ISBN 978-602-344-251-5, DOI: 10.5281/zenodo.3345298

Estimation of methane enteric fermentation from ruminants in Indonesia using ALU software at tier 1 and tier 2 levels

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ABSTRACT

The estimation of methane enteric fermentationemission from ruminants in Indonesia using the Tier 1 approach seems to overestimatefrom the actual emission value. Onthe other hand, using Tier 2 is very complicated because of very diverse circumstance of managements and environmental systems in Indonesian livestock. The purpose of this study was to compare the estimation of ruminant enteric emissions in Indonesia using the Tier 1 and Tier 2 approaches. Those estimations were calculated using the "Agriculture and Land Use-National Greenhouse Gas Inventory" (ALU) Software. The livestock (buffalo, dairy cattle, beef cattle, sheep and goats) population data were from the Indonesian Livestock and Animal Health Statistics by 2016. At Tier 1 approach, we used the default emission factors of IPCC (2006), while at Tier 2,we used emission factors for livestock subcategories. The values were obtainedfrom enhanced inventory data and other data such as age, animal productivity, diet quality and management circumstances; afterward by ALU software, the data were entered step by step to estimate methane emission from each type of livestock. The estimated enteric methane emissions using Tier 1 was1,030,851 Gg CH4yr-1, consisted of 74,532; 36,307; 752,193; 78,583; and 89,236 Gg CH4 yr-1 from buffalo, dairy cows, beef cattle, sheep and goats, respectively. Using Tier 2 approach it was845,951 consisted of 60,578;26,262; 596,931; 72,944and 89,236 Gg CH4yr-1,from buffalo, dairy cattle, beef cattle, sheep and goats, respectively. This concluded that the Tier 2 estimation of enteric methane emissions of major livestock in Indonesia was 15% lower than that of Tier 1. The Tier 2 estimation was likely to be closer with the actual condition.

Keywords: *Methane emission, livestock, Tier 1, Tier 2*

INTRODUCTION

Indonesia play an active role in global climate change. Indonesia has ratified the climate change convention through UU No. 6/1994, has also ratified the Kyoto Protocol through UU No. 17/2004, as well as the Paris Agreement in 2016 under the United Nations Framework Convention on Climate Change (UNFCCC).

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One of the substance of the Paris Agreement is the commitment of the member countries to make efforts to reduce emissions quickly through mitigation actions with increasing values every period. The mitigation process certainly requires an inventory of greenhouse gas emissions as information on the value of emissions and the foundation of the mitigation process itself.

The inventory data is reported every two years to the UNFCCC (United Nations Framework Convention on Climate Change). In the inventory and reduction program of greenhouse gas emissions, in the past, Indonesia used the default emission factor of the Intergovernmental Panel on Climate Change (IPCC 2006). Activities of the National Greenhouse Gas-Action Plan (RAN-GRK) include agriculture, forestry and peat land, energy and transportation, industry, waste management and other supporting activities.

Agriculture produces about 10%–12% of total global anthropogenic greenhouse gas emissions; methane contributes about 50% of it(Eckard et al., 2010) and 33% of methane emission is from ruminant livestock (Beauchemin, et al., 2008). Most (about 97%)of methane originated from livestock is from enteric fermentation while 3% is from manure (Broucek, 2014). Methane is a powerful greenhouse gas in terms of its radiative force, with the global warming potential (GWP) for a time horizon of 100 years of 25 (Boucher et al., 2009).

In the livestock sector, breed, type of production system, climate conditions affect the amount of emitted methane. Haryanto and Thalib (2009) stated that the kind and quality of feed are the main factors determining the amount of methane emissions. Inventory of methane emission from ruminants can be estimated using Tier 1, Tier 2 or Tier 3 approached. Tier 1 is quite simple, in principle only multiplying the populations of livestock (buffalo, dairy cows, beef cattle, sheep and goats) with the default emission factors provided in IPCC (2006). The Tier 2 approachcouldbe producing a more accurate estimate, but it requires more data that are complex. By using Tier 2 approached, we have to provide enhanced livestock characterization for each type (Dong et al., 2006). Emission factors for Tier 2 to estimate methane gas emissions from livestock had not been widely studied in Indonesia, but several data categories and sub categories of livestockhad already available. By ALU software, the existing categories and sub categories data can be processed using the Tier 2 method to estimate methane gas emissions. Some data that were not yet available would be provided by data-default from the software.

The complete and accurate enhanced livestock data for every area and condition in Indonesia is not easyto collect instantly, because Indonesia is a vast country, it hasvaried on land contours, which make variation on climates, vegetation and breed of livestock. Indonesian people also have variation on cultural backgrounds; it leads variation on farming management.

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By exist enhanced data we estimated ruminant enteric emissions in Indonesia by Tier 2 approach and compare the value with Tier 1using the "Agriculture and Land Use-National Greenhouse Gas Inventory" (ALU) Software as the calculator.

MATERIALS AND METHODS

Estimation of methane enteric emission was calculated with ALU Software (version 6.0.1) (https://www2.nrel.colostate.edu/projects/ALUsoftware/). The software was prepared by the Natural Resource Ecology Laboratory of Colorado State University, United States Environmental Protection Agency and UnitedStates Agency for International Development. ALU software is based on methodologies in the 2006 IPCC Guidelines.

In this study, we used data from five type of animal livestock (buffalo, dairy cattle, beef cattle, sheep and goat). The population data were from inventory 2016, the sex and age ratio of large ruminant (beef cattle, dairy cattle and buffalo) based on cencus 2011 and the sex and age ratio of small ruminant (sheep and goat) were from survey of livestock household 2008. The all data were taken from Livestock and Animal Health Statistics2017 in Indonesia (Director General of Livestock and Animal Health Service, 2017)

The estimation of methane enteric approached by Tier 1 used equation:

AAP = Daysalive x (NAPA/365)

AAP : anual average population
NAPA : number of animals produced annually
365 : days in a year

Tier 2 approached neededthe base population (primary data), it divided into main-categories and subcategories as Table 10.1 of IPCC (2006), guidelines (Table 1). The variable data of main category and sub category on Tier 2 approached as much as possible were fulfilled from previous supported research. When some variables are still unfulfilled, the calculation used default variable from Asia data in ALU software. The data were entered step by step on ALU software to estimate methane emission from each type of livestock.

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Table 1. Representative livestock categories

Main Categories	Subcategories
Mature Dairy Cow or Mature Dairy Buffalo	– High-producing cows that have calved at least once and are used principally for milk production – Low-producing cows that have calved at least once and are used principally for milk production
Other Mature Cattle or Mature Non-dairy Buffalo	Females: – Cows used to produce offspring for meat – Cows used for more than one production purpose: milk, meat, draft Males: – Bulls used principally for breeding purposes – Bullocks used principally for draft power
Growing Cattle or Growing Buffalo	– Calves pre-weaning – Replacement dairy heifers – Growing / fattening cattle or buffalo post-weaning – Feedlot-fed cattle on diets containing > 90 % concentrates
Mature Ewes	– Breeding ewes for production of offspring and wool production – Milking ewes where commercial milk production is the primary purpose
Other Mature Sheep (>1 year)	No further sub-categorization recommended
Growing Lambs	– Intact males – Castrates – Females

RESULT AND DISCUSSIONS

The primary data werepresented on Table 2. In Indonesia, the highest livestock population in 2016 was goat (17847197 head)and followed by beef cattle, sheep, buffalo and dairy cow. The sex ratio of large ruminants were almost the same, the average percentage of male was 28.05% and the female was 71.95%. The sex ration of small ruminants were similar also, most of them were female with the average percentage of male was 37.48% and the female was 62.43%.

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Table 2. Ruminant population in 2016 and their categories

Livestock	Population (head)	Weaning (%)		Yearling (%)		Mature (%)				Total (%)		
		Male	Female	Male	Female	Male	F (2-4 y)	F (4-6 y)	F (>6 y)	Male	Female	Total
Buffalo	1,355,124	8.31	8.01	9.71	10.97	13.23	14.12	18.48	17.18	31.25	68.76	100
Dairy Cow	533,933	9.37	12.36	8.40	15.62	3.28	25.52	21.21	4.23	21.05	78.94	100
Beef Cattle	16,004,097	9.76	9.54	12.27	13.56	9.81	18.15	18.74	8.15	31.84	68.14	100

Livestock	Population (head)	Weaning (%)			Yearling (%)			Mature (%)			Total (%)		
		Male	Female	castrate	Male	Female	castrate	Male	Female	castrate	Male	Female	castrate
Goat	17,847,197	12.06	15.04	0.02	12.01	14.38	0.07	12.99	32.93	0.05	37.06	62.80	0.14
Sheep	15,716,667	12.49	15.17	-	11.62	14.26	0.02	13.78	32.63	0.02	37.90	62.06	0.04

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The estimation of methane enteric from Ruminants in Indonesia, using ALU software atTier 1 leves wereshown in Table 3. The methane enteric emission from beef cattle was the highest (752.193 Gg $CH_4 yr^{-1}$), it was72.97% of the total methane enteric . The lowest methane emission was from dairy cows of 36.307 Gg CH_4 yr^{-1} or 3.52%. The average annual population of sheep and goat were similar with beef cattle, but the enteric methane emission were just 7.62% and 8.66% of five category. It wascaused byemission factor of sheep and goat is just about 10% than emission factor of large ruminant (Dong et al., 2006). This condition wasapparently related with their feed intake, the estimation of gross energy intake was used for deriving the final CH_4emission factor for different subcategories animals (Lokupitiya, 2016)

Table 3. Estimation of Indonesian methane enteric in 2016, approachby Tier 1

Livestock Category	Mean Annual Temperature (°C)	Average Annual Population (head)	Emission Factor (kg $CH_4 head^{-1} yr^{-1}$)	CH4 enteric (Gg $CH_4 yr^{-1}$)
Buffalo	≥ 28	1,355,124	55	74.532
Dairy Cows	24	533,933	68	36.307
Beef Cattle	≥ 28	16,004,100	47	752.193
Sheep	≥ 28	15,716,670	5	78.583
Goats	≥ 28	17,847,200	5	89.236
TOTAL				1030,851

The estimation of methane enteric from buffalo with in its subcategory was displayedon Table 4. The highest emission wasfrom mature buffalo (51.898 Gg $CH4yr^{-1}$) or about 85.67%. The high of CH4 emission factor and average annual population of mature buffalo affected thehigh value. The feeding situation, we chose 50% grazing in large areas and 50% in stall. The equation factors i.e. average live weight of animal, mature live weight, average daily weight gain, milk produced, fat content of milk, hours of work per day, percent females pregnant, percent digestibility energy of feed and fraction N retention,thevalue used default Asia Table (IPCC, 2006) while Percent female lactating used 18% and percent crude protein in diet used 9.5%, those valuesconsidered an expert judgement.

ISBN 978-602-344-251-5, 10.5281/zenodo.3345298

Table 4. Estimation of buffalo methane enteric fermentation emission in 2016, calculated by Tier 2

Livestock category	Livestock Population	Mean Annual Temperature (°C)	Average Annual Population (head)	Enteric CH4 Emission Factor: Enhanced Characterization (kg CH_4head^{-1}yr^{-1})	CH4 enteric (Gg CH4yr^{-1})
Buffalo	Mature	≥ 28	853,864	134.561	51.898
	Weaning	≥ 28	221,156	27.134	3.003
	Yearling	≥ 28	280,104	40.636	5.678
TOTAL			1,355,124		60.578

The estimation of methane enteric from dairy cowwith in its subcategory was displayed on Table 5. The highest emission wasstill from mature (21.816 Gg CH4yr^{-1}) or about 83.07%. The high of CH4 emission factor and average annual population of mature dairy cows affected this high value. The feeding situation we selected 100% in stall. Most of equation factors used expert judgement except percent digestibility energy of feed and fraction N retention the value used default from Asia Table (IPCC, 2006).

Table 5. Estimation of dairy cows methane enteric in 2016, approached by Tier 2

Livestock category	Livestock Population	Mean Annual Temperature (°C)	Average Annual Population (head)	Enteric CH4 Emission Factor: Enhanced Characterization (kg CH4^{-1}head^{-1}yr^{-1})	CH4 enteric (Gg CH^{4}yr^{-1})
Dairy Cow	Mature	24	289,605	75.329	21.816
	Weaning	24	116,024	7.520	0.872
	Yearling	24	128,304	27.855	3.574
TOTAL			533,933		26.262

The methane enteric from beef cattle and its subcategory was presentedon Table 6. The mature beef cattle methane enteric emission wasvery high (482.058 Gg CH4yr^{-1}) or about 80.76%. The highest of mature wasrelated with CH4 emission factor and average annual population of mature beef cattle. Onfeeding situation we selected50% grazing large areas and 50% in stall. Similary with the dairy cows, most of equation factors used expert judgement except percent digestibility energy of feed and fraction N retention their value used default from Asia Table (IPCC,2006).

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Table 6. Estimation of Beef cattle methane enteric in 2016, approached by Tier 2

Livestock category	Livestock Population	Mean Annual Temperature (°C)	Average Annual Population (head)	Enteric CH4 Emission Factor: Enhanced Characterization (kg CH_4head^{-1}yr^{-1})	CH4 enteric (Gg CH4yr^{-1})
Beef Cattle	Mature	≥ 28	8,778,247	120.365	482.058
	Weaning	≥ 28	3,091,991	24.770	38.308
	Yearling	≥ 28	4,133,859	37.097	76.565
TOTAL			16,004,097		596.931

The estimation of methane enteric from sheep with in its subcategory was shownon Table 7. The mature and weaning sheep hadmethane emission value almost similarThe highest methane enteric emission from sheep was the mature one (32.314 Gg CH4yr^{-1}) followed by weaning (31.075 Gg CH4yr^{-1}) and yearling (9.555 Gg CH4/yr). The feeding situation we chose 50% grazing in large areas and 50% in stall.

The birthing situation, as ALU software data needed, used category no-birth 40%, single birth 40.91%, double birth 17.09% and triple birth or more 2 %; those percentage citated from Inounu et al. (2006). The average of live body weight at birth was 2.65 kg (Somanjaya et al. 2015). The average of live body weight at weaning was 19.28 kg (Warsiti et al., 2004). The average of yearling live body weight of sheep was taken from Inounu (2011). The average of mature live body weight of sheep was 28.86 kg (Sumantri et al., 2007).

Table 7. Estimation of sheep methane enteric in 2016, approached by Tier 2

Livestock category	Livestock Population	Mean Annual Temperature (°C)	Average Annual Population (head)	Enteric CH4 Emission Factor: Enhanced Characterization (kg CH_4head^{-1}yr^{-1})	CH4 enteric (Gg CH_4yr^{-1})
Sheep	Mature	≥ 28	7,297,249	14.743	32.314
	Weaning	≥ 28	1,071,920	63.867	31.075
	Yearling	≥ 28	3,068,087	9.204	9.555
TOTAL			11,437,256		72.944
Goats		≥ 28	17,847,200	5	89.236

On Table 7 we could observe the methane enteric of goat has the same value with calculation using Tier 1 approached (Table 3), their value was 89.236 Gg CH4/yr. This condition appear since IPCC (2006)is still not categorizedgoat further. In the ALU software, goat automatically entered in basic characterization andcalculated as Tier 1, not in enhanced characterization.

ISBN 978-602-344-251-5, 10.5281/zenodo.3345298

Table 8 showed comparison of estimated methane enteric which calculated by ALU software between Tier 1 and 2approached, from Indonesian ruminant livestock. The tier 2 values was lower than Tier 1.

Table 8. Comparison methane enteric emission approached by Tier 1 and Tier 2

Livestock Category	Base Population (head)	CH4 enteric Tier 1 (Gg $CH_4 yr^{-1}$)	CH4 enteric Tier 2 (Gg $CH_4 yr^{-1}$)	Difference Tier 1 minusTier 2 (%)
Buffalo	1,355,124	74.532	60.578	18.72
Dairy Cows	533,933	36.307	26.262	27.67
Beef Cattle	16,004,097	752.193	596.931	20.64
Sheep	15,716,667	78.583	72.944	7.18
Goats	17,847,197	89.236	89.236	0.00
TOTAL/AVERAGE	51,457,018	1,030.851	845.951	14.84

The higher decrease was dairy cows 27.67% followed by beef cattle, buffalo and sheep respectively were 20.64%, 18.72% and 7.18%; overall, using Tier 2 approached the methane enteric emission in Indonesia was 14.84% decreased.by a separated research.

CONCLUSIONS

Using the Tier 1 level, the amount of livestock enteric fermentation emissionwas apparently over estimates. The estimation by Tier 2 approached was about 14.84% lower than Tier1. Collaboration between the enhanced inventory data, proper research result and a proper tool delivered amount of Tier 2 obviously was lower than Tier 1. It can be predicted when all of equation factors were acommodated and adjusted in every single condition in livestock, the methane emission will be lower and lower.

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