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Assessing greenhouse gas emissions from outdoor cattle sleeping areas in Cameroon

N. Martin Ngwabie[a,*], Divine Ngwa[a], Chanceline Njuasu[a], Theodore Chenwi[a], Fabrice Yengong[b], Andrew VanderZaag[c]

[a] Department of Agricultural and Environmental Engineering, College of Technology, The University of Bamenda, Box 39, Bambili, N. W. Region, Cameroon
[b] Department of Environmental Science, Faculty of Science, University of Buea, Cameroon
[c] Science and Technology Branch, Agriculture and Agri-food Canada, Ottawa, Ontario, Canada

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ABSTRACT

Cattle production is an important source of greenhouse gas (GHG) emissions which affects the environment. While emissions have mostly been quantified from barns and manure storage facilities, little information is available on emissions from outdoor sleeping areas, especially in Africa. This project was carried out in two beef cattle farms (Banshe and Menteh) in Cameroon, with the aim of quantifying GHG emissions from the outdoor sleeping areas. The sleeping areas were fenced with planks and the floor was bare soil covered mainly with cattle manure. Gas emission rates were measured when the cattle were on pasture using 2 non-steady state flux chambers during the wet season for 1 week in each farm. Manure dry matter, determined using method 1648 of the U.S. Environmental Protection Agency, was in the range of 28–38% while the volatile solid content was in the range of 41–57%. Emission hotspots and hot moments were observed with large variations in time and location. The methane (CH_4) emissions were 4.04 ± 4.3 and 1.85 ± 1.7 mg m^{-2} min^{-1} in Banshe and Menteh, respectively. The nitrous oxide (N_2O) emissions were 0.008 ± 0.02 and 0.049 ± 0.06 mg m^{-2} min^{-1} in Banshe and Menteh, respectively. The sleeping area with high CH_4 emissions was associated with low N_2O emissions and vice versa. The carbon dioxide (CO_2) to CH_4 emission ratios were high; ~7 for Banshe and ~15 for Menteh, indicating more aerobic conditions. The total GHG ($CH_4 + N_2O$) emission rates were 139.7 and 77.5 mg CO_2e m^{-2} min^{-1} in Banshe and Menteh, respectively. This indicated that CH_4 contributed 98 and 81% of the total GHG in Banshe and Menteh, respectively. This shows that mitigation strategies should be geared more towards CH_4 in the sleeping areas in this study during the wet season. The GHG emission factors estimated in this research were the first of its kind in Cameroon, and can be used as a basis for planning management practices that mitigate emissions.

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* Corresponding author.
E-mail address: ngwabie@yahoo.co.uk (N.M. Ngwabie).

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Introduction

Livestock production is a major source of anthropogenic greenhouse gas (GHG) emissions, with substantial emissions associated with manure management [1,11]. In particular, livestock sleeping areas or corrals have been characterized by emission hotspots and hot moments driven by patterns in manure deposition [8,9], especially for nitrous oxide (N_2O). There is very limited information available in the literature on GHG emissions from cattle manure systems and especially from overnight sleeping areas in Africa, with a few published data in Kenya, East Africa [10,13] on emissions from urine and dung deposited in pastures. Accurate estimates of emissions related to manure management practices is needed for identifying suitable mitigation strategies. With the availability of limited data from direct measurements, models such as those of the IPCC [2] that are based on emission factors, have been used to estimate emissions. Such emission factors may not reflect local management and climate conditions. In Africa in general and Cameroon in particular, the cattle industry is dominated by beef cattle that are kept in pasture during the day and often kept in outdoor fenced corrals overnight. The fenced and unroofed corrals that protect the cattle overnight usually have bare soil surfaces. These enclosures are convenient in the dry season, but become muddy constituting a mixture soil, dung, urine and rain water in the wet season, and could enhance GHG emissions. Differences in cattle production systems and climatic conditions highlight the need for data which reflects local production and climatic systems. As such, this project was carried out in two beef cattle sleeping areas located in Bamenda, Cameroon, with the aim of quantifying methane (CH_4), N_2O and carbon dioxide (CO_2) emission rates.

Materials and methods

Description of cattle overnight sleeping areas

Gas emissions were measured from the overnight sleeping areas of two beef cattle farms (Banshe and Menteh) located in Bamenda, Cameroon. Bamenda is located at 5°56′N 10°10′E, with an elevation of 1614 m. The average annual air temperature is 21.5 °C, while the average annual rainfall is 2145 mm. Bamenda is characterised by savanna vegetation where cattle feed predominantly on pennisetum purpureum, brachiaria, paspalum and panicum maximum.

The Banshe and Menteh farms were chosen because of their locations and types of cattle they reared. The Banshe farm represents farms in the vicinity of cattle markets, with a mixture of residential cattle and cattle from other herds that are on transition to or from the market. The Menteh farm represents normal farms with traditionally only residential cattle that are reared to maturity before being taken to the market. Management routines were similar in the Banshe and Menteh farms. The cattle were predominantly West African Zebu raised on pasture and measurements were conducted for a week in each farm during the wet season. The herd was made up of cattle of all ages with an average body mass at slaughter of about 420 kg [5]. The sleeping areas were fenced with planks, and the floor was bare soil covered mainly with a mixture of dung, urine and soil (Fig. 1). The Banshe farm was a 20 × 15 m fenced area with about 60 cattle or 85.7 Tropical Livestock Units (TLU, where 1 TLU = 0.7 cattle) during the measurement period, resulting to a stocking density of 0.2 cattle m^{-2} (0.24 TLU m^{-2}). Cattle manure covered about 90% (270 m^2) of the surface area in Banshe with the remaining 10% not used as it was on a slope. The Menteh farm was a 52 × 20 m fenced area with about 56 cattle (80 TLU) during the measurement period, resulting to a stocking density of 0.1 cattle m^{-2} (0.08 TLU). Cattle manure covered about 40% (416 m^2) of the surface area in Menteh with the remaining 60% covered with bare soil and vegetation (Fig. 1). Cattle manure is usually taken out from the sleeping arears periodically during dry weather when it is easier to handle, for application to farm land. Cattle

Fig. 1. Overnight sleeping area for beef cattle in Banshe (right) and Menteh (left) - Cameroon.

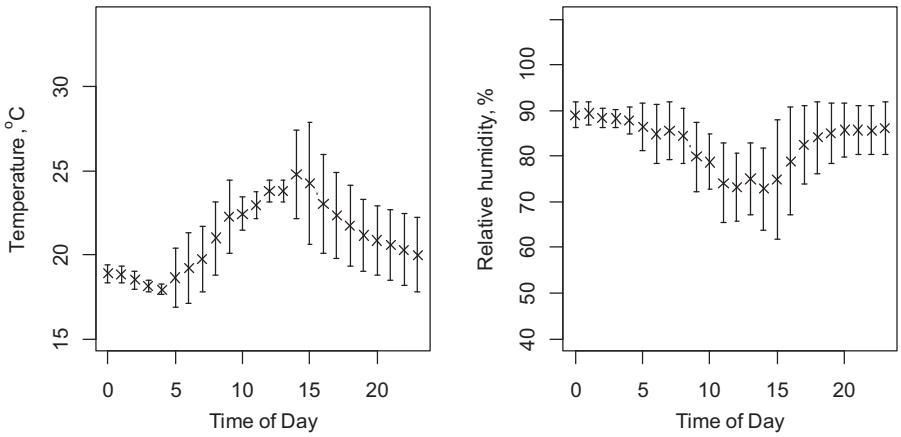

Fig. 2. Outdoor air temperature and relative humidity around the cattle sleeping area in Banshe. Each data point represents an hourly average for the measurement period. Error bars show the standard deviation within each hourly bin.

from both farms were taken out for grazing daily at about 9 a.m. and brought back into the fenced area at about 5 p.m. During grazing, the cattle were provided with water, hence no additional feed or water was provided in the sleeping area.

Measurement of methane, nitrous oxide and carbon dioxide emission rates

Gas emission rates from the sleeping areas were measured using 2 non-steady state flux chambers, with details described elsewhere [6], for a duration of 1 week in Banshe and another 1 week in Menteh. Gas emissions from the sleeping surfaces were measured during the day, when the cattle were out on pasture. Chamber locations on the sleeping surfaces were moved daily during the measurement period to account for the heterogeneous nature of the emitting surfaces. Gas was sampled from the chamber airspace in the mornings (three times at 10:00, 10:10, and 10:20) and in the afternoons (three times at 15:00, 15:10, and 15:20) during the measurement period. The gas samples were injected into evacuated vials for concentration measurements using a chromatograph. The chromatograph had a thermal conductivity detector, elector capture detector and flame ionization detector for the measurement of CO_2, N_2O and CH_4, concentrations respectively.

Emissions were calculated using the linear regression approach with regressed slopes and hence measurement points rejected for the few cases (<5%) where the coefficient of determination (R^2) was less than 0.80. The slope was used together with the chamber surface area (0.108 m^2) and headspace volume (0.03 m^3) to calculate the emissions as shown in Eq. (1). A comparison of the emissions between the farms was carried out using the Student's *t*-test and the Wilcoxon test.

$$\text{Emission rate} = \frac{\text{slope } x \text{ chamber headspace volume}}{\text{chamber collar sruface area}} \tag{1}$$

Manure characterisation and environmental data

At the start of measurements, manure samples were collected from ten locations within the sleeping surface of each farm, mixed homogenously and sub-sampled in duplicates into vials. The procedure was repeated in both farms at the end of the measurements. The vails were stored at −18 °C for subsequent laboratory analyses of the dry matter (DM) and volatile solid (VS) contents. Method 1648 of the U.S. Environmental Protection Agency [12] was used for the measurement of the DM and VS in the manure with details reported elsewhere [3]. Air temperature and relative humidity around the sleeping areas were measured using a Tinytag data logger (Gemini Data loggers, Chichester, UK) at 5 min intervals. The data loggers were placed in the eaves of a nearby building used by the herdsmen.

Results and discussion

Air temperature and relative humidity

Diel patterns in average hourly outdoor air temperature and relative humidity around the Banshe and Menteh farms are shown in Figs. 2 and 3 respectively. The average hourly air temperature and relative humidity in Banshe were 21 °C and 83%, with ranges of 18–25 °C and 73–89%, respectively. The average hourly air temperature and relative humidity in Menteh were 22 °C and 83%, with ranges of 19–28 °C and 60–94%. The air temperature in both farms were close to the annual average of 21.5 °C for this region. The sleeping surfaces with manure were high in moisture as it rained periodically for short intervals during the measurements with a historical monthly average rainfall of about 214 mm around May and June.

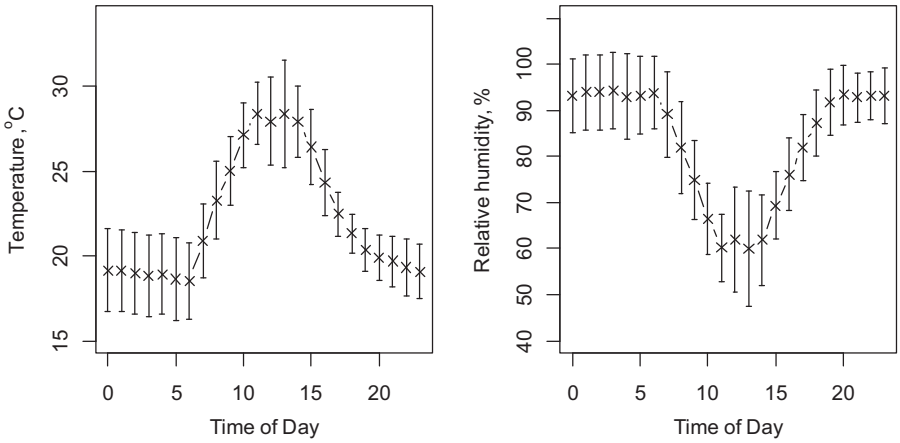

Fig. 3. Outdoor air temperature and relative humidity around the cattle sleeping area in Menteh. Each data point represents an hourly average for the measurement period. Error bars show the standard deviation within each hourly bin.

Table 1
Manure characteristics from cattle overnight sleeping areas in two farms. Measurements in Banshe were completed before measurements started in Menteh.

	Measurement time (Day)	Moisture (%)	DM (%)	Ash (%DM)	VS (%DM)
Banshe	1	72	28	43	57
	7	65	35	51	49
Menteh	1	62	38	59	41
	7	71	29	52	48

DM: dry matter, VS: volatile solids.

Table 2
Gas emissions from manure in the outdoor overnight sleeping areas of two cattle farms.

Farm	Description, units	CH_4*	N_2O*	CO_2 NS
Banshe	Mean ± SD (Range), mg m^{-2} min^{-1}	4.04 ± 4.3 (0.26–15.52)	0.008 ± 0.02 (0.001–0.063)	27 ± 11 (13–49)
	Mean ± SD, kg yr^{-1}	573.32 ± 610.2	1.135 ± 2.84	3832 ± 1561
	Mean ± SD, kg hd^{-1} yr^{-1}	9.56 ± 10.2	0.019 ± 0.05	64 ± 26
Menteh	Mean ± SD (Range), mg m^{-2} min^{-1}	1.85 ± 1.7 (0.34–7.33)	0.049 ± 0.06 (0.001–0.229)	27 ± 10 (10–47)
	Mean ± SD, kg yr^{-1}	404.50 ± 371.7	10.714 ± 13.12	5904 ± 2186
	Mean ± SD, kg hd^{-1} yr^{-1}	7.22 ± 6.6	0.191 ± 0.23	105 ± 39

Test of significant difference in emissions between the two farms.
* $p \leq 0.05$.
NS Not significant.
SD: standard deviation, surface area: 270 m^2 in Banshe and 416 m^2 in Menteh, Cattle number: 60 and 56 in Banshe and Menteh respectively.

Manure characterisation

Table 1 shows the average manure characteristics in the sleeping areas of both farms as recorded on the first and last days of measurement. Although not directly measured, heavy rains at both sites during the measurements contributed to the moisture content of the manure as seen in Fig. 1. Changes in the VS of the manure within and between farms could be due to natural variations resulting from changes in forage composition. The high ash content could due to a mixture of soil with the manure.

Methane, nitrous oxide and carbon dioxide emission rates from overnight sleeping areas

The measured emission rates for CH_4, N_2O and CO_2 from the sleeping surfaces are presented in Table 2. Temporal and spatial variations in emission rates of CH_4, N_2O and CO_2 are shown in Fig. 4 with notable emission hotspots and hot moments. Large temporal and spatial variations in emissions could be associated with the non-homogenous distribution and inconsistency of the manure on the resting surfaces, resulting to emission hotspots and hot moments [9].

It was observed that manure on sloped sections of the sleeping surface was lower in moisture and thickness, whereas manure on level sections of the sleeping surface was higher in moisture and thickness. During rainy events, manure moisture content further increased, as such, it can be expected that low lying sections of the resting surfaces with more liquid manure

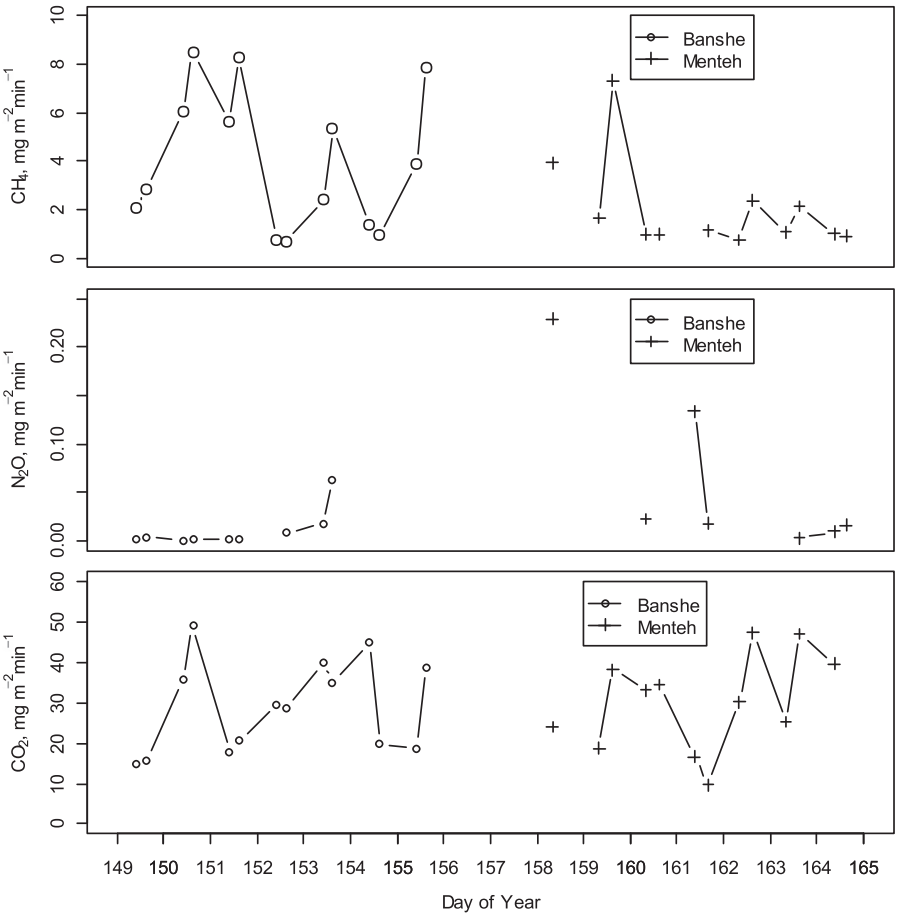

Fig. 4. Variations in CH_4, N_2O, and CO_2 emission rates from manure in the outdoor overnight sleeping areas of two cattle farms. There was no measurements conducted on days 156 and 157 as the instruments were moved from Banshe to Menteh farms.

will experience high CH_4 and low N_2O emissions. The CO_2:CH_4 emission ratios from Table 2 was twice higher in Menteh (~15) as compared to Banshe (~7), indicating a more likely aerobic condition in Menteh when compared to Banshe. When expressed in CO_2e, the CH_4 emissions were 137.4 mg CO_2e m^{-2} min^{-1} and the N_2O emissions were 2.4 mg CO_2e m^{-2} min^{-1} in Banshe, while the CH_4 emissions were 62.9 mg CO_2e m^{-2} min^{-1} and the N_2O emissions were 14.6 mg CO_2e m^{-2} min^{-1} in Menteh. These resulted to a total GHG (CH_4 + N_2O) emission rate that was nearly twice as high in Banshe (139.7 mg CO_2e m^{-2} min^{-1}) compared with Menteh (77.5 mg CO_2e m^{-2} min^{-1}). Methane contributed 98 and 81% of the total GHG in Banshe and Menteh, respectively. This shows that mitigation strategies should be geared more towards CH_4 in sleeping areas similar to that in the present study during the wet season, which constitutes about half of the year in Cameroon. Reducing the moisture content by having a roof over resting areas in the wet season could reduce the anaerobic nature of the manure and hence CH_4 emissions. Information provided by the farmers indicated that the manure was hardly removed during the wet season due partly to difficulties in handling wet manure, which will provide a rich inoculum base for further CH_4 emissions [4]. Unlike indoor sleeping areas where bedding material is often used, and could potentially mitigate emissions [7,14], no bedding material was used in the overnight sleeping areas in the present study.

With a manure covered surface area of about 270 m^2 and 416 m^2 in Banshe and Menteh respectively, the average emissions can be expressed as 9.6 and 7.2 kg CH_4 hd^{-1} yr^{-1} in Banshe and Menteh respectively (Table 2). The estimated extrapolation to annual emissions is Table 2 was carried out with the assumption of wet season emission factors all year and the same number of cattle in the corrals. This is far higher than the IPCC emission factor of 1 kg CH_4 hd^{-1} yr^{-1} for cattle manure management in Africa [2] and the measured emissions factors of 0.12–0.33 kg CH_4 hd^{-1} yr^{-1} from feces and urine applied to grassland in kenya [10]. With regards to N_2O, the scaled emissions in the present study were 0.02 and 0.19 kg N_2O hd^{-1} yr^{-1} for Banshe and Menteh respectively, being rather lower than 1.5 ± 0.8 kg N_2O hd^{-1} yr^{-1} for corrals reported elsewhere [8]. Differences in emissions factors could among other factors be associated to the climate, feeding and the management practices which may also include the time animals spent inside corrals.

Conclusions

Measurements were carried out in the sleeping areas of two beef cattle farms (Banshe and Menteh) to quantify CH_4, N_2O and CO_2 emission rates from manure surface. Results show that outdoor sleeping areas are emissions hotspots and hot moments with large variations in time and location. CH_4 emissions were 4.04 ± 4.3 and 1.85 ± 1.7 mg m^{-2} min^{-1} in Banshe and Menteh respectively. N_2O emissions were 1.85 ± 1.7 and 0.049 ± 0.06 mg m^{-2} min^{-1} in Banshe and Menteh, respectively. High CH_4 emissions is associated with low N_2O emissions, and vice versa. The total GHG ($CH_4 + N_2O$) emission is dominated by CH_4, contributing more than 80% of the total GHG. As such, mitigation strategies should be geared more towards CH_4 in open air sleeping areas, especially during the wet season. Long-term measurements are needed to cover seasonal variations in GHG emissions from sleeping areas, so as to better plan and implement waste management strategies that mitigate GHG emissions.

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Conflict of interest

The authors declare they have no competing interests.

CRediT authorship contribution statement

N. Martin Ngwabie: Conceptualization, Formal analysis, Writing - original draft. **Divine Ngwa:** Formal analysis, Writing - original draft. **Chanceline Njuasu:** Formal analysis, Writing - original draft. **Theodore Chenwi:** Formal analysis, Writing - original draft. **Fabrice Yengong:** Formal analysis, Writing - original draft. **Andrew VanderZaag:** Formal analysis, Writing - original draft.

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Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.sciaf.2019.e00088.

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