared to rural dairy production. Larger farms such as urban farms store their manure in liquid and store longer time than smaller dairy farms and this is similar with the previous studies in Wisconsin dairy farms (Aguirre-Villegas & Larson, 2017). According to Janzen *et al.* (2008), the liquid state of slurry facilitates the decomposition process, converting carbohydrates into methane, which has a higher global warming potential than carbon dioxide.

Greenhouse Gas from Manure Management

There was higher methane emission from urban dairy cattle manure management than the rural dairy production. The methane emissions from dairy cattle manure management practices were found to be 168.64± 9.52 kg of CO_2 eq in rural dairy production and 282.2 ± 18.7 kg of CO_2 eq in urban dairy production. These values were lower than those reported in previous studies conducted in Enderta and Mekelle, where methane emissions from manure management practices were 1037.11 kg of CO_2 eq in rural dairy production and 3923.44 kg of CO_2 eq in urban dairy production (Berhe *et al.*, 2020). The variation in these values could be attributed to methodological differences, as the current study used IPCC tier 2 methodology while the latter employed GLEAM-i (Berhe *et al.*, 2020). The variations in methane production between the rural and urban dairy production in the present study could be attributed to various factors such as differences in body weight of dairy cows, types of dairy feed resources used, milk production levels, and manure management practices related to storage, handling and application. Other studies have made similar observations regarding the impact of these factors on methane emissions, including those of Eggleston *et al.* (2006) and Opio *et al.* (2013).

A previous study has shown a comparable result with rural dairy production, at 4.23 kg of CH_4/head/year in southern Ethiopia (Birhanu *et al.*, 2024). However, there were no significant differences in direct and indirect Nitrous oxide between the two dairy and non-dairy productions, though there was variation in manure management and feed resources use.

Both direct and indirect nitrous oxide emissions from dairy cattle manure management practices showed no variation between the two dairy production systems. In the present study, the direct nitrous oxide emission factor per cow per year was found to exceed the value reported by Birhanu *et al.* (2024), which documented direct nitrous oxide emissions at 0.01 kg per cow per year.

Lower-quality feeds produce excreta with lower nitrogen concentrations and higher carbon to nitrogen ratio is inversely related to nitrogen and N_2O level (Pelster *et al.*, 2016). Carbohydrates typically result in lower direct and indirect nitrous oxide emissions compared to nitrogen-rich feed resources (Almeida *et al.*, 2020). This is because carbohydrate rich feeds improve the nitrogen use efficiency and retain more nitrogen in the body. This in turn resulted in lower direct and indirect N_2O (Almeida *et al.*, 2020). Additionally, under anaerobic manure management conditions, more methane and less nitrous oxide are typically produced, further contributing to the similar levels of nitrous oxide emissions observed in urban and rural dairy cattle production (Moeletsi and Tongwane, 2015).

Conclusion

In conclusion, there were variations in dairy herd structures, feed resources utilized, and differences in manure management practices among urban and rural dairy production. The difference in manure management practices resulted in variations in greenhouse gas emission among the two dairy production systems. Urban dairy production had greater methane emissions than rural dairy production, emanating from manure management practices. Despite these differences, nitrous oxide emissions did not differ between urban and rural dairy production.

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Conflict of Interests

The authors declare that they have no competing interests.

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