The greenhouse gas emission factor of dairy cows in Hubei Province, China

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Abstract. The methodology 1 provided by the Intergovernmental Panel on Climate Change (IPCC) guidelines is widely used for estimating CH4 and N2O production by cattle, but the reference value is only distinguished between developed and developing countries, with large uncertainties. The objective of this study was to calculate the CH4 and N2O emissions factor by dairy and beef cattle, and the emissions in the Hubei province according to the recommendations of IPCC (2006) using regional farm management data. CH4 emission factors from enteric fermentation in Hubei province was 81.560 kg CH4/head/year for dairy cattle with CH4 emissions of 930.844 kg. CH4 and N2O emission factors from manure management were 0.408 kg/head/year and 1.307 kg/head/year for dairy cattle. The greenhouse gas emissions from breeding cows in Hubei Province in 2012 was 950.418 kg. In general, CH4 emission estimates using Tier 2 (IPCC, 2006) were slightly lower than those from Tier 1, mainly due to use of lower emission factors, especially for CH4 emitted from manure management. The main CH4 emission source was enteric fermentation, being 99.512% of livestock CH4 emissions. Direct emission was the largest component of total N2O emission (56.695%).

1. Introduction
Greenhouse gas (GHG) emissions and their potential effect on the environment has become an important national and international issue [1] It is a major challenge of the twenty-first century for the entire world. Greenhouse gas emissions are mainly concentrated in ruminant livestock and poultry intestinal fermentation to produce methane, and waste management in methane and nitrous oxide [2]. As people living standard gradually increase and diet structure change, livestock greenhouse gas emissions must be increased with the increase of its breeding. Thus, accurate estimation of enteric CH4 production by cattle is required in order to develop a national GHG inventory and to establish mitigation strategies for GHG emissions from livestock production. Ruminant greenhouse gas emissions inventory and emission factor research can intuitive response the ruminant greenhouse gas emissions in a region. Therefore, it is an essential step to evaluate the greenhouse gas emission reduction of agricultural greenhouse gases. The Intergovernmental Panel on climate change (IPCC) has compiled a national greenhouse gas emission inventory guide, which provides a way to calculate the greenhouse gas emission factor for the greenhouse gas, as well as the recommended values for reference [3]. The reference value is only
distinguished between developed and developing countries, with large uncertainties. We have obtained the dairy farming data enterprises in Hubei province by the field investigation so as to estimate the greenhouse gas emission factors in Hubei Province. The results not only provide the research methods and important reference data for the latter researchers, but also provides data support for the reasonable reduction of greenhouse gas emissions.

2. Material and methods

2.1. Estimation of methane emission factor from enteric fermentation

We completed emission factors estimates through the implementation of Tier 2 methodology as:

\[
EF = \frac{GE \left(\frac{Y_m}{100}\right) 365}{55.65} \tag{1}
\]

\[
GE = \frac{\left(NE_m + NE_a + NE_1 + NE_{work} + NE_p\right) \cdot \left(NE_p + NE_{word}\right)}{100} \tag{2}
\]

where \(EF\) is annual enteric \(\text{CH}_4\) EF (kg \(\text{CH}_4/\text{hd/yr}\)), \(GE\) is gross energy (GE) intake (MJ/hd/yr), \(Y_m\) is \(\text{CH}_4\) conversion factor (proportion of GE in feed converted to \(\text{CH}_4\)),

\[c_2 = a_2 + b_2\tag{3}\]

2.2. Estimation of emission factors in feces management mode

2.2.1. Emission factor of \(\text{CH}_4\). For estimated \(\text{CH}_4\), emission factors from manure management based on Tier 2 methodology and information related to manure characteristics management system was:

\[
EF_T = (VS_T \cdot Days) \cdot \left[B_{O_T} \cdot 0.67 \text{ kg/m}^3 \cdot \Sigma_{S,k} \frac{MCF_{S,k}}{100} \cdot MS_{(T,S,k)}\right]. \tag{4}
\]

Where \(EF_T\) is annual \(\text{CH}_4\) emission factor from manure management (kg \(\text{CH}_4/\text{hd/yr}\)), \(VS_T\) = daily volatile solid excreted (kg DM/hd/d), \(B_{O_T}\) is maximum \(\text{CH}_4\) producing capacity for manure produced by livestock category (m\(^3\) \(\text{CH}_4/kg\) of VS excreted), \(MCF_{S,k}\) is \(\text{CH}_4\) conversion factor for each manure management system \(S\) by climate region \(k\) (%), \(MS_{S,k}\) is fraction of manure handled using manure management system \(S\) in climate region \(k\) (dimensionless).

2.2.2. Direct emission factor of \(\text{N}_2\text{O}\). We estimated \(\text{N}_2\text{O}\) emissions from manure storage according to Tier 2 as:

\[
N_2O_{D(mm)} = \left[\Sigma_S \left\{N_{(T)} \cdot N_{ex(T)} \cdot MS_{(T,S)}\right\}\right] \cdot EF_{3(S)} \cdot \frac{44}{28}. \tag{5}
\]

Where \(N_2O_{D(mm)}\) is annual \(\text{N}_2\text{O}\) emission factor from manure management (kg \(\text{N}_2\text{O}/\text{hd/yr}\)), \(N_{ex(T)}\) is annual N excretion/ hd of species (kg N/hd/yr), \(MS_{(T,S)}\) is fraction of total annual N excretion for each livestock species that is managed in the manure management system S, \(EF_{3(S)}\) is EF for \(\text{N}_2\text{O}\) emissions from manure management system S in the country (kg \(\text{N}_2\text{O}-\text{N/kg}\) N in manure management system S). N intake \(N_{(T)}\) was estimated based on GE intake and crude protein (CP, proportion of crude protein in feed DM) in diets from commercial farms as:

\[
N_{(T)} = \frac{GE}{18.45} \left[\frac{CP/100}{6.25}\right]. \tag{6}
\]
2.2.3. Indirect emission factor of N$_2$O.

$$N_{\text{volatilization-MMS}} = \sum_S \left[ \sum_T \left( N_{(T)} \cdot N_{\text{ex}(T)} \cdot MS_{(T,S)} \cdot \left( \frac{\text{FracGasMS}}{100} \right)_{(T,S)} \right) \right] \quad (7)$$

$$N_2O_{G(mm)} = (N_{\text{volatilization-MMS}} \cdot EF_4) \cdot \frac{44}{28} \quad (8)$$

Where $N_2O_{G(mm)}$ is annual direct N$_2$O emission factor from manure management (kg N$_2$O/hd/yr).

$$N_{\text{eluviation-MMS}} = \sum_S \left[ \sum_T \left( N_{(T)} \cdot N_{\text{ex}(T)} \cdot MS_{(T,S)} \cdot \left( \frac{\text{FracEluMS}}{100} \right)_{(T,S)} \right) \right] \quad (9)$$

$$N_2O_{L(mm)} = (N_{\text{eluviation-MMS}} \cdot EF_5) \cdot \frac{44}{28} \quad (10)$$

Where $N_2O_{L(mm)}$ is annual indirect N$_2$O emission factor from manure management (kg N$_2$O/hd/yr).

2.3. Accounting methods.

2.3.1. Calculation method of CH$_4$ emission.

$$E = (EF_{fi} + EF_{mi}) \times LP_i \times 10^{-6} \quad (11)$$

Where EF$_{fi}$ is annual enteric CH$_4$ emission factor (kg CH$_4$/hd/yr), EF$_{mi}$ is annual CH$_4$ emission factor from manure management (kg CH$_4$/hd/yr), LP$_i$ is

2.3.2. Calculation method of N$_2$O emission.

$$N = (N_2O_{D(mm)} + N_2O_{G(mm)} + N_2O_{L(mm)}) \times LP_i \times 10^{-6}. \quad (12)$$

2.4. Research on related emission influencing factors

The necessary information to calculate the emission factor and emissions through field survey has included weight of dairy cows, average daily increase in weight, fat percentage (%), Mature body weight, feeding mode, daily average milk yield, farrowing rate of females, feed digestibility (DE%), type of housing, daily volatile solid waste, the local temperature, manure storage systems and proportion. Dairy cattle activity level data of Hubei Province were obtained from rural statistical yearbook of Hubei province.

3. Organization of the Text

3.1. Methane emission factors from cow enteric fermentation in Hubei Province

This paper investigated the breeding management and basic situation of the 5 dairy farms from Wuhan, Enshi, Xianning, Jingzhou and other regions in Hubei province. Emission factors associated with cows (Table 1). According to IPCC recommended method, the calculated CH$_4$ emission factor from enteric fermentation for dairy cattle was 81.560 kg CH$_4$/hd/yr, which is overestimated dairy cattle compared with the Asian regional cows emission factor that the IPCC recommended (61 kg CH$_4$/hd/yr), whereas factors from dairy cows were slightly lower than emission values of South Central China recommended by China's provincial greenhouse gas emission guidelines (88.100 kg CH$_4$/hd/yr).
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Table 1. The basic energy parameters of dairy cows in Hubei Province

| Basic parameter | NEm | NEa | NEg | NEl | NEp | DE% | REM | REG | GE | Ym |
|-----------------|-----|-----|-----|-----|-----|-----|-----|-----|----|----|
| numerical value | 42.297 | 0.000 | 11.872 | 84.900 | 84.900 | 75% | 1.110 | 1.014 | 177.644 | 7.5% |

Research has shown that 15%−30% reduction in CH$_4$ emission (17.11kg/cow/year) of a cow mainly due to the feeding use ammoniated straw, whereas excessive dietary fiber may result in low nutrient concentration, so the increase of cows feed intake in order to take enough nutrients that leads to an increase in CH$_4$ emissions. If the percentage of fine grain feed is 80%, the 3%-4% energy of the feed will be lost in the form of CH$_4$ emission. If the crude fiber was used as the feed, there are more than 10% of the energy loss in the form of CH$_4$ emission [4]. Our survey shows that: Hubei Province dairy feed grain and other feedstuffs accounted for the proportion of less than 50% and mainly fresh forage, which can accurately reflect the Hubei Province dairy characteristic emission factors. In addition, the temperature of the environment and storage device, waste retention time, humidity and so on greatly affect the production of methane, in the low-temperature dry environment, the propagation and decomposition rate of microorganism is greatly reduced.

3.2. Methane emission factors from cow manure management system in Hubei Province

Calculated using the IPCC Tier 2 cow manure management of CH$_4$ emission factor (0.408 kg/cow/year) is much lower than the values calculated by the IPCC recommended (16 kg/cow/year) and the greenhouse gas emission inventory report of Hubei Province in 2005 (8.449 kg/cow/year). According to the IPCC guidelines, the main influencing factors of methane emission were the amount of feces produced and anaerobic degradation ratio of the feces. The former depends on the number of dairy cows and the productivity of the waste in the unit, the latter depends on how to carry out the manure management. When manure storage or administration in liquid form, such as septic tanks, ponds, septic tank or pit manure anaerobic degradation can produce large amounts of methane. When the waste is treated in a solid form, such as a pile or pile up, or in a pasture or pasture, the feces tends to be degraded under more oxygen consumed conditions, resulting in less methane.

Research shows: Use biogas engineering methane as a fuel, the unit cubic meters of biogas can replace 2 kg coal, thereby reducing greenhouse gas emissions. Aerobic compost is used to replace existing waste treatment system, which can make the potential of greenhouse gas emission reduction of 96.9% [5]. Therefore, the livestock farm can reduce methane emission by aerobic composting or construction of biogas project [6]. In this experiment survey points, five of these breeding point sold dung to fish pond as a feed or earthworm fertilizer and compost, manure management are in aerobic mode, so the methane emission factor calculated value is lower than the other two.

3.3. Nitrous Oxide emission factors from cow manure management system in Hubei Province

According to the Tier 2 of IPCC, the N$_2$O emission factor in the feces management of dairy cows was slightly lower than the reference value. The N losses caused by volatilization and leaching through its indirect emissions respectively were 0.283 and 0.283 kg N$_2$O/head/year, direct emission and indirect emissions of N$_2$O severally accounted for 56.695% and 43.305% of N$_2$O emission factors discharge by dairy cows in Wuhan city. Cows Nex is 94.353 kg N/head/year. The amount of N$_2$O emissions from manure management depends on the amount of carbon and nitrogen in the feces and the duration of storage and the types of management methods. The direct emission of N$_2$O is occurred through digestion and anti-digestion of nitrogen in feces. The existence of nitrite or nitrate is a necessary condition for the production and discharge of N$_2$O in feces management. In addition, it is necessary to prevent low pH or limited moisture conditions as a result of N$_2$O reduced to N$_2$, while its indirect emissions is based on the form of ammonia and NOx emissions by volatile losses, such as urea (mammals) and uric acid (poultry) and other forms of simple organic nitrogen will quickly form a highly volatile substance ammonia.
 nitrogen which is easy to cycle air diffusion. The proportion of ammonia nitrogen in the process of feces collection and storage is mainly determined by the time, followed by temperature [7]. The nitrogen loss is beginning from the discharge points of feeding and other livestock production areas (such as milking hall), and through the storage and management system (ie, the feces management system) on site management of sustained losses.

Research shows: Under different fertilization way of nitrous oxide emission flux exists obvious difference. Using reasonable mode of administration can reduce N₂O emissions in the process of land use. After processing through the casing applicator tillage and banding can effectively inhibit the ammonia volatilization and nitrous oxide emission reduction. Therefore, both fecal management and nitrogen excretion conjointly affect N₂O emissions. Since the experimental sample point generally use the way of aerobic waste management practices, which leads to more nitrogen losses. So the calculation of the feces management N₂O emission factor value is slightly lower than the reference value.

3.4. Analysis of greenhouse gas emission from dairy cows in Hubei Province

From 2011 to 2015, the total carbon emissions of dairy cows increased in Hubei province, as emissions from dairy cattle were increased (Table 2). During the period 2001-2015, carbon emissions in Hubei province have been presenting an increasing trend, from 162736.75 t-eq in 2001 to 196887.69 t-eq in 2015, an increase of 21%. Carbon emissions of Hubei province consist of two parts: first, CH₄ emissions caused by enteric fermentation and manure management the second is N₂O emission from manure management. The largest component of total carbon emission came from CH₄ emissions at 82%. For CH₄ emissions, the emissions in Hubei province have been presenting an increasing trend, from 5343.25 t in 2001 to 6462.03 t in 2015, an increase of 20.93%; Dairy cows increased during the period 2001–2015, with the corresponding rise on CH₄ emissions from enteric fermentation and manure management. For this latter emission source, N₂O emissions in Hubei province also have been presenting an increasing trend, from 94.05 t in 2001 to 113.99 t in 2015, an increase of 21.25%; Use of solid storage has increased considerably resulting in higher N₂O losses from manure.

| Hubei province | total emissions from dairy cow (t-eq) | CH₄(t) | N₂O(t) |
|----------------|--------------------------------------|--------|--------|
| 2001           | 162736.75                            | 5343.25| 94.05  |
| 2005           | 138770.06                            | 4556.34| 80.20  |
| 2010           | 183448.70                            | 6023.30| 106.02 |
| 2015           | 196887.69                            | 6462.03| 113.99 |

4. Conclusion

We have provided IPCC Tier 2 to calculate the CH₄ and N₂O emission factors of Wuhan region, which the calculation of the low value. The methane emission factor from enteric fermentation was 81.560 kg CH₄/head/year from the dairy cows in Hubei province. Methane and nitrous oxide emissions factors from manure management were respectively 0.408 kg/head/year and 1.307 kg/head/year. The greenhouse gas emissions from breeding cows in Hubei Province in 2012 were 950.418 kg. These data provide the support for reducing greenhouse gas emissions of ruminants. With a reasonable feed composition, reduce the proportion of grain which can effectively reduce the production of intestinal fermentation CH₄. In addition, the use of aerobic means to carry out manure management, as much as possible to produce the manure used as fish feed or compost, which not only can reduce emissions of greenhouse gases but also a good use of resources and can provide farmers with good economic benefit.

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