INVENTORY ESTIMATES OF METHANE EMISSIONS FROM INDIAN LIVESTOCK

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Livestock are an integral part of agriculture in India and are likely to be the instrument of the economic growth and development of the country. As per livestock census in 1992 India possess 204 million cattle and 84 million buffaloes besides large number of other livestock, which are essentially integrated with agriculture system and socio economic system in the country and playing an instrument in providing the employment and nutritional security in spite of large gaps between the demand and supply of feed resources (NCA, 1976; Jain et al., 1996). In spite of poor productivity and deficient feed resources, livestock contribution in national economy can only be visualized by the fact that India is currently the top milk producer in the world.

Livestock, particularly the ruminants, is one of the important sources of methane emission on a global scale. Fermentation of carbohydrates in anaerobic environment results in the production of hydrogen. Methanogenic bacteria utilize this excess hydrogen to reduce carbon dioxide into methane. The symbiosis between bacteria (that ferment carbohydrates) and the methanogens (such as methanobrevibacter ruminantium and methanomicrobium mobile), results in the increased digestion and microbial production. In general, in ruminants 8 – 12 per cent of dietary energy is lost in the form of methane (Blaxter, 1967). Methane production in ruminants depends upon quality, quantity of feed, type of animal and digestibility of pasture and feeds. Ruminants are capable of subsisting on relatively low quality forages and crop residues. Low intake clubbed with low digestibility of these feed resources contributes substantially to limit their productivity with emission of sizable quantity of methane.

Various attempts have been made to estimate the methane emission from Indian livestock as a result of enteric fermentation and the value ranged from 7.257 (Garg and Shukla, 2002) to 10.4 Tg/year (EPA, 1994) without conducting the actual experiments on animals and considering the amount and quality of available feed resources. Singh (1998) reported a 9.023 Tg methane emission from Indian livestock on the basis of livestock population in the year of 1992 and the in vitro evaluation of feed resources in the different regions of the country. In the present study attempt has been made to estimate the total methane emission from different categories of animals fed on different types of feeds under different agro-climatic conditions on the basis of actual measurement of methane emission/kg feed intake (Table 1). Attempts were also made to reduce the uncertainties and increase the quality assurance by conducting the actual methane emission in crossbred cows fed on typical Indian diet to further validate the methane emission from Indian livestock

Materials and Methods

Livestock population in each Indian state, as per the census conducted in 1992 (Anon., 1999) was taken. This population was extrapolated for the year 1994 as per the growth rate of each sub-category of animals, published by Government of India on the basis of livestock population recorded during 1987 to 1992. The data of livestock census, conducted in 1997 has not been published so far.

Body weight and feed intake varies between male and female, age, breed, availability of feeds and feeding practices in different states. Dairy animals are generally fed at higher plane of nutrition than non-dairy animals. Only seventy per cent of the total population of young animals of cattle and buffaloes (in the age group of 0-1 yr) was considered for methane emission, as methane is not produced in young calves (0 - 3 months) due to the non-functioning of rumen. Kids and lambs (0-2 months old) were also taken as non- methane producing animals. However, total population of other categories of livestock was taken for methane estimation.

Categorization of livestock and their bodyweight:

The livestock were classified in different categories depending upon their age and type of productivity as follows:

Crossbred Male	**B. Wt**	**Crossbred female**	**B. Wt.**
Calves < 1 year age (70%)	70-88.5	Calves < 1 year age (70%)	75-88
Calves 1-3 years age	154-195	Calves < 1-3 years age	165-194
Breeding bulls	280-354	Milking cows	300-352
Working bulls	280-354	Dry cows	300-352
Breeding + working bulls	280-544	Heifers	165-194
Others	266-336	Others	200-330
Indigenous Cattle Male		**Indigenous Cattle Female**	
Calves <1 year age (70%)	65-80	Calves <1 year age (70%)	65-75
Calves 1-3 years age	136-157	Calves < 1-3 years age	136-157
Breeding bulls	260-320	Milking cows	200-333
Working bulls	260-320	Dry cows	200-363
Breeding + working bulls	260-320	Heifers	200-250
Others	247-285	Others	200-330
Buffaloes Male		**Buffaloes female**	
Calves < 1 year age (70%)	70-80	Calves < 1 year age (70%)	80-100
Calves 1-3 years age	160-200	Calves < 1-3 years age	176-220
Breeding bulls	475-550	Milking buffaloes	400-516
Working bulls	475-550	Dry buffaloes	400-516
Breeding + working bulls	475-550	Heifers	276-320
Others	450-500	Others	275-416
Goats Male		**Goats Female**	
< 1 year age ((70%)	8.8-21.7	< 1 year age (70%)	8.8-21.7
1-2 years age	12-27	1-2 year age	12-25.6
Sheep Male		**Sheep Female**	
< 1 year age ((70%)	14-22	< 1 year age (70%)	14-22
1-2 years age	30-40	1-2 year age	25-30
Camel	300		
Pigs	70		
Horses & Ponies			
MALE			
<3 years	200		
>3 years	300		
Donkey	150		
Mithun	400		
Yak	230-300		
Mule	150		

Nivsarkar et al. (2000) has provided the information about body weight of male and female animals of Indian breed of cattle and buffaloes. But majority of Indian cattle population (80%) is non-descript due to the reckless breeding system. Due to the nonavailability of data on body weight of non-descript breeds, experts from various regions were consulted to get the information.

The reports on the body weight of Indian breeds of goats (Acharya 1992) and sheep (Arora 1992), formed the basis for the assumption of their body weight in different Indian states. Goats and sheep are maintained on grazing/browsing and consumption of DM in these animals is about 3 per cent of the body weight. These body weights provided the base for the estimation of DM intake. The body weight of other animals e.g. camel, mithun, yak, donkey etc. were taken from literature to estimate the DMI in respective animals.

The data on feed (DM) intake/day of various classes of the animals were collected from the published reports. Here emphasis was given on the availability of feed rather than the requirement of the animals as methane is produced from the feed consumed during the course of its digestion. Information about the DM intake/100 kg b. wt. In various categories of animals is presented in Table 2. Care was taken that total feed consumed by the animals should match with availability of feed in each state.

Methane emission factor

Methane emission factor as methane emission/kg DM intake in actual feeding experiments conducted in Indian laboratories have been summaries in (Table 1).

The estimates given by various workers possibly have not considered the variation in the type and size (Body weight) of animals, quantity of feed availability and the type of feeds being used in various regions. So these estimates are open to question. Therefore these factors were take in to consideration in present study. The average value of the methane emission factor (g methane/kg DM intake) for a particular category of animal was utilized for the calculation of total methane emission from that particular category of livestock. The methane emission factors for pigs, horses, donkey and other animals were taken from Mc Allister et al. (1996). Experiments were conducted to confirm the emission factor taken for methane estimation from key source (Cattle and Buffalo).

Experiment 1: Methane emission from crossbred dairy cattle fed different levels of green fodder in the ration

To estimate the methane emission from lactating cows, six crossbred cattle of mid lactation period, yielding 3-6 kg milk per day was divided in two groups based on the milk yield. All the animals were fed according to their nutrient requirement (NRC, 1990). Group I was fed concentrate mixture (groundnut cake – 40, maize – 35, wheat bran- 27, mineral mixture– 2 and common salt – 1 part) and green fodder available at farm. Forage requirement in-group II was fulfilled by green fodder and dry fodder (wheat straw) in 50:50 ratio. After preliminary feeding of 21 days, 7 days digestibility trial was conducted to estimate digestibility of nutrients by keeping the account of feed offered, residue left and dung voided out per day. Actual amount of nutrients taken by each animal was calculated.

During trial period, sample of gases expired through mouth and nose was collected daily in canisters for estimation of methane production by sulfur hexafluoride (SF_6) tracer technique (Johnson *et al.,* 1994) using the standard of methane gas provided by National Physical Laboratory to decrease the uncertainty in estimation.

Results and Discussion

The total methane emission from Indian livestock has been estimated 10.07 Tg for the year 1994 after consuming 601.95 million tonnes of DM (Table 3). Contribution of crossbred cattle, indigenous cattle, buffaloes, goats and sheep in methane emission through enteric fermentation was 4.63, 48.49, 38.96, 4.71 and 1.79 percent, respectively. The other livestock (mules, yak, camel, donkey, pigs, mithun, horses and ponies) produced only 1.42 per cent of total methane emission. Cattle, buffaloes, goats and sheep consumed about 97 per cent of total feeds. It is very close to the value reported by Ranjhan (1997) and Jain et al. (1996). In the present estimate, the other livestock were also considered, hence the value is higher than that reported by Jain et al. (1996) and lower than that reported by Ranjhan (1997).

The total methane emission from male crossbred cattle was 0.127 Tg and the sub-categories of these animals i.e. 4-12 months, 1-3 years, breeding, working, breeding + working and others emitted 7.03, 15.21, 3.52, 63.85, 8.38 and 1.99 percent of total methane. These sub-categories of indigenous male cattle emitted 2.20, 8.78, 11.59, 67.44, 9.29 and 0.70 per cent of 2.652 Tg methane emitted by indigenous cattle. The corresponding values for the same categories of buffalo male were 3.63, 9.33, 4.97, 60.98, 19.29 and 1.80 per cent of 0.69 Tg. Methane emission from male cattle and buffaloes was 3.389 Tg and young calves (4-12 months), growing calves, breeding, working, breeding + working stocks and others emitted 4.29, 11.11, 6.69, 64.09, 12.32 and 1.50 per cent of total methane emitted from these animals, respectively. Out of total emission of 9.93 Tg from cattle, buffaloes, sheep, and goats, the contribution from male animals was 34.12 per cent in which working males were the major source of methane emission due to their large population. In near future, the contribution of male working animals in methane emission is likely to decrease due to the less dependence of farmers on them for agricultural and transportation operations. However, male buffalo bulls are still preferred in some states for the transportation work, particularly in sugarcane producing areas.

Dairy crossbred cows, indigenous cows, and buffaloes emitted 52.37, 44.75, and 62.5 per cent of total methane emitted by female livestock. Lower methane emission from indigenous dairy cows may be attributed to their smaller body size, and less feed intake than in crossbred cows and milch buffaloes. On an average, dairy animals emitted 54.2 per cent of total methane emitted by female livestock as a result of enteric fermentation.

Total emission from crossbred female cattle (0.339 Tg) was higher than its male counterpart (0.127 Tg) due to their higher population but the situation was just opposite in case of indigenous female cattle, which produced a total of 2.23 Tg methane. The female buffaloes emitted 3.31 Tg against 0.60 Tg from male buffaloes due to their large population.

Methane emission/ bovine

The average annual methane emission value for the working stock was highest (45.14 kg) followed by working + breeding stock. Young calves (4-12 months age) produced about 7 kg methane/year (Fig1). Methane emission/male buffalo/year was higher than crossbred or indigenous bull. The higher emission from 'other' category of male animals, especially from buffaloes needs checking.

Methane emission/crossbred cow was similar to the dry crossbred cow (Fig. 2), as the owners of crossbred animals feed them optimally even when they are non-lactating. However, indigenous dairy cow emitted more methane than non-dairy cow, possibly due to less attention on their feeding due to their low productivity. Dairy crossbred cow, indigenous cow, and buffalo emitted 38.98, 35.9 and 76.6 kg CH^4/hd/yr, respectively. Female animal under the category 'others' emitted on an average 28.9kg CH^4/hd/yr. Male and female sheep and goat in the sub-categories of <1 years and > 1 years age produced 26.18 and 73.82 % of total emitted methane by these animals.

State wise methane emission from Indian livestock:

State wise and species wise methane emission from different livestock is presented in Fig 3. Among the Indian states, UP topped in methane emission followed by MP, Bihar, AP, and Rajasthan, which may be attributed to the difference in their population and feed availability. Species wise methane emission picture was different, as cattle were the major source of methane in MP, and Bihar whereas buffaloes were the major producers in UP, AP, Punjab and Haryana in comparison of cattle. Sheep and goats emitted sizable quantity of methane in Rajasthan and AP only.

Methane emission/ kg milk from different species:

Considering the total methane emission (10.6 Tg) and the total milk yield (60.6 million tones) during the period 1993-94 (Anon 1996), the methane emission/ kg milk worked out to be 175.7g/ kg milk, which appears to be higher than that recorded in US and other western countries due to the higher productivity of their animals and feeding of high concentrate diets. It is also evident from Indian animals as the methane emission/ kg milk was about 25% lesser in crossbred cows (having higher productivity) than indigenous cows (having low productivity). Buffaloes and indigenous cows emitted similar similar amount of methane/kg milk but buffaloes had higher milk yield owing higher energy value (due to higher fat) than indigenous cows. From methane emission from dairy, non-dairy cattle, buffalo and goats (9.73 Tg) the value for methane/kg milk was worked out as 160g, however, on consideration the methane emission of 6 Tg from all the female cattle, buffaloes and goats, irrespective of their age and production status, the value for methane emission/ kg milk was calculated as 99.0g. These values are far lower than the value (243g) reported by Aneja (1992) and that (175-210g) by Singh and Mohini (1996) from Indian milch animals.

Experiment

Data of feed intake and methane emission / kg DM intake obtained from the feeding experiment on lactating cows is presented in Table 5.

All the animals were fed concentrate mixture according to their nutritional requirements (2.25 and 2.55±0.15 kg/day) in both the groups. DM intake decreased in-group II because of replacement of green fodder by less nutritious wheat straw. Inclusion of 100% green fodder in the diet reduced methane emission as a result of enteric fermentation by 5.7 per cent in-group I.

The methane emission / kg DM intake was higher on feeding wheat straw in comparison with green fodder. The values in both the groups were higher than taken for the calculations of methane emission from total livestock in the country. It is possibly due to the fact that methane emission was calculated on the basis of our own standard gas as it contained higher concentration with respect to the NPL standard. By taking the NPL standard in consideration, the value for the methane emission/ kg DMI came closer to the value taken for the calculation of methane emission. DM intake was very close to the values, taken for the estimation of total DM intake from lactating cows in the present study. The values for methane emission/kg milk yield, recorded in the present study were higher than the value worked out from the crossbred cows at the national level.

Table 1. Dry matter intake (kg/100 kg b. weight) in different categories of animals

Age	**Male crossbred**	**Male indigenous**	**Male Buffalo**	**Male Sheep**	**Male Goat**
0-1 year	2-3	1.8-2.0	1.8	3.0	3.0
1-3 years	2-3	1.8-2.0	1.8	3.0-4.0	3.0-4.0
Breeding	2-3	1.8-2.0	2.2		
Breeding+ work	2-3	1.8- 2.5	2.2		
Nothing	2.0	1.8	2		
Age	**Female crossbred**	**Female indigenous**	**Buffalo female**	**Female Sheep**	**Female Goat**
0-1 year	2.0-2.2	2.0	2.0	3.0	3.0
1-3 year	2.5-2.8	2.0	2.2	3.0-4.0	3.0-4.0
Milking	3.0	2.2	2.8		
Dry	2.0	2.0	2.5		
Heifers	2.0	2.0	2.5		
other	1.8	1.8	2.0		

Table 2: Methane emission from lactating crossbred cows fed green and dry roughages*.

Parameter	Green + Conc. Mix. Group I	Green: wheat straw (50:50) + Conc. Mix. Group II
B.wt (kg)	358±90.19	362±16.21
DM intake (kg)		
Green	6.10±0.74	2.80±0.17
Straw		2.66±0.12
Conc.	2.25	2.55±0.15
Total	8.35±0.74	8.01±0.18
DMI/100 kg B.wt (kg)	2.53±0.43	2.23±0.07
Milk yield (kg)	4.86±0.22	4.93±0.32
CH_4 g/day	207.77±4.97	220.43±21.62
CH_4 g/kg litre milk	42.71±2.79	45.35±6.05
CH_4 g/kg DMI	23.58±2.19	27.30±1.95

Table 3. Methane Emission Factors reported by various workers

Animal category	Type of feed	CH^4 g/kg DMI	Reference
Cattle (Crossbred)			
0-1 yr	Conc. + Wheat straw	14 –20	Debashish Dey (1998)
1 yr	Paddy straw+ fodder	19.26	Srivastava & Garg (2002)
	Paddy straw + fodder +Conc.	18.40	
1.5 yr Sahiwal	Paddy straw + Conc. mix.	18.57	
	Paddy straw + UMM block	16.02	
1-3 yr	Conc. + Wheat straw	19-20	Singh et al. (1998)
Holeisten Heifer	Conc. + Hay	20.16	Shibata et al. (1992)
Holeisten Heifer	Hay	23.98	Shibata et al. (1992)
Steers	Conc. : Roughage (97:3)	20.0	Horiguchi et al. (2000)
Lactating cows	Conc.+ straw ad lib	16.04	Singh et al. (2001)
Lactating cows	Conc.+ straw + UMMB	14.24	Do
Lactating cows	Conc.+ straw + fodder	19-21	Singh et al. (1999)

Lactating cows (indigenous)	As in Gujarat villages	16.6	ATI (2000)
Exotic lactating	Alfalfa + pasture	23.28	Mc Caughey (1999)
Exotic cows	Alfalfa hay + silage.	20.85	Shibata et al., (1993)
Buffaloes			
0-1 yr	Green fodder + Conc.	9-11	Mohini et al (unpublis.)
1-1.5 yr Male	Jowar fodder + Conc.	10.06	Mohini & Singh (2001)
1-1.5 yr Female	do	9.25	Do
Female calves	Maize fodder + conc.	15.97	Mohini & Singh (2001)
Male calves	Maize fodder + conc.	18.34	-do-
2 yr Male	Conc : Roughage 60:40	14.14	Saraswat et al (2001)
1- 3 yr	Conc.+ Wheat straw	10-16	Barman et al. (2001)
Lactating	As in villages in Gujarat	18.0	ATI (2000)
Goats	Conc: Roughage 30:70*	28.79	Datta et al (2001)
	Hay+ conc.	19.24	Shibata et al,. (1992)
	Oat hay**	22.0	Khan et al..(1986)
	Oat hay + Conc mix I**	24.0	Do-
	Oat hay + conc Mix II**	22.0	D0-
Adult Sheep	Hay + conc.	18.39	Shibata et al.. (1992)
Sheep	High roughage diet	13.04	Singh and Leng (1989)
Adult sheep	Conc : Roughage 80:20	8.63	Horiguchi et al (2000)
Adult sheep	High roughage diet	12.76	Haque and Bhar (2001)

- Based on in vitro estimation ** Based on respiration calorimeter

Table 4: Methane emission from different categories of livestock in 1994

	Population X1000	DMI (Million Ton)	Dung (Million ton)	CH_4 (1000g) emission	CH_4/animal/ Annum (g)	CH_4/day (g)
Crossbred (male)						
4-12 months	991.33	0.559	0.255	8943471	9021.69	24.72
1 -3 years	983.3	1.209	0.55	19344038	19672.57	53.90
<3 Yr breeding	123.89	0.279	0.126	4477925	36144.36	99.03
Working	2235.684	5.128	2.327	81181712	36311.80	99.48
Breeding+Working	312.92	0.66	0.308	10657620	34058.61	93.31
Others	97.19	0.158	0.0792	2534229	26075.00	71.44
Total	**4744.507**	**8**	**3.649**	**127138995**		

Crossbred (Female)						
4-12 months	1875.996	1.135	0.523	18217593	9710.89	26.61
1-3 years	2180.956	2.905	1.33	46491208	21316.89	58.40
Milking	4580.185	11.116	5.105	177871162	38834.93	106.40
Dry	2061.999	4.963	2.282	79417704	38514.91	105.52
Heifer	650.099	0.873	0.397	13970271	21489.45	58.88
Others	155.88	0.229	0.107	3679130	23602.32	64.66
Total	11506.12	21.221	9.749	339647038		
Indigenous (male)						
0-12M	7670.611	3.6455	1.691	58328253.67	7604.12	20.83
1-3 yr	14236.15	14.55	6.77	232918261	16361.04	44.82
< 3 Yr breeding	8815.661	15.36	7.35	307376342	34867.08	95.53
Working	54290.33	111.8	51.35	1788846766	32949.64	90.27
Breeding +Working	8374.85	15.4	7.45	246441013	29426.32	80.62
Others	759.614	1.15	0.535	18517092	24376.98	66.79
Total	**94147.17**	**161.93**	**75.14**	**2652427747**		
Indigenous (female)						
4-12 months	10593.57	4.86	2.28	78363677	7397.29	20.27
1-3 years	19725.51	18.98	8.88	303686887	15395.64	42.18
Milking	27797.5	62.5	29.06	1000076610	35977.21	98.57
Dry	24219.72	44.48	20.69	711687118	29384.61	80.51
Heifer	4270.7	5.98	2.8	95765931	22423.94	61.44
Others	1804.539	2.71	1.26	43489232	24099.91	66.03
Total	**88411.53**	**139.53**	**64.99**	**2233069455**		
Buffalo (male)						
0-12M	4346.92	2.21	1	22137384	5092.66	13.95
1-3 years	3843.496	4.37	1.988	56828296	14785.57	40.51
<3 Yr breeding	516.412	1.68	0.7735	30310620	58694.65	160.81
Working	5617.619	16.19	7.37	371612268	66151.21	181.24
Breeding+Working	2165.23	6.52	3.058	117536449	54283.59	148.72
Others	180.99	0.609	0.281	10969866	60610.34	166.06
Total	16665.67	31.6	14.47	609394884		
Buffalo (Female)						
0-1	9435.28	5.72	2.59	57205289	6062.91	16.61

1-3 years	11364.05	15.17	6.88	197219064	17354.65	47.55
Milking	27075.543	115.29	52.1	2075332653	76649.71	210.00
Dry	15099.35	47.21	21.5	849911053	56287.92	154.21
	2953.3	6.04	2.738	108732749	36817.37	100.87
Others	708.61	1.53	0.708	27633712	38997.07	106.84
Total	66636.14	190.98	86.53	3316034521		
Goat (male)						
<1Yr	13486	1.78	0.71	38151826	2828.99	7.75
>1Yr	16343.13	3.236	1.294	69223209	4235.62	11.60
Goat (Female)						
<1Yr	17849.76	2.44	0.976	52199498	2924.38	8.01
>1Yr milking	25271.91	5.89	2.35	126107610	4990.03	13.67
	38280.91	8.8	3.298	188990509	4936.94	13.53
Total	111231.9	22.19	8.64	474672653		
Sheep	49404.14	14. 21	5.63	181309675	3669.9	10.05
Others	16363,99	12. 25	5.81	141519901	8648.25	23.69
Grand Total	**459111.19**	**601.95**	**275.02**	**10075214867**		

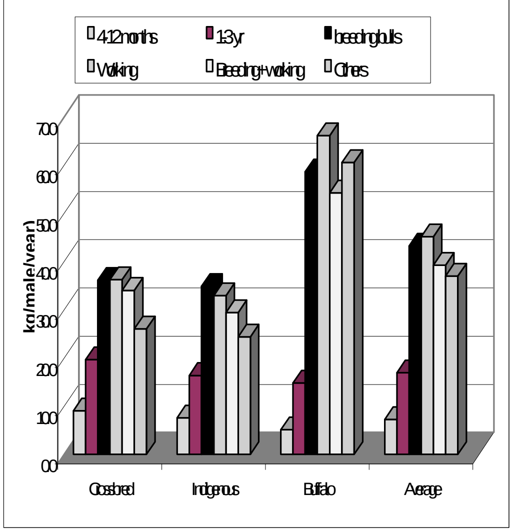

Fig.1: Methane emission (kg/male bovine/year)

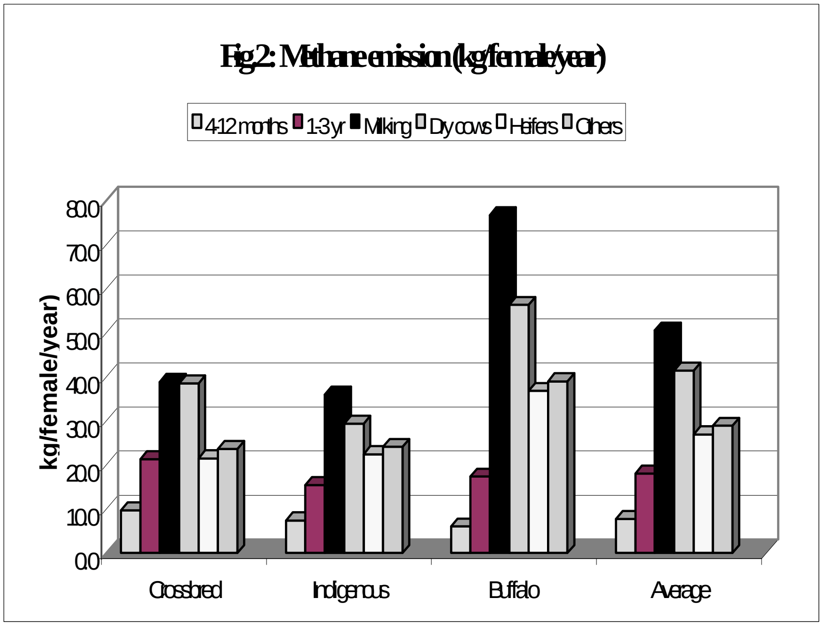
Fig.2: Methane emission (kg/female/year)
4-12 months
1-3 yr
Milking
Dry cows
Heifers
Others
kg/female/year)
80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0.0
Crossbred
Indigenous
Buffalo
Average

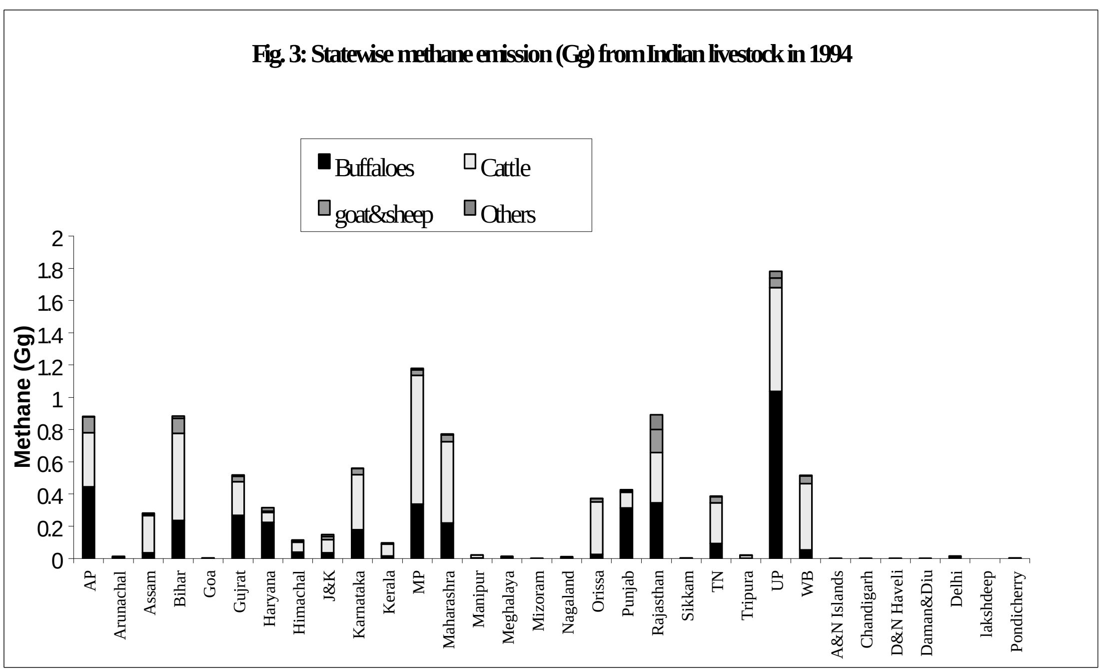
Fig. 3: Statewise methane emission (Gg) from Indian livestock in 1994
Buffaloes
Cattle
goat&sheep
Others
Methane (Gg)
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
AP
Arunachal
Assam
Bihar
Goa
Gujrat
Haryana
Himachal
J&K
Karnataka
Kerala
MP
Maharashra
Manipur
Meghalaya
Mizoram
Nagaland
Orissa
Punjab
Rajasthan
Sikkam
TN
Tripura
UP
WB
A&N Islands
Chandigarh
D&N Haveli
Daman&Diu
Delhi
lakshdeep
Pondicherry

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