Assessment of the potential for methane emissions caused by the livestock sector in the region of Kankan, Guinea

ABSTRACT

Man has always organized his agrarian space along with his farm animals. Nevertheless, the population growth and the healthiness of cattle and their droppings have motivated to work on the recovery of animal waste. Cattle are the main conributor to the sectors emissions of about 5 gigatonnes which is 62 percent of the sector's emissions. Furthermore, the study evaluates methane emissions from the livestock sector in the Administrative Region of Kankan. The methodological approach adopted are field survey conducted to get the census of animal herd and data from different livestock services were collected.

The results obtained from the analysis shows that the average daily quantities of cow dung and chicken droppings in the Kankan region are cow dung (4.45 kg) and chicken droppings (0.015 kg). Number of animal livestock by prefecture of the region, i.e.bovine population of the region (1572132) which is the daily regional potential of biogas and energy respectively (763588.006 m3/d) and (3497233.069 kWh/d) and annual regional methane emissions (108908054 kg/year). It is the first estimate of methane emissions from livestock sector in the Kankan region.

Keywords: Cow dung, droppings, Livestock, methane, emissions.

1. INTRODUCTION

Climate change, its causes and effects are responsible to a rise in a large number of scientific works. Research works have emphaised the study of the coupling between human activities and climate change, in particular, to limit the harmful impacts on our societies [1]. In 2013, Intergovernmental Panel on Climate Change (IPCC) highlighted the effect of human activities in the increase in greenhouse gas (GHG) concentrations and therefore average surface temperatures (the temperature at the surface of the Earth would have increased by 0.85°C since 1850) since the beginning of the industrial era, atmospheric concentrations of nitrous oxide (N_2O), carbon dioxide (CO_2) and methane (CH_4) have increased by 15%, 30% and 150% respectively [2].

Faced with this environmental threat, the developed countries agreed in 1997 to establish a plan to reduce GHG emissions, this is the Kyoto Protocol. The report of the Intergovernmental Panel on Climate Change (IPCC) confirms and reinforces the certainty of the existence of an increase in the greenhouse effect due to human activities [3]. The consequences of climate change due to GHGs are multiple, we can cite: the melting and disappearance of glaciers, the reduction of water resources, the health consequences and the rise in sea level [4, 5].

Like any human activity, livestock farming exerts a strong influence on the natural environment. This impact can be positive and/or negative for the ecosystems involved by the provision of benefits and pressures on the environment by emissions of GHGs throughout the chain. There are three main GHGs emitted in the context of livestock-related activities, which are: carbon dioxide (CO2), methane (CH_4) and nitrated nitrogen (N_2O). About 44% of GHG emissions from the livestock sector are made up of CH_4 [6, 7].

In Guinea, livestock farming is the second most important activity in the rural enivirons. It is a growth-enhancing sector that contributes substantially to food security and to erradicate poverty. The national livestock census in 2017 proved to enumerate cattle (6407000); sheep and goats (459400). The poultry population is estimated at 28400000 poultry of local varieties and 1500000 hens of improved strains in semi-intensive poultry farms [8]. Livestock are an important source of CH_4 emissions due to their numbers, their ruminant digestive systems, in which enteric fermentation takes place and the management of their excreta (dung, manure, slurry, etc.) is essential for the study.

The global anthropogenic emission (63%) of the total CH_4 emissions comes mainly from swamps, ruminant breeding, rice cultivation, household waste dumps, oil and gas operations [9]. CH_4 emissions from manure management are generally less significant than enteric emissions. The largest emissions are associated with animal management operations in confined spaces, where manure is treated using liquid systems. Two-thirds of the CH_4 from ruminant farming comes from enteric fermentation and one-third from animal waste. The average annual values of potential CH_4 emissions due to livestock are: dairy cows (90 kg/year), growing cattle (65 kg/year) and cattle from 2 to 6 years old (51 kg/year) [10,11]. This study falls within this perspective wherein the objective is to assess methane emissions from livestock sector in the administrative region of Kankan.

2. MATERIAL AND METHOD

2.1. Presentation of the study area

The administrative region of Kankan is located 781 km from the capital Conakry. It is the largest administrative region of Guinea, it covers an area of 72145 km², with five prefectures (Kankan, Kérouané, Kouroussa, Mandiana and Siguiri). The sub-Sudanian climate is characterized by the alternation of two seasons (dry and rainy) with temperatures ranging from 25°C to 41°C and rainfall varying between 1100 and 1800 mm of water per year [12]. The population of the Kankan region is estimated at 2097257 inhabitants in 2016, with an average density of 28 inhabitants per km². The prefecture of Siguiri is the most populated in the region and in Guinea, with 724631 inhabitants, including 360147 women (49.70%) [13].

2.2. Process of methane emissions from livestock

CH_4 emissions from manure management are generally less significant than enteric emissions. The largest emissions are associated with animal management operations in confined spaces, where manure is treated using liquid systems. Two-thirds of the CH_4 from ruminant farming comes from enteric fermentation and one-third from animal waste [14]. In a suckler cattle farm, enteric methane is responsible on average for 59% of greenhouse gas emissions [15]. Fig. 1 shows the process of enteric methane formation.

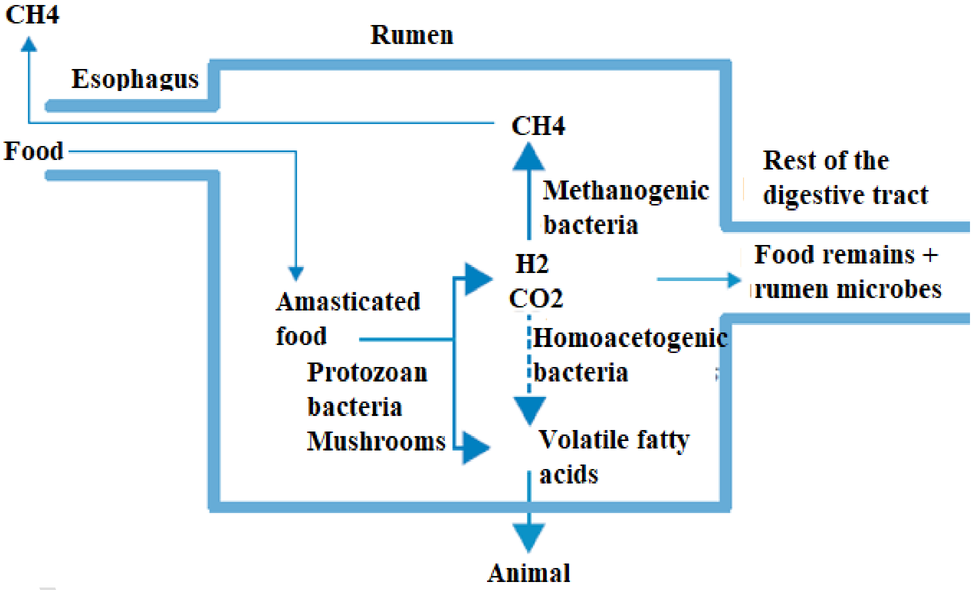

Fig.1. Formation of enteric methane [15]

The management of manure from breeding sites to pastures through storage and spreading is the most impactful item of the livestock operation from an environmental point of view. These effluents are responsible for non-enteric CH_4 emissions.

The method for estimating CH_4 emissions from livestock consisted of categorizing livestock, assessing populations and knowing the characteristics of the diet. The equations are applied seasonally to assess livestock feed consumption, while taking into account certain performance parameters of the different animal categories, which are: average weight, average weight gain per day, average mature weight, average number of working hours per day, feeding conditions, average temperature of the rearing environment, average daily milk production, and feed digestibility rate [16].

Gross energy (GE) is the energy needed by an animal to survive and support activities such as growth, lactation and gestation. This energy consumption for cattle is calculated by relation 1 [11].

$$\mathrm{EB} = \left[\frac{\left(\frac{\mathrm{EN_s}+\mathrm{EN_a}+\mathrm{EN_l}+\mathrm{EN_{tra}}+\mathrm{EN_g}}{\mathrm{TES}}\right)+\left(\frac{\mathrm{EN_{cce}}}{\mathrm{TEC}}\right)}{\frac{\mathrm{DA\%}}{100}}\right] \quad (1)$$

With :

ENs: Net energy necessary for survival in MJ/d; NEa: Net energy necessary for the activities in MJ/d; ENl: Net energy required for lactation in MJ/d; ENtra: Net energy required for work in MJ/d; ENg: Net energy required for gestation in MJ/d; ENCce: Net energy required for growth in MJ/d; TES: Rate of net energy available in food for survival in %; TEC: Net energy rate in the feed available for growth in %; DA%: Digestible energy expressed as a percentage of gross energy. These different parameters are defined as follows [17, 18].

The Net Energy Needed for Survival is the amount of energy needed to keep the animal in balance (the body neither loses nor gains energy). It is determined by relation 2.

$$\mathrm{EN_S} = \mathrm{Cf_i}(\mathrm{PV})^{0{,}75} \quad (2)$$

PV: Average live weight of the animal in (kg); Cfi: Coefficient varying for all animal categories in MJ/d.kg (Cfi = 0.322 for cows outside the lactation period, Cfi = 0.386 and Cf = 0.370 for bulls).

Net energy needed for activities is the energy that animals need for food, drink and shelter. It is based on dietary conditions rather than the characteristics of the diet itself. This energy is calculated by relation 3.

$$\mathrm{EN_a} = \mathrm{C_a}.\mathrm{EN_S} \quad (3)$$

With: C_a the activity coefficient, corresponding to the animal's food conditions ($C_{a/}$ = 0.36 for large open pastures).

The Net energy needed for growth is the energy of weight gain. It is determined by the relationship.

$$\mathrm{ENC_{ce}} = 22{,}02.\left(\frac{\mathrm{PV}}{\mathrm{C.PM}}\right)^{0{,}75}\mathrm{PP}^{1{,}097} \quad (4)$$

Or :

C: Coefficient equal to 0.8 for females; 1.0 for castrates and 1.2 for bulls;
MP: Mature live weight of adult female of moderate body condition in kg;
PP: Average weight gain per day in kg/d.

The net energy needed for lactation in cattle is expressed as a function of the quantity of milk produced and the fat content in % equal to 4%. It is determined by relation 5.

$$\mathrm{EN_1} = \mathrm{lait}.(1{,}47 + 0{,}40.\mathrm{mat\_gra}) \quad (5)$$

Milk: Quantity of milk produced in kg/d,
Mat_gra: Milk fat content in % of weight.

The Net Energy Needed for Work is the energy needed to pull the cattle. This net energy necessary for work is determined by relation 6.

$$\mathrm{EN_{tra}} = 0{,}10.\mathrm{EN_s}.\mathrm{t} \quad (6)$$

Where: t is the average number of working hours per day.

Net energy needed for gestation, the energy needed for gestation lasting an average of 281 days per year, is estimated at 10% of NEs. Relation 7 makes it possible to evaluate this energy.

$$\mathrm{EN_g} = \mathrm{C_g}.\mathrm{EN_s} \quad (7)$$

Where: Cg is the gestation constant for cattle, it is 0.10.

The rate of net energy available in food for survival in relation to the digestible energy consumed (TES) is calculated by relation 8.

$$\mathrm{TES} = [1{,}123 - (4{,}092.10^{-3}.\mathrm{DA\%}) + [1{,}126.10^{-5}.(\mathrm{DA\%})^2] - \left(\frac{25{,}4}{\mathrm{DA\%}}\right)\Big] \quad (8)$$

The rate of net energy in the feed available for growth in relation to the digestible energy consumed (TEC) is calculated by relation 9.

$$\mathrm{TEC} = [1{,}164 - (5{,}160.10^{-3}.\mathrm{DA\%}) + [1{,}308.10^{-5}.(\mathrm{DA\%})^2] - \left(\frac{37{,}4}{\mathrm{DA\%}}\right)\Big] \quad (9)$$

Feed consumption in units of dry matter (DMC) per day (kg/d), is estimated by dividing the BE by the energy density of the feed. A default value of 18.45 MJ/kg dry matter can be used if specific feed information is not available. The CMS value should be in the range of 2 to 3% of the body weight of mature or growing animals. For high-producing dairy cows, consumption may exceed 4% of body weight [19]. Relations 10 and 11 allow us to evaluate this consumption.
For growing and end-of-life cattle, we have:

$$\mathrm{CMS} = \mathrm{PV}^{0,75}.\left[\frac{(0,2444.\mathrm{EN_{ma}} - 0,0111.\mathrm{EN_{ma}^2} - 0,472)}{\mathrm{EN_{ma}}}\right] \tag{10}$$

For mature cattle we have:

$$\mathrm{CMS} = \mathrm{PV}^{0,75}.\left[\frac{(0,0119.\mathrm{NE_{ma}^2} + 0,0119)}{\mathrm{EN_{ma}}}\right] \tag{11}$$

Where: ENma is the estimated net dietary energy concentration of the diet.

2.2.1. Potential for CH_4 emissions from enteric fermentation

Herbivores produce methane as a byproduct of enteric fermentation. The amount of methane emitted depends on the type of digestive tract, the age, the weight of the animal and the quality and quantity of food consumed. The potential for CH_4 emissions due to enteric fermentation is calculated by relationships 12 and 13.

$$\mathrm{Em_{CH4}} = \mathrm{FE_{(T)}}.\left(\frac{\mathrm{N_{(T)}}}{10^6}\right) \tag{12}$$

$$\mathrm{TEm_{CH4}} = \textstyle\sum_i \mathrm{E_i} \tag{13}$$

Or :

TEmCH4: Annual methane emissions due to enteric fermentation in (Gg CH_4/year);
EF(T) : Emission factor for the livestock category defined in (kg CH_4/head year);
N(T) : Number of heads of livestock species/category T; T: Livestock species/category;
Ei : Emissions of livestock category and sub-category i.
The EF emission factor for each animal category is given by relationship 14.

$$\mathrm{FE} = \left[\frac{\mathrm{EB}.\left(\frac{\mathrm{Y_m}}{100}\right).365}{55,65}\right] \tag{14}$$

Or :

EB: Gross energy consumption in MJ/head.day;
Ym: CH_4 conversion factor, this is the percentage of gross energy in the feed converted to CH_4 and the value 55.65 (MJ/kg CH_4) represents the value

2.2.2. Potential for CH_4 emissions from manure management

The decomposition of manure under anaerobic conditions, during storage, processing and application to pasture produces CH_4. The different steps used to assess non-enteric or manure management CH_4 emissions consist of:

- Gather data corresponding to livestock populations based on their characteristics;
- Use default values or develop country-specific emission factors for all livestock subgroups in terms of kg CH_4/animal/year;
- Multiply the emission factors of the livestock subgroup by the population of the subgroup;
- Add emissions from all defined livestock species to determine national emissions.

Relationship 15 is used to evaluate CH_4 emissions due to manure management for a defined population, in Gg CH_4/year.

$$\mathrm{CH_{4fumier}} = \textstyle\sum_{(T)} \frac{(\mathrm{FE_{(T)}}.\mathrm{N_{(T)}})}{10^6} \tag{15}$$

Or :

$EF_{(T)}$: Emission factor for the livestock category defined in kg CH4/head year;
$N_{(T)}$: Number of heads of livestock species/category T in the country;
T: Livestock species/category.

The value of the MCF of a system varies according to the way of managing the manure and the climate, it varies from 0 to 100%. The evaluation of the FCM is thus done using relation 16.

$$\mathrm{FE_{(T)}} = \left(\mathrm{SV_{(T)}}.365\right).\left[\mathrm{B_{O(T)}}.0,67\mathrm{kg/m^3}.\textstyle\sum_{\mathrm{S.K}}\frac{\mathrm{FCM_{S.K}}}{100}.\mathrm{GF_{(T,S,K)}}\right] \tag{16}$$

With :

VS(T): Volatile Solid or OM excreted daily by livestock category T in (kg VS/animal day); 365: Basis for the annual calculation of VS production per day and per year; B0(T): Maximum methane production capacity for the manure produced by livestock category T in m3 CH4/ kg SV; 0.67: Conversion factor from m3 of CH4 to kg of CH4; MCF(S,k): Methane conversion factor for manure management system S per climatic region k; GF(T,S,k): Fraction of manure from livestock category T treated using manure management system S in climate region k, non-dimensional.

The levels of Volatile Solid or MO daily excreted by the categories of livestock are determined by relation 17.

$$\mathrm{SV} = \left[\mathrm{EB.}\left(1 - \frac{\mathrm{DA\%}}{100}\right) + (\mathrm{EU.EB})\right].\left[\left(\frac{1-\mathrm{CENDRE}}{18{,}45}\right)\right] \qquad (17)$$

Or :

SV in (kg SV/day) is the volatile solids excretion per day based on dry organic matter; DA = 60: Digestibility of food; (EU • BE): Urinary energy expressed as a fraction of BE. In general, most ruminants have a urinary energy of 4% BE (reduce to 2% for ruminants fed a diet of at least 85% cereals or for swine). ASH: Ash content of manure, calculated as a fraction of dry matter intake of feed (8% for cattle). If possible, use country-specific values; 18.45 in (MJ/kg) is the conversion factor for BE of diet per kg dry matter. This value is relatively constant for many types of feed based on forage or cereals, frequently consumed by livestock [20].

Given the lack of certain data related to farming methods and certain types of livestock (poultry, goats and sheep) in the region, we used the annual values of CH4 emissions from the literature (65 kg CH_4/year for growing cattle; 0.05 kg CH_4/year for poultry and 8 kg CH_4/year for goats and sheep) [21, 22]. Fig. 2 shows some images from the survey.

Picture 1. Cattle

Photo 2. Goats

Photo 3. Poultry

Photo 4. Farm dung

Photo 5. Slaughterhouse dung

Photo 6. Manure

Fig. 2. Field survey images

3. RESULTS AND DISCUSSION

The results obtained during this study are presented in Table 1 and by the diagrams in Fig. 3. 4 and 5.

Table 1: CH_4 emissions from livestock and poultry in the Kankan region

N°	Prefecture	Cattle		Poultry		Goats		Total
		Numbers	CH_4 (kg/an)	Numbers	CH_4 (kg/an)	Numbers	CH_4 (kg/an)	CH_4 (kg/an)
1	Kankan	23281	15228265	105000	5250	113834	910672	16144187

2	Kouroussa	294137	19 118 905	794	39.7	174614	1396912	20515857
3	Mandiana	326462	21 220 030	2 500	1025	225247	1801976	23023031
4	Siguiri	372411	24 206 715	100000	5000	195151	1561208	25772923
5	Kérouané	344841	22 414 665	95350	4767.5	129078	1032624	23452057
	TOTAL	1572132	102188580	321644	16082.2	837924	6703392	108908054

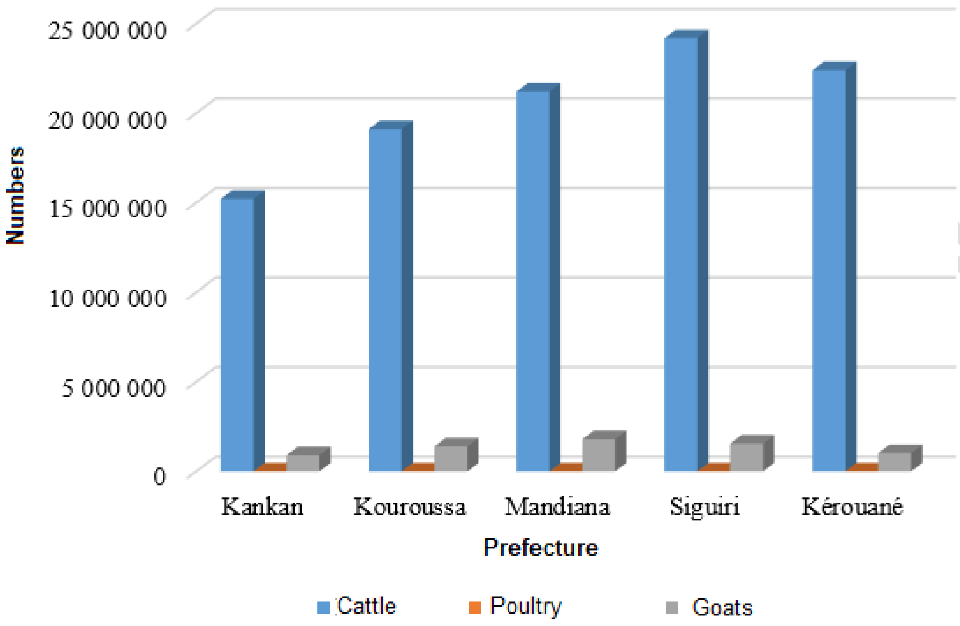

Fig. 3. Number of livestock by prefecture

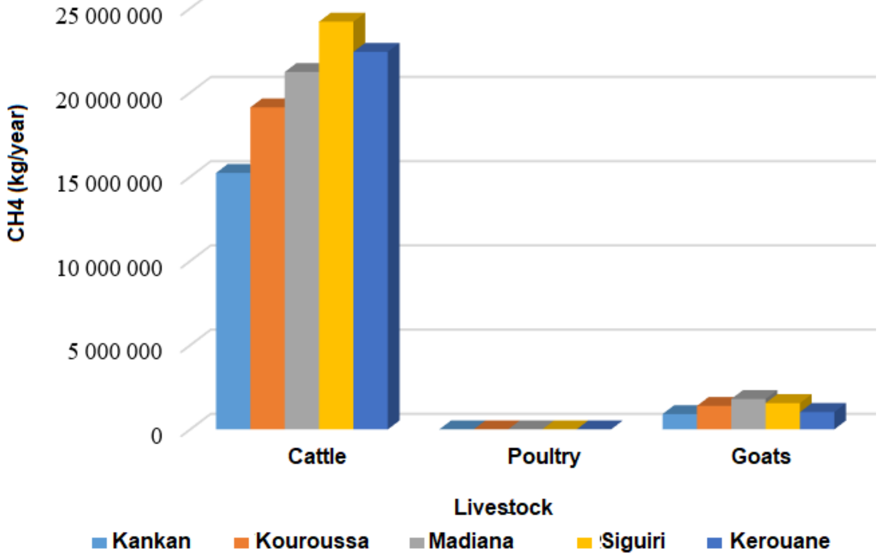

Fig. 4. Potential for CH4 emissions from the livestock sector by species

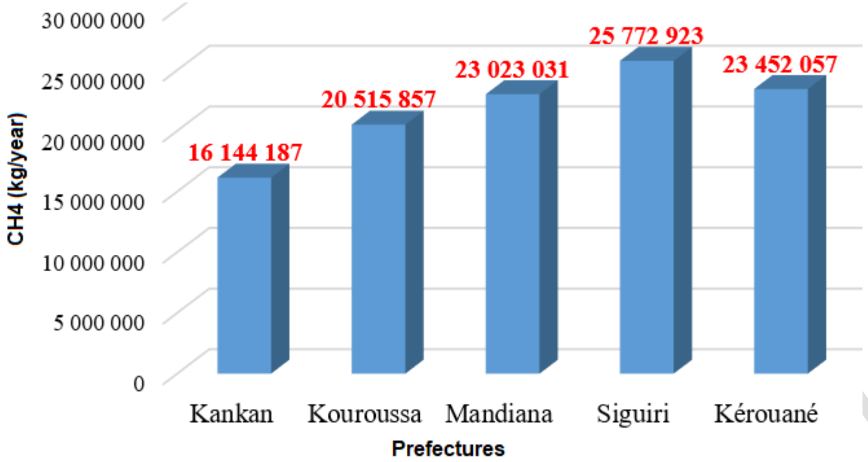

Fig. 5. Potential annual CH4 emissions due to the livestock sector by prefecture

The diagrams in fig. 3, 4 and 5 show the potential annual CH_4 emissions due to the livestock sector by prefecture in the region. The results obtained show that the greatest quantity of emissions is recorded in Siguiri (25772923 kg/year), followed respectively by Kérouané (23452057 kg/year), Mandiana (23023031 kg/year), Kouroussa (20515857 kg/year), and Kankan (16144187 kg/year). With total annual emissions in the region of 108908054 kg/year. This result is a first estimate of the contribution to greenhouse gases of the livestock sector in the Kankan region.

4. CONCLUSION

Diagonistic study carryed out tests to assess the potential for methane emissions due to the livestock sector in the Administrative Region of Kankan. The results show that the greatest amount of CH_4 emissions is recorded in Siguiri, followed respectively by Kérouané, Mandiana, Kouroussa, and Kankan. Thus, the management and recovery of this animal waste could be locally reduce methane emissions.

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