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Greenhouse gases emission from livestock production system of India: An actual consumption approach

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ABSTRACT

The present study was undertaken to quantify methane emission from livestock production system in India. The computational results showed that the total methane emission from the livestock production system at 2012 population base was 12.28 million tonne. In the total methane emission from enteric fermentation, share of cattle is marginally lower (60%) than its share in the bovine population (64%) while the share of buffalo (40%) is marginally higher than its share in the population (36%). Cattle adult male account for more than 35% of the emission while buffalo in-milk accounts for little more than 46.7% of the emission. Methane emission from manure management for 2012 livestock population was estimated to be 0.20 million tonne. Other livestock like goat, sheep, camel and horses emit around 7.5% of total methane emission from both the sources. The estimates of methane emission from Indian livestock will help the policy makers and environmentalist of the country in designing mitigation strategies.

Key words: Enteric fermentation, Manure management, Methane emission, Mitigation

Livestock, the largest source of methane emission in India, contribute approximately 63.5% to the total greenhouse gases emission from agriculture sector (INCCA 2010). In the process of conversion of feed into nutrients, a part of feed energy is used up in methane formation, which the animals release in the atmosphere largely through eructation. This is termed as emission from ‘enteric fermentation’. Methane, formed during the process of feed fermentation, is a wasted energy which reduces animal production efficiency. The other source of methane emission from livestock production system is through ‘manure management’. The Intergovernmental Panel on Climate Change (IPCC) terminology includes all systems of disposal of animal excreta such as disposal in lagoons and landfills, disposed as dropping by animals in pastures, disposal by burning as dung cake. Methane is naturally present in the atmosphere, second only to carbon dioxide in terms of anthropogenic contributor to climate change and has 21 times higher global warming potential than carbon dioxide.

Various attempts were made to quantify methane emission due to enteric fermentation from livestock production system at different livestock population base (Crutzen *et al.* 1986, Lerner *et al.* 1988, Krishna *et al.* 1978, Singh 1997, Bhattacharya and Mitra 1998, Mishra and Dikshit 2004, Swamy and Bhattacharya 2006). Attempts were made to estimate methane emission from manure mangement at the national level (ALGAS 1998, Scheehle 2002, Mishra and Dikshit 2004, Swamy and Bhattacharya 2006). However, most of these estimates of emission from enteric fermentation are either based on lab or organised dairy farms experiments instead of actual field conditions. Emission factors derived using gross energy intake (GEI) approach largely based on dry matter intake on assumed body weight taken from Indian feed standards instead of actual consumption. Indian feed standards provide information on gross energy requirement for maintenance and production. However, in field conditions, actual consumption is much lower than that of requirement. The availability of feed assumed equal to their production; and production was assumed equal to consumption. These assumptions are unrealistic. Availability is also affected by its non-feed uses. Further, there is huge variability in agro-climatic conditions across regions of India, the animal and feed characteristic also varies. Hence, this would mean varying emission rates depending on the region as well. The prerequisite condition for precise estimates of methane emission is an availability of feed fodder consumption rate at country level by type of livestock. In the present study, an effort was made to estimate greenhouse gases emission from livestock production system in India based on actual consumption (gross energy intake) rather than requirements. The present study will be useful to research in environment, concerned scientists, policy makers and in international negotiation on greenhouse gases emission reduction.

The paper deals with approach of the research, including formation of livestock regions, sampling design, estimation

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of per animal/day feed consumption and dung production, methane conversion rate; analytical approach to estimate methane emission from enteric fermentation and manure management; outcomes of this study; and possible mitigation strategies.

MATERIALS AND METHODS

Information on feed consumption level by different categories of bovines at country level is the precondition to estimate greenhouse gases emission from livestock production system. IPCC guidelines gave 2 methods to estimate emission factors. In Tier 1 method, default emission factors are used and data on number of animals for different livestock groups are needed. Tier 2 method requires country specific data on: animal population, average daily feed intake and methane conversion rate (% of feed energy converted to methane). This requires high level efforts. Alternatively, data collected from interviews are generally less reliable (Gibbs *et al.* 2002). The Tier 2 was considered more accurate than the Tier 1 method because it incorporates country specific information.

To our knowledge so far national level consumption level by types of feed and fodder have not been estimated accept a few surveys by the IASRI during 1960s to early 1980s (Amble 1965, Jain and Singh 1990). These intake levels are not only old but there are problems to pooling of the data from surveys spread over such long period.

The paper makes use of data from a feed consumption survey undertaken as part of a larger project 'India's livestock feed balance and its environmental implications' funded by the ICAR under NATP, and carried out jointly by NCAP and SESR, Delhi.

Sample survey: The sampling in the survey was conducted by stratified multistage random sampling. Of 11 livestock regions, survey was conducted in 10 regions, viz. western Himalaya, north-west plain, eastern plain, central highlands, eastern plateau and highlands, Deccan plateau and hills, Rajasthan-Gujarat plains, eastern ghats, western ghats, Asom-Bengal plain, and north-eastern highlands. Two districts were selected at random from each region for implementation of the survey. From each selected district, 2 villages were selected at random. From each selected village level, 24 households were selected at random with the provision that the selected households must have one or another species of livestock. To capture seasonal variations, each sample household was revisited at an interval of 15 days, particularly for repeated measurement of feed fed to animals. To collect information on several other characteristics like body weight, dung production and its utilization, etc. the investigator visited sample households once in each season. All animals, irrespective of species, belonging to the sample household were covered in the survey.

Estimation procedure

Feed consumption and methane conversion rate: Per day mean consumption (Table 1) of green fodder was 5.96 kg for a buffalo in-milk, 5.44 kg for a dry buffalo, 4.06 kg for an adult male buffalo and 2.29 kg for a young one, average for heifers and calves. Corresponding consumption rate of dry fodder was 6.34 kg for a buffalo in-milk, 4.95 kg for a dry buffalo, 7.47 kg for an adult male buffalo and 2.22 kg for young stock. Consumption rate of concentrate feed, which is essential for animal's growth and production, was estimated to be 1.05 kg for a buffalo in-milk, 0.52 kg for a dry buffalo, 0.36 kg for an adult male buffalo and 0.19 kg for a young one. These consumption rates, for any kind of feed, are lower for their counterpart categories of cattle,

Table 1. Feed consumption rates and dung production, 2001–02

Animal categories	Feed fed (raw material basis) kg/day			Per animal per day dry matter (DM) intake** (kg)	Gross energy intake (million joules)	Per animal per day wet dung production (kg)
	Green fodder*	Dry fodder	Concentrates			
Cattle						
In-milk	4.75	5.50	0.64	7.01	113.85	6.63
Dry	3.40	4.02	0.40	5.15	83.61	6.58
Adult male	4.06	6.03	0.33	7.51	121.55	4.46
Young stock	2.18	2.13	0.18	3.07	50.50	4.43
Buffalo						
In-milk	5.96	6.34	1.05	8.88	145.82	8.35
Dry	5.44	4.95	0.52	7.35	121.48	8.49
Adult male	4.04	7.47	0.36	8.83	142.01	6.65
Young stock	2.29	2.22	0.19	3.69	61.67	4.43
Goat	1.50	0.20	0.06	0.61	10.58	0.30
Sheep	1.66	0.20	0.04	0.63	10.93	0.80
Others***	15.62	6.72	0.49	10.39	172.50	6.10
Energy value (M cal/kg)	4.34	3.69	4.38			
Dry matter fraction	0.25	0.90	0.90			

Source: Dikshit and Birthal (2010).* includes cultivated fodder and the fodder gleaned and gathered from cultivated and uncultivated lands.** includes dry matter intake through grazing. *** includes horses and camels.

and the difference was larger in case of in-milk and dry animals, especially for concentrate feed. There was hardly any difference in the feeding rates of young stock of buffalo and cattle. However, per animal/day dry matter intake in kg was 0.61, 0.63 and 10.39 for goat, sheep and other includes horses and camels respectively. More and less similar trends were observed in intake of feed and fodder in terms of energy value i.e. gross energy intake (GEI). Per animal/day wet dung production more and less also seems associated with dry matter intake.

IPCC provides methane emission rates in kg/animal/year in different regions of the world according to age group and functional categories like dairy-cows and non-dairy cows. IPCC calls these rates as '*default rates*'. The major untenable assumption behind it that gross energy requirement of the animal is equal to its gross energy intake. However, most studies to date in India have claimed that there is a gap between availability and requirement (GoI 1976; Singh and Mujumdar 1991; Ramachandra *et al.* 2007). Experimental research, however, showed that range of variance of methane emission ranges increases with the increase in digestibility. The range of methane emission varies from about 5.5 to 8% of GEI in the digestibility range of 50 to 60% (Johnson and Johnson 1995). Swami and Ramasami (1997) also used methane conversion factor for a different category of bovine varies from 5.50 to 6.00% of GEI. In the present study, methane loss in enteric fermentation of feed was 6% of the gross energy intake.

Several estimates of methane emission from India's ruminants reported earlier (Singh 1997; Bhattacharya and Mitra 1998; USEPA 1990; Swamy and Bhattacharya 2006; Singhal *et al.* 2005) assumed/consulted/adopted the average body weights of Indian bovines (cattle and buffaloes) those belongs to different sex, age and functional categories or physiological stages. Using those body weights they have worked out the gross energy requirement based on nutritional requirements for maintenance, growth and production. It is worthwhile to mention here that it is gross energy intake rather than requirement that is relevant for estimating methane emission.

Methane emission from enteric fermentation

Per animal per day feed fed to the animals are adopted from Dikshit and Birthal (2010) and which also estimated dry matter intake through grazing. An Environmental Model of Livestock Production System (Mishra and Dikshit 2004) was used to estimate emission from enteric fermentation which is largely based on IPCC Tier 2 methodology. To derive the energy content of feeds, green fodder, dry fodder and concentrates have to be reduced to their respective dry matter equivalents. The dry matter fractions for green, dry and concentrates were 0.25, 0.90 and 0.90, respectively. The dry matter fractions were adopted from Mishra and Dikshit (2004). It is said that energy value of all types of feed on dry matter basis, irrespective of their quality, is the same (4.4 M cal/kg). Yet differences were reported in the calorific values of concentrates, dry and green fodder (Krishna *et al.* 1978). Study uses energy value of feed 4.38, 3.69 and 4.34 M cal/kg of concentrate, dry fodder and green fodder respectively as per Krishna *et al* .(1978). Given the quantities of different types of feed consumed per animal/day, their respective dry matter equivalents and energy values per unit, provided the gross energy intake per animal/day. Methane loss in enteric fermentation of feed was on an average of 6% of the gross energy intake in most cattle feeding situations (IPCC 1995). Gross energy intake per animal/day in million joules and 55.65 is conversion rate to convert million joules of methane to kg. Multiplying the total population of the animal with emission per animal per year gives us the total methane emission from the stock.

Emission from 'manure management'

According to IPCC (1995) aerobic 'manure management systems' like dung droppings in pastures, spreading dung on field or storing it in solid form on the open ground or in shallow pits produces 'little or no methane'. In the anaerobic management systems, prevalent in the developed countries, such as storage in lagoons or underground liquid slurry tanks, methane emission is incomparably higher. In the former case methane emission ranged from 1 to 2% of volatile solids in dung, its range is 65 to 90% in the latter case (IPCC 1995). Out of total dung produced in the country, about 60% is utilized as manure (NATP project database 2001–02). This quantity of dung is wholly managed in aerobic conditions. The dung stored as solid in the open by the farmer for subsequent use as organic fertilizer, or dung converted into dung-cake for later use as fuel, or dung dropped by animals during grazing on pastures, wastelands and in the forests. For this reason methane emission from manure management in India should be expected to be small. Nonetheless, it is additive to total emission from livestock sources. Accordingly, we provide here the formal framework for its determination.

Dung evacuation rate and production of wet dung by different categories of bovine was also taken from NATP Project database 2001–02. It was recorded fortnightly. Per day dung output will depend upon the quantity of feed intake and digestibility. The lower the digestibility of the feed intake the larger the undigested part. Methenogenic bacteria operate on the volatile solids in the dung output for producing methane. The volatile solids are the animal's dung output on dry matter basis net of its ash content. Ash contents of various types of Indian feeds are available from their chemical analysis (Krishna *et al.* 1978; Sen *et al.* 1978; Ranjhan 1998). An Environmental Model of Livestock Production System (Mishra and Dikshit 2004) was adopted to estimate volatile solids in dung. The multiplier 0.67 was used as the conversion factor from volume to weight (0.67 kg = 1.0 cubic meter of CH_4), maximum methane producing potential adopted from IPCC guidelines 1995. Total methane emission in terms of weight, both from enteric fermentation and manure management, for bovines, goats, sheep and others were worked out using the said model.

RESULTS AND DISCUSSION

Emission from enteric fermentation and manure management

The estimates of methane emission from enteric fermentation for different categories of bovines are based on feed consumption rates (Table 2). Out of total methane emission of 12.28 million tonne; 12.08 million tonne come from enteric fermentation from the bovine stock.

In the year 2012, the share of cattle and buffalo was more and less close to their share in the total population of bovines. The share of buffalo in emission was slightly higher (40%) than its share in the population (36%). This may possibly be due to higher gross energy intake by the buffalo in-milk (145.82 MJ). Among the buffalo category, buffalo in-milk accounts more than 46% emission from enteric fermentation, although having 34% share in total buffalo population. Within cattle, adult males, most of them are probably used for work emit 35% of methane to total emission from cattle. The population share of adult male cattle (26%) was lower than the young stock cattle (34%). However, per day gross energy intake of adult males was marginally higher than that of cow in-milk (121.55 MJ). The pattern of methane emission from enteric fermentation follows the relative importance of functional groups of bovines. Population share of goat, sheep and others to total livestock was 40%. However, this group emits 7.6% of total methane emission from both the sources. Having a lion share (67%) in terms of number in this group, goat emit about 0.5 million tonne of methane through enteric fermentation followed by sheep (0.28 million tonne) and others (0.07 million tonne).

Table 2. Methane emission from enteric fermentation and manure management 2012

(million tonne)

Animal categories	Population* (million)	CH_4 emission from enteric fermentation	CH_4 emission from manure management	Total CH_4 emission	CO_2 equivalent
Cattle					
In- milk	44.0	1.97	0.032	2.00	42.02
Dry	32.7	1.08	0.023	1.10	23.11
Adult male	48.9	2.34	0.024	2.36	49.60
Young stock	65.3	1.30	0.032	1.33	27.93
Total cattle	190.9	6.68	0.110	6.79	142.66
Buffaloes					
In- milk	36.6	2.10	0.033	2.13	44.77
Dry	20.0	0.96	0.018	0.98	20.48
Adult male	5.3	0.30	0.004	0.30	6.30
Young stock	46.8	1.14	0.023	1.16	24.34
Total buffaloes	108.7	4.49	0.078	4.57	95.88
Goat	135.2	0.56	0.004	0.57	11.91
Sheep	65.1	0.28	0.006	0.29	6.00
Others**	1.0	0.07	0.001	0.07	1.48
Total	500.9	12.08	0.199	12.28	267.75

*19th Indian livestock census, 2012; ** includes horses and camels.

Our estimates of methane emission from enteric fermentation 11.17 million tonne from bovine stock (cattle and buffaloes) seems to be on lower side than other contemporary studies. FAO statistics division estimated 13.44 million tonne for 2012 bovine population, other livestock (goat, sheep, camel, horses, mules and asses) emit 1.21 million tonne. Swamy and Bhattacharya (2006) worked out 8.12 million tonne of methane from bovine stock based on 1997 livestock population. However, Singhal *et al.* (2005) estimated 9.28 million tonne of methane from bovine based on 1994 livestock population. The other estimates given by CLRI, IPCC default rates, IPCC II energy equation and ALGAS based on 1997 population varied from 5.82 to 11.14 million tonne. Singhal *et al.* (2005) estimated 0.47 million tonne methane from goats, 0.18 million tonne from sheep and 0.14 million tonne from others for the 1994 livestock population.

The second source of methane emission from the ruminant livestock is their dung output. Manure is principally comprised organic substance. When this organic substances decompose in anaerobic conditions methanongenic bacteria produce methane. In India, dung is almost managed in aerobic conditions for subsequent use as organic fertilizer or dung cake used as fuel. According to IPCC (1995), dung droppings in pastures, spreading dung on field, and storing in solid form on the open ground or in shallow pits produces ‘little or no methane’.

The precondition to estimate methane emission from manure management is production of dung and its utilization pattern as manure, fuel and others. This study uses National Agriculture Technology Project (NATP) project database for species-wise wet dung production in the country (Table 1). The total wet dung production for the year 2012 was estimated to be about 668 million tonne. Species-wise share in total dung production shows a contribution of 55% by the cattle, and obviously, cattle have a larger share in total bovine population. Share of buffaloes in total dung production is 39%. But, on individual basis, evacuation rate per day was higher for buffaloes than for cattle. However, goat, sheep and others together produced 5% of total dung production.

The methane emission from manure management is comparatively very small than the emission from enteric fermentation. The total emission from this source is worked out to be 0.20 million tonne from the management of dung output of the total stock in 2012.The shares of cattle and buffalo in the total methane emission were 55 and 30% respectively. The emission from enteric fermentation, the share of adult male accounted for the largest share of the total, but emission from manure management, in-milk, young stock and adult male constitutes equal share (29%) each to total emission from the cattle stock. In contrast, buffalo in-milk alone constitute about 42% share to total emission from buffalo through this source. This may be due to high feed intake of buffaloes in-milk which is reflected in their per day dung evacuation rate. Furthermore, goat, sheep and other animals (camel and horse) together contribute about 0.01 million tonne to methane emission from manure management.

Our estimate of 0.20 million tonne of methane emission from manure management is much lower than the estimates available from previous studies. Swamy and Bhattacharya (2006) estimated about 1 million tonne of methane from bovine stock for the 1997 population. This may be because the authors adopted higher methane emission factor for dairy, non-dairy and buffalo as suggested in Tier 2 approach of IPCC. FAO statistics division estimated 1.17 million tonne based on 2012 livestock population. Our estimates are based on dung evacuation rates collected from field survey. It is worthwhile to account feed consumption for dung evacuation rather then the feed requirement for emission estimation. The total methane emission from the production system from both the sources i.e. from enteric fermentation (12.08 million tonne) and manure management (0.20 million tonne) was estimated to be 12.28 million tonne for 2012 livestock population.

Mitigation strategies

Available literature suggested several mitigation strategies for reduction of methane emission from enteric fermentation. Strategies focused on feeding and breeding programmes. Germplasm improvement through crossbreeding programme will increase the yield of the animals and reduce methane per unit of output. Animal factor is being considered an important and powerful tool in adopting mitigation strategies. Each animal heard/flock have some efficient animals i.e. animals having high production potential at a comparability low feed intake with better metabolic efficiency. This is considered a higher efficiency of animal for unit feed intake and product output. A wide variation among animals exists for methane emission at similar feed intake and production level. Therefore, breeding programme may consider methane emission and productivity level to select efficient animals for improvement of productivity with lower level of methane emission. Removing the low producer animals from the herd/flock and retaining the efficient ones will reduce methane emission per unit of output.

Several feeding strategies involving improved feeding practices through increased concentrate level, use of plant bioactive compounds (tannins, sporium, essential oils etc.), supplementation of fat and oils, and feed additives such as probiotics, antibiotics and certain chemical have proven methane emission reduction potential. However, their extended period uses have animal and human health concerns, moreover adaptability of these additives and regeneration of methanogenic activity has another major concern.

Considering the all suggested strategies to reduce methane, all suited the animals, which remained under confinement or under intensive production system. The major animal production system around the world especially in Afro-Asian countries is under extensive system and grazing based. Therefore, animal factor and improved pasture quality are the 2 major strategies that could be employed as enteric methane reduction.

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