



## Trends and Projected Estimates of GHG Emissions from Indian Livestock in Comparisons with GHG Emissions from World and Developing Countries

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**ABSTRACT:** This study presents trends and projected estimates of methane and nitrous oxide emissions from livestock of India vis-à-vis world and developing countries over the period 1961 to 2010 estimated based on IPCC guidelines. World enteric methane emission (EME) increased by 54.3% ( $61.5$  to  $94.9 \times 10^9$  kg annually) from the year 1961 to 2010, and the highest annual growth rate (AGR) was noted for goat (2.0%), followed by buffalo (1.57%) and swine (1.53%). Global EME is projected to increase to  $120 \times 10^9$  kg by 2050. The percentage increase in EME by Indian livestock was greater than world livestock (70.6% vs 54.3%) between the years 1961 to 2010, and AGR was highest for goat (1.91%), followed by buffalo (1.55%), swine (1.28%), sheep (1.25%) and cattle (0.70%). In India, total EME was projected to grow by  $18.8 \times 10^9$  kg in 2050. Global methane emission from manure (MEM) increased from  $6.81 \times 10^9$  kg in 1961 to  $11.4 \times 10^9$  kg in 2010 (an increase of 67.6%), and is projected to grow to  $15 \times 10^9$  kg by 2050. In India, the annual MEM increased from  $0.52 \times 10^9$  kg to  $1.1 \times 10^9$  kg (with an AGR of 1.57%) in this period, which could increase to  $1.54 \times 10^9$  kg in 2050. Nitrous oxide emission from manure in India could be  $21.4 \times 10^6$  kg in 2050 from  $15.3 \times 10^6$  kg in 2010. The AGR of global GHG emissions changed a small extent (only 0.11%) from developed countries, but increased drastically (1.23%) for developing countries between the periods of 1961 to 2010. Major contributions to world GHG came from cattle (79.3%), swine (9.57%) and sheep (7.40%), and for developing countries from cattle (68.3%), buffalo (13.7%) and goat (5.4%). The increase of GHG emissions by Indian livestock was less (74% vs 82% over the period of 1961 to 2010) than the developing countries. With this trend, world GHG emissions could reach  $3,520 \times 10^9$  kg CO<sub>2</sub>-eq by 2050 due to animal population growth driven by increased demands for meat and dairy products in the world. (**Key Words:** Greenhouse Gas, Methane, Nitrous Oxide, Livestock, India, Developing Countries)

### INTRODUCTION

It is generally predicted that global warming is caused due to increases in the concentrations of greenhouse gases (GHGs) from anthropogenic activities. The major anthropogenic GHGs are carbon dioxide, methane, nitrous oxide and chlorofluorocarbons (IPCC, 2007). Agriculture sector is the second largest contributor of anthropogenic greenhouse gas (GHG) emissions after the energy sector. A life cycle assessment of GHG emissions indicated that livestock contributes about 18% to the global anthropogenic

GHG emissions accounting for 37% of anthropogenic methane and 65% of anthropogenic nitrous oxide (FAO, 2006) and dairy cattle sector 4% of total anthropogenic GHG emissions (FAO, 2010). The increases in methane and nitrous oxide concentrations in the atmosphere may largely be due to agriculture, while those of carbon dioxide are mostly due to fossil fuel use and land use change (IPCC, 2007).

Management decisions have conventionally been focused to improve efficiency, reducing costs and maximizing profit at the farm level (Zervas and Tsipalou, 2012). The use of advanced technologies in animal production has spurred impressive yields. This will continue to translate into growing productivity to fulfill the demands

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Submitted Jun. 17, 2013; Accepted Aug. 23, 2013; Revised Sept. 12, 2013

of meat, milk and eggs of increasing human population, which will also increase GHG emissions (FAO, 2006). Globally, human population of 7.2 billion in mid-2013 is expected to increase by almost one billion to 8.1 billion in 2025, and to further grow to 9.6 billion in 2050 (UN, 2013). This is also essential to consider environmental concerns, animal welfare and food safety issues in animal production systems (Zervas and Tsiplakou, 2012). Concerns over the contribution of the livestock farming to the global warming have prompted to a number of studies at improving the scientific knowledge regarding the GHG emissions by livestock at global, national local levels (Gerber et al., 2011; Ji and Park, 2012; Bellarby et al., 2013) and mitigation strategies (Patra, 2012a; Bellarby et al., 2013). It is imperative to assess the trends and projections of GHG emissions from livestock in different countries. In India, albeit various estimates of GHG emissions from Indian livestock had been reported using various approaches in different years (Singhal et al., 2005; Swamy and Bhattacharya, 2006; Chhabra et al., 2009; Patra, 2012b), a study involving trends of GHG from various livestock species over last 50 years and in comparison with World and developing countries has perhaps not assessed. Therefore, the objective of this study was to analyze current trends and projected estimates of GHG emission from livestock of India in comparison with GHG emissions from world and developing countries over the years 1961 to 2050. Due to paucity of various activity data for life cycle assessment of GHG emissions from global livestock sectors, GHG emissions from enteric fermentation and manure management have been assessed in this study.

## MATERIALS AND METHODS

### Livestock population

Livestock population data were obtained from FAO database for each year from 1961 to 2010 to estimate methane and nitrous oxide emissions from 1961 to 2010 by different species of livestock (cattle, buffaloes, sheep, goats, pigs, horse, mules, ass, duck, chicken, camel, and alpaca) of all the countries of world. Developed and developing countries list was obtained from FAOSTAT (2013). Dairy cattle population in each region of the world was estimated by dividing average milk production by cattle as provided by IPCC (2006) for each region of the world by total milk production data (FAOSTAT, 2013). Thus, the other cattle population was obtained by subtracting the dairy cattle population from total cattle population. Marketing swine population typically represents 90% of total swine population and rest for breeding swine population (IPCC, 2006), and this typical proportion was used to estimate greenhouse gas emissions by these categories of swine population.

### Enteric methane emission

Methane production from microbial fermentation of feeds in the digestive tract was estimated using the Tier 1 approach of IPCC (2006) guidelines for each species of livestock. The default IPCC (2006) for methane emission factors (i.e. annual methane emissions per animals) for enteric fermentation in each species and type of animals (Tier I method) were adopted. To estimate total enteric methane emission, the emission factors were multiplied by the associated animal population in each country (FAO, 2013), and summed all over the countries in each year.

### Methane emission from manure management

Estimates for methane emission from manure management are based on methane emitted during the storage and treatment of manure, and from manure deposited on pasture lands. Methane emission factors in manure management are required for estimation of total methane emissions by each type of animals. Because methane emissions from manure management systems are highly temperature dependent, the average annual temperature for all countries in the world, where manure is managed, were adopted from <http://www.weatherbase.com>. The IPCC (2006) default values of methane emission factors in manure management for all species of livestock in each annual average temperature of all countries were used for estimation of methane emissions from manure management from these animals. Total methane emission in manure management was estimated by multiplying the emission factors in manure management for a particular category of livestock animals by the animal population in each country, and summed all over the countries in each year.

### Nitrous oxide emission from animal waste management systems

Direct nitrous oxide emissions from manure management was estimated by multiplying the total amount of nitrogen excretion (from all livestock species/categories) in each type of manure management system by an emission factor for that type of manure management system using the Tier 1 method of IPCC (2006). Default values of N excretion per animal in each region were adopted from IPCC (1996) instead of IPCC (2006) owing to the paucity of information related to body weights of different types of animals in all countries of the world. Emissions are then summed over all manure management systems in country-wise followed by all countries. The IPCC default nitrous oxide emission factors, default nitrogen excretion data, and default values for percentages of manure management system data in each regions of the world were adopted (IPCC, 2006). Manure managed by daily spread, and pasture/range/paddock system was not included in the

estimates of nitrous oxide emission from manure by livestock as these are to be reported under direct soil emissions from animal production (IPCC, 2006). The nitrous oxide emission associated with the use of manure as fuel is also to be reported under the IPCC category Fuel Combustion (IPCC, 2006).

Methane and nitrous oxide emissions were converted to CO<sub>2</sub> equivalent (CO<sub>2</sub>-eq.) using the factors (IPCC, 2007) of 25 and 298 g/g. Trends for enteric methane, methane and nitrous oxide emissions from manure management in each year from 1961 to 2010 for each species of livestock were regressed to predict the different GHG emissions by livestock of world, India and developing countries in the year 2025 (short range projection) and 2050 (long range projection).

## RESULTS AND DISCUSSION

Enteric methane emission from livestock was the major source (Table 1) accounting 85.6% of total GHG from world livestock in year 2010. Cattle alone accounted for about three-fourth (73.7%) of the total enteric methane emission, followed by buffalo (11.3%), sheep (6.36%), goat (4.86%), camel (1.17%), swine (1.14%), horse (1.11%) and other livestock. From the year 1961 to 2010, enteric methane emission increased by 54.3% (61.5 to 94.9 ×10<sup>9</sup> kg/yr). In this period, the highest positive annual growth of enteric methane was noted for goat (2.0%), followed by buffalo (1.57%), swine (1.53%), camel (1.28%), cattle (0.87%), alpaca (0.81%) and other livestock species, while enteric methane emission from horse (-1.25%) experienced negative growth rate between these periods. Although sheep contributed third major share of the enteric methane emission, the growth rate of GHG from sheep remained generally stable over the period. Total enteric methane emission was projected to increase by 105×10<sup>9</sup> kg and

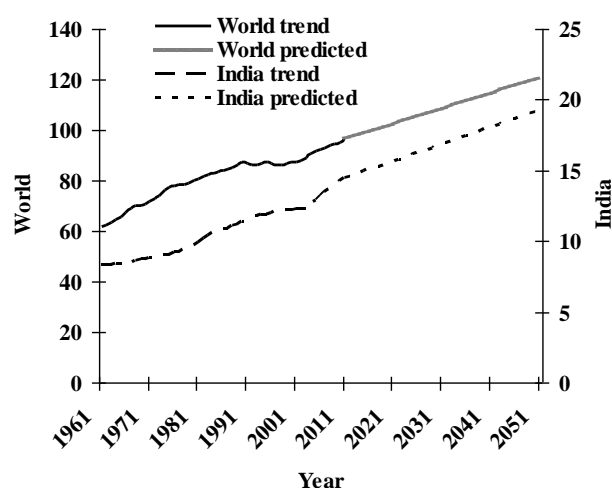
120×10<sup>9</sup> kg in 2025 and 2050, respectively.

Enteric methane emission from Indian livestock contributed 15.1% of total global enteric methane emission. In India, contribution of enteric methane was 91.8% of the total GHG emissions, followed by manure methane (7.04%) and manure nitrous oxide (1.15%) in the year 2010. In India also, cattle ranked first in emitting enteric methane contributing about half (49.1%) of total enteric methane, followed by buffalo (42.8%), goat (5.38%) and sheep (2.59%) and other (0.73%). The percentage increase in enteric methane emission by Indian livestock was greater than world livestock (70.6% vs 54.3%) between the years 1961 to 2010. Between these periods, annual positive growth rate was highest for goat (1.91%), followed by buffalo and mule (1.55% each), swine (1.28%), sheep (1.25%) and cattle (0.70%), but negative annual growth rate was observed for ass (-2.44%), horse (-1.88%) and camel (-1.43%). In India, total enteric methane emission was projected to grow by 15.8×10<sup>9</sup> kg and 18.8×10<sup>9</sup> kg in 2025 and 2050, respectively. By year 2050, enteric methane release of about 15.7% of global enteric methane would likely to be shared by Indian livestock. Current and projected trends of total enteric methane emission (kg×10<sup>9</sup>) from total livestock population in World and India in different years are presented in Figure 1, which indicated that methane emission linearly increased in world (emission = 65.4+0.6075×yr, R<sup>2</sup> = 0.94) and India (emission = 7.61+0.121×yr, R<sup>2</sup> = 0.97). Various attempts had been made to estimate the enteric methane emission from Indian livestock. On the basis of *in vitro* dry matter digestibility evaluation of feed resources and their combination used for livestock feeding in the different regions of the country and livestock populations in the year 1992, enteric methane emission from livestock was estimated to be 9.02 Tg (EPA, 1990). Singhal et al. (2005) estimated the enteric methane emission of 10.08 Tg in 1994 using Y<sub>m</sub> from published reports and

**Table 1.** Estimated and projected enteric methane emission (kg ×10<sup>9</sup>) from different species of livestock in World and India

	World					India				
	Estimated			Projected		Estimated			Projected	
	1961	2010	AGR	2025	2050	1961	2010	AGR	2025	2050
Cattle	45.7	69.9	0.87	77.3	88.0	4.97	7.02	0.70	7.57	8.53
Buffalo	4.86	10.7	1.57	12.1	14.9	2.82	6.12	1.55	6.92	8.65
Sheep	6.02	6.04	0.01	6.18	5.90	0.20	0.37	1.25	0.38	0.47
Goat	1.74	4.61	2.00	5.19	6.70	0.30	0.77	1.91	0.87	1.11
Swine	0.51	1.08	1.53	1.29	1.55	0.005	0.010	1.28	0.017	0.021
Camel	0.59	1.11	1.28	1.17	1.36	0.042	0.021	-1.43	0.018	0.006
Horse	1.12	1.05	-1.25	1.03	1.01	0.024	0.009	-1.88	0.008	0.003
Ass	0.37	0.42	0.27	0.45	0.46	0.011	0.003	-2.44	0.002	0.001
Mule	0.10	0.11	0.06	0.09	0.08	0.0005	0.001	1.55	0.002	0.003
Alpaca	0.042	0.063	0.81	0.13	0.15	0	0	0	0	0
Total	61.5	94.9	0.90	105	120	8.38	14.3	1.10	15.8	18.8

AGR = Annual growth rate (%).



**Figure 1.** Trends and projections of total enteric methane emission ( $\text{kg} \times 10^9$ ) from livestock population in World and India in different years.

DM intake approach. According to the estimate based on India's Initial National Communication to the UNFCCC and 2003 Indian Livestock populations, total enteric methane emission was 10,650 Gg (Chhabra et al., 2009). The total

enteric methane emissions using default IPCC emission factors (Tier I) were about 9.65 to 10.95% greater than the estimates using Tier II methodology of IPCC (2006).

This study indicated that global methane emission from manure management increased from 6.81 million tonnes in 1961 to 11.4 million tonnes in 2010 (Table 2). Major share was contributed from cattle, followed by swine, buffalo, sheep, poultry and goat, and other livestock species in 1960; whereas in the year 2010, poultry ranked 4th after cattle, swine and buffalo. Annual growth rate for manure methane production was highest for poultry, followed by goat, buffalo, camel, swine, cattle and other species. Negative growth rate had been recorded for horse and sheep. Methane emission from manure management increased by 67.6% from the year 1960 to 2010, and was projected to rise 15 million tonnes in 2050.

In India between the years 1960 to 2010, the annual manure methane emission increased from 0.52 million tonnes to 1.1 million tonnes with an annual growth rate of 1.57%. Highest annual growth was noted for poultry (4.28%, which was greater than world), followed by goat (1.91%), buffalo (1.60%), mule (1.55%), cattle (1.45%), swine (1.28%), sheep (1.25%) and other species. Methane

**Table 2.** Estimated and projected methane and nitrous oxide emissions ( $\text{kg} \times 10^6$ ) from manure management of different species of livestock in World and India

	World					India				
	Estimated			Projected		Estimated			Projected	
	1961	2010	AGR	2025	2050	1961	2010	AGR	2025	2050
<b>Methane</b>										
Cattle	4,127	6,516	0.94	7,002	7,955	215	434	1.45	464	571
Buffalo	355	828	1.74	933	1,172	256	557	1.60	629	789
Sheep	181	177	-0.04	183	180	6.0	11	1.25	12	14
Goat	57	157	2.11	222	367	10	26	1.91	30	38
Swine	1,844	3,127	1.08	3,700	4,305	26	48	1.28	64	100
Poultry	82	413	3.37	537	759	2.3	18	4.28	20	30
Camel	28	58	1.47	62	74	1.7	0.9	-1.43	0.9	0.5
Ass	32	38	0.37	40	43	1.0	0.3	-2.45	0.3	0.1
Mule	9.0	10	0.10	9.0	9.0	0.05	0.1	1.55	0.22	0.29
Horse	95	90	-0.11	86	84	2.2	0.9	-1.88	0.69	0.23
Total	6,810	11,414	1.06	12,849	15,046	520	1,096	1.53	1,221	1,543
<b>Nitrous oxide</b>										
Cattle	157	177	0.25	201	210	4.2	4.1	-0.06	4.1	3.9
Buffalo	18	29	1.05	33	38	2.2	4.8	1.60	5.4	6.8
Sheep	13	12	-0.19	12	11	0.6	1.2	1.25	1.3	1.5
Goat	3.7	9.6	1.98	12	16	1.0	2.4	1.91	2.7	3.4
Swine	37	95	1.94	112	138	0.29	0.54	1.28	0.94	1.2
Poultry	15	59	2.90	74	102	0.3	2.3	4.28	3.0	4.6
Camel	0.07	0.10	0.66	0.11	0.13	0.014	0.007	-1.43	0.006	0.005
Ass	0.32	0.33	0.023	0.33	0.34	0.017	0.005	-2.45	0.004	0.003
Mule	0.089	0.076	-0.32	0.074	0.069	0.001	0.002	1.55	0.002	0.002
Horse	0.63	0.53	-0.36	0.50	0.47	0.004	0.002	-1.88	0.002	0.001
Total	244	383	0.92	445	516	8.67	15.3	1.17	17.5	21.4

AGR = Annual growth rate (%).

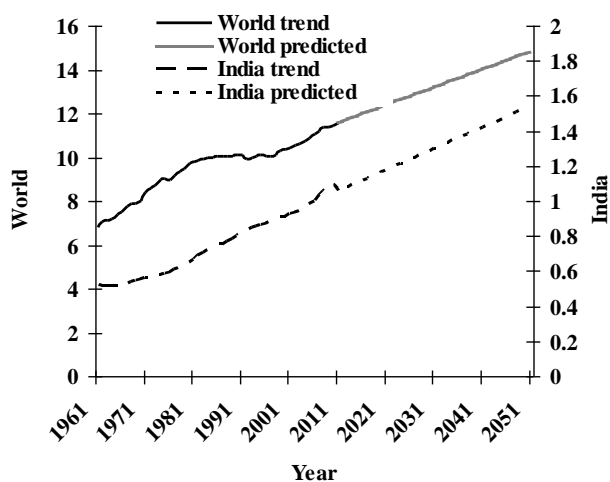
from manure showed negative growth rate for horse, camel and ass. In India, major contribution came from buffalo, followed by cattle, swine, goat, sheep and other species. Buffalo shared about half (50.8%) and cattle 39.6% of the total manure methane emission. The annual manure methane could increase to 1.54 million tonnes from present level of 1.1 million tonnes.

Nitrous oxide from manure management contributed a small amount to the total GHG emissions compared with methane emission. In World, major share came from cattle (46.2%), followed by swine (24.8%), poultry (15.4%) and buffalo (7.57%) and rest from other species of livestock. Maximum growth rate was noted for poultry, followed by goat, swine and buffalo between the years 1961 to 2010 with an average annual growth rate of 0.92%. Figure 2 suggested that methane emission ( $\text{kg} \times 10^9$ ) from manure management system of all livestock species linearly increased in world (emission =  $7.42 + 0.081 \times \text{yr}$ ,  $R^2 = 0.91$ ) and India (emission =  $0.44 + 0.0121 \times \text{yr}$ ,  $R^2 = 0.98$ ). Methane emission from manure management was 17.52 million tonnes globally (FAO, 2006), which was less in this study. FAO (2006) estimates considered methane emission from manure after application to the soil. However, IPCC (2007) methodology suggests reporting this emission under agricultural soil. In the present estimate, methane emission from manure was higher than the other studies. Annual methane emissions from manure management from Indian livestock were estimated to be 950 Gg in 2004 by FAO (2006), 1110 by ALGAS (1998) and 910 Gg in 1997 by Swamy and Bhattachary (2006). In this study, methane production from manure in India was 1,096 Gg in 2010. The estimate of manure methane by Patra (2012b), which was 1,250 Gg in 2007, was more accurate and country specific as the study estimated manure methane emission

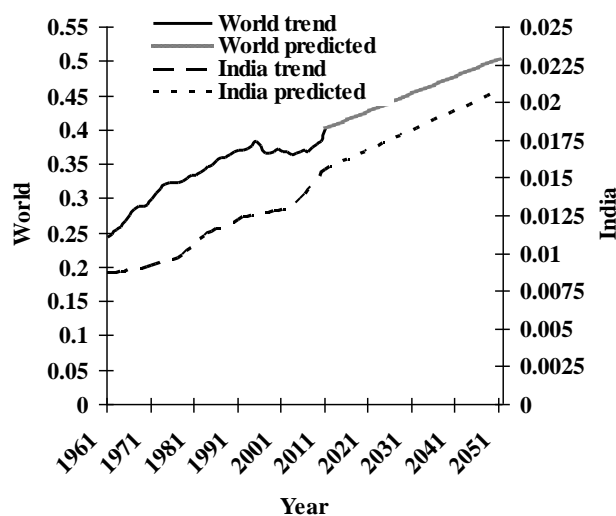
following the IPCC (2006) Tier II methodology and energy requirements of animals specific to Indian condition (thus utilized country-specific manure methane emission factors). Methane emission from manure could reach to 1,325 Gg by 2012, and 1,455 Gg by 2020 (Patra, 2012b).

In India, nitrous oxide emission from manure was only 4.0% of total nitrous oxide emission from manure in 2010. Nitrous oxide emission was mostly contributed by buffalo (31.4%) and cattle (26.8%), goat (15.8%), poultry (15.0%), sheep (7.8%) and rest by other species. It was projected that nitrous oxide emission from manure in India could be 21.4 million kg in 2050 from 15.3 million kg in 2010. Trends and projections of total nitrous oxide emission from manure management system of all livestock species in World and India in different years are shown in Figure 3, which signified that methane emission ( $\text{kg} \times 10^9$ ) from manure management linearly increased in world (emission =  $0.271 + 0.0026 \times \text{yr}$ ,  $R^2 = 0.86$ ) and India (emission =  $0.0079 + 0.00013 \times \text{yr}$ ,  $R^2 = 0.97$ ).

Total global GHG emissions (in  $\text{CO}_2$ -equivalent) in world increased from 1769 million tonnes in 1961 to 2,771 million tonnes in 2010 at the annual growth rate of 0.92%, while in India this rate was higher (1.13%) than world (Table 3). The annual growth rates of GHG emissions in World in comparison with India were 0.86% vs 0.74% for cattle, 1.57% vs 1.59% for buffalo, 0.002% vs 1.27% for sheep, 2.01% vs 1.94% for goat, 1.33% vs 3.11% for swine and 3.01% vs 4.26% for poultry. Total annual GHG emissions were forecast to be 3,073 million tonnes ( $\text{CO}_2$ -equivalent) in 2,025 and 3,528 million tonnes ( $\text{CO}_2$ -equivalent) in 2050. Thus, GHG emissions from livestock would be double in the year 2050 with comparison to the year 1961. While for India, total GHG emissions from livestock are expected to be 515 million tonnes annually in



**Figure 2.** Trends and projections of total methane emission from manure management ( $\text{kg} \times 10^9$ ) of livestock species in World and India in different years.



**Figure 3.** Trends and projections of total nitrous oxide emission from manure management ( $\text{kg} \times 10^9$ ) of livestock species in World and India in different years.

**Table 3.** Estimated and projected greenhouse gas emissions ( $\text{kg} \times 10^9$  in  $\text{CO}_2$ -equivalent) from different species of livestock in World and India

	World					India				
	Estimated			Projected		Estimated			Projected	
	1961	2010	AGR	2025	2050	1961	2010	AGR	2025	2050
Cattle	1,292	1,963	0.86	2,167	2,461	131	188	0.74	202	229
Buffalo	136	292	1.57	336	413	78	168	1.59	190	238
Sheep	159	159	0.002	163	155	5.3	9.9	1.27	10.2	12.5
Goat	46	122	2.01	139	181	8.1	20.6	1.94	23.3	29.7
Swine	70	134	1.33	158	188	0.86	3.86	3.11	2.31	3.38
Poultry	6.3	28	3.01	35	49	0.15	1.14	4.26	1.39	2.12
Camel	15.6	29	1.31	31	36	1.10	0.55	-1.40	0.47	0.16
Horse	30.5	28.7	-0.13	28	27	0.63	0.23	-2.00	0.22	0.08
Ass	9.5	11	0.26	12	13	0.28	0.08	-2.55	0.06	0.03
Mule	2.88	2.97	0.06	2.50	2.25	0.07	0.05	-0.72	0.06	0.08
Alpaca	1.06	1.57	0.81	1.93	2.65	0	0	0	0	0
Total	1,769	2,771	0.92	3,073	3,528	225	392	1.13	430	515

AGR = Annual growth rate (%).

the year 2050, which is about 2.3 times greater than the year 1961. Cattle (70.8%), buffalo (10.5%) sheep (5.74%), goat (4.40%) and swine (4.84%) contributed 96.3% of the total GHG emissions by livestock in world, while in India cattle (48.0%), buffalo (42.9%), sheep (2.53%), goat (5.26%) and swine (0.98%) contributed 99.6% of the total GHG emissions by livestock. In India, share of GHG emissions from manure management system was 8.0% of the global GHG emissions from manure management, which was less than the share of enteric methane emission. This is because of the major use of manure as fuel or application in agricultural fields in Indian cattle and buffalo production systems (Gupta et al., 2007; Patra, 2012b). The estimate of nitrous oxide by Indian livestock was much greater in this

study than the estimate by Swamy and Bhattacharya (2006); however, was closer to the value (10 Gg) reported by Garg et al. (2001). In India, nitrous oxide emission was 14.41 Gg in year 2007 using IPCC (2006) tier II methodology (Patra, 2012b); whereas this emission was 15.3 in 2010 using IPCC (2006) tier I methodology in this study. The share of GHG emissions by Indian livestock of the global GHG emissions by livestock was 14.1% in this study. It should be noted that Indian livestock produced 0.32 tonnes per million human population, which was considerably lower than world average (i.e. 0.40 tonnes per million human population).

Total global GHG emissions by livestock from developed countries increased to a small extent (only 0.11%) between the periods of 1961 to 2010 (Table 4). But

**Table 4.** Estimated and projected greenhouse gas emissions ( $\text{kg} \times 10^9$  in  $\text{CO}_2$ -equivalent) from different species of livestock in developed and developing countries

	Developed					Developing				
	Estimated			Projected		Estimated			Projected	
	1961	2010	AGR	2025	2050	1961	2010	AGR	2025	2050
Cattle	450	482	0.14	496	492	841	1,481	1.16	1,672	1,969
Buffalo	0.30	0.65	1.55	0.70	0.96	135	296	1.61	335	413
Sheep	73	45	-0.98	43	40	86	114	0.60	119	127
Goat	3.14	5.75	1.24	7.86	10.5	43.0	116	2.05	141	189
Swine	39.9	58.2	0.77	67.6	76.7	29.4	75.4	1.94	91.0	111
Poultry	3.25	7.84	1.81	9.36	11.8	3.09	20.0	3.88	30.0	51.5
Camel	0.33	1.13	2.57	1.43	1.90	15.3	28.0	1.25	29.3	34.0
Ass	0.70	0.21	-2.43	0.15	0.10	9.43	11.4	0.38	12.0	12.7
Mule	0.65	0.20	-2.31	0.16	0.12	2.23	2.76	0.43	1.96	0.59
Horse	6.08	6.52	0.14	6.72	6.96	24.4	22.2	-0.19	21.4	19.4
Alpaca	0	0	0	0	0	1.06	1.57	0.81	1.93	2.65
Total	577	608	0.11	633	641	1,190	2,168	1.23	2,455	2,930

AGR = Annual growth rate (%).

in developing countries, GHG emissions rate increased significantly (1.23%). In developing countries, annual GHG emissions growth rates were positive for all livestock except for horse, while in developed countries, GHG emissions from sheep, ass and mule showed negative growth rates. Major contributions of GHG in world came from cattle (79.3%), swine (9.57%) and sheep (7.40%), and rest 3.8% came from other livestock species in 2010. For developing countries, major shares were contributed by cattle (68.3%), buffalo (13.7%), sheep (5.3%), goat (5.4%) and swine (3.48%). With comparison to the developing countries, overall annual growth rate of GHG emissions by Indian livestock was less. Over the period 1961 and 2010, GHG emissions increased by 82% in developing countries and by 74% in India. However, growth rates of GHG emissions from sheep, swine and poultry were greater in India than world. With this trend, GHG emission could reach 2,930 million tonnes CO<sub>2</sub>-eq in 2050 due to animal population growth driven by increased demands of meat and dairy products in the developing countries. As per estimates of FAO (2006), global GHG emissions in CO<sub>2</sub> eq. from enteric fermentation and manure management was  $2.32 \times 10^9$  tonnes in the year 2004; whereas this figure was  $2.77 \times 10^9$  tonnes in 2010 in the this study. This increase in global GHG emissions from these sources had resulted from increased global livestock population. In India, total GHG emissions (CO<sub>2</sub> eq.) from enteric fermentation and manure was  $0.333 \times 10^9$  tonnes in 2007 estimated using IPCC (2006) tier II methodology (Patra, 2012b), and this estimate in 2010 was  $0.392 \times 10^9$  tonnes as noted in this study. This change in GHG emissions is due to increased livestock population and use of different methodology (i.e. IPCC (2006) tier I approach).

### CONCLUSIONS

Total methane emissions from enteric fermentation and manure management, and nitrous oxide emission from manure management had steadily increased by livestock of India, world and developing countries over the period 1961 to 2010. The percentage increase in enteric methane emission by Indian livestock was greater than world livestock (70.6% vs 54.3%) over the years 1961 to 2010. Total increase of GHG emissions by Indian livestock is less (82% vs 74% over the period of 1961 to 2010) than the developing countries. With this trend, GHG emission could reach 3,528 million tonnes CO<sub>2</sub>-eq in 2050 (an increase of 27.2% with respect to 2010 year), which is expected due to animal population growth driven by increased demands of meat and dairy products, especially, in the developing countries, unless proper GHG mitigation measures are not adopted in these countries.

### ACKNOWLEDGEMENT

The research grant provided by Indian Council of Agricultural Research, New Delhi is gratefully acknowledged.

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