ASSESSING THE ROLE OF INDIAN LIVESTOCK IN CLIMATE CHANGE

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ABSTRACT:

Livestock has been the mainstay of Indian agriculture sector and also a major source of GHGs emissions from the world's largest livestock population. The milching livestock (including lactating dairy cattle, buffalo and goat) constitutes 21.3% of the country's livestock. We present a detailed inventory of GHGs emissions from milching livestock (using the recent census and country-specific emission coefficients based on IPCC guidelines) vis-a-vis milk production in the country. The total CH_4 emission from enteric fermentation and manure management was estimated at 3.16 Tg/yr for the year 2003. Enteric fermentation contributes 91.3% of total CH_4 emissions as compared to only 8.7% by manure management. The detailed spatial analysis in GIS identified the districts with high CH_4 emissions. The N_2O emission from milching dairy cattle was estimated at 0.021 GgN_2O/yr, with a share of 77.5% by indigenous cattle. The total GHG emission is estimated at 66.4 Mt in terms of total CO_2 equivalent. The CH_4 emission in terms of milk production is less in exotic cows (23.8 $gmCH_4$/kg milk) as compared to indigenous cows (44.6 $gmCH_4$/kg milk). The projected estimates of livestock population indicates that lactating dairy cattle and buffalo are expected to increase by 3.5 and 5.6 million resulting to an expected increase of ~36% and 17% methane emissions, respectively by the year 2021. These estimates are important indicators for studying the future impacts of livestock to climate change and their role in food security, and may also serve as an important pathway for formulating policy measures for sustainable livestock production.

1. INTRODUCTION

Climate change is widely considered to be one of the most potentially serious environmental problems ever confronting the global community. Besides being a major contributor to climate change, livestock play important roles in farming systems in developing countries by providing food and income, draught power, fertilizer and soil conditioner, household energy and a means of disposing of otherwise unwanted crop residues. About 12% of the world's population depends solely on livestock for its livelihood (FAO, 2006). It has been noted that the global livestock sector is growing faster than any other agricultural sub-sector and contributes about 40% to global agricultural output. Livestock has made an important contribution to the food supplies globally through various products like milk, meat eggs, etc. The production of livestock products is increasing fast, particularly in developing countries which reported an increase of 78%, 127% and 331% in cereal, meat and egg production, respectively, over the past two decades (FAO, 2006).

1.1 Livestock's Role in Climate Change

Besides contributing to the global food security, livestock activities have significant impact on virtually all aspects of the environment including air and climate change, land and soil, water and biodiversity (FAO, 2006). It is reported that livestock production accounts for ~18% of the global GHGs emissions including methane (CH_4) emission from enteric fermentation and manure management, nitrous oxide (N_2O) emissions from animal manure, and carbon-di-oxide (CO_2) emissions from land-use change caused by demand for feedgrains, grazing land and agricultural energy use.

Directly and indirectly, through grazing by ruminants and through feed crop production, the livestock sector occupies ~30% of the ice-free terrestrial surface on the Earth (Asner et al., 2004). Grazing systems have a high impact on the carbon cycle and therefore the climate through deforestation and land degradation. In many situations, livestock is a major source of land-based pollution, emitting nutrients, organic matter, pathogens and drug residues into rivers, lakes and seas.

Livestock forms a major anthropogenic source of CH_4 emission from the agriculture sector. Globally, livestock accounts for ~37% of anthropogenic CH_4 which is largely produced by enteric fermentation in ruminants as part of their normal digestive processes (FAO, 2006). Ruminants (cattle, sheep and goats) account for a large share of total livestock emissions, because they are less efficient in converting forage into useful products than monogastrics (pigs and poultry). The global atmospheric CH_4 concentration has more than doubled over the last two centuries after remaining fairly constant for the preceding 2,000 years (IPCC, 2007). Although CH_4 concentration in the earth's atmosphere is small, it has contributed ~15% to the global warming during 1980-1990 as a potent GHG gas with a global warming potential (GWP), 21 times more than that of CO_2. More recently, CH_4 concentration in the atmosphere was 1774 ppb as measured in 2005 (IPCC, 2007). Livestock also accounts for 64% of human-induced ammonia, which significantly contributes to acid rain. Livestock manure is primarily composed of organic material and water. Under anaerobic conditions, the organic material in the livestock manure is decomposed by anaerobic and facultative

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bacteria resulting into formation of CH_4, CO_2, and stabilized organic material. Livestock manure management is also a significant source of CH_4 emission (Swamy and Bhattacharya, 2006). The total global CH_4 emissions from livestock manure management have been estimated as 9.3 Tg/year (Scheehle, 2006).

Besides methane, livestock also contributes a small but significant emission of N_2O from animal waste management systems. Nitrous oxide, a potential GHG (global warming potential, GWP: 310) is produced during the microbial processes of nitrification-denitrification of nitrogen contained in livestock waste. The amount of N_2O released depends on the system and duration of waste management (Swamy and Bhattacharya, 2006). N_2O is also involved in the catalytic destruction of stratospheric ozone following its photolytic oxidation to nitric oxide (NO). Livestock activities contribute almost two-thirds of all anthropogenic N_2O emissions, and 75-80% of agricultural emissions. According to the recent estimates the global atmospheric concentration of N_2O has increased from 270 ± 7 ppbv in the pre-industrial period to 319 ± 12 ppbv in 2005 (IPCC, 2007).This recent report predicts that global temperatures will rise by 2-4.5°C by the end of this century and for the next two decades a warming of about 0.2°C per decade is projected. It has been further concluded that under scenarios without climate policy, increasing GHGs concentrations may cause global mean temperature to rise by up to 7°C compared to pre-industrial levels by the end of the present century. Thus, GHGs emissions need to be reduced substantially to avoid such an increase in global mean temperature that may lead to climate change resulting in large changes in ecosystems, leading to possible catastrophic disruptions of livelihoods, economic activity, living conditions, and human health.

1.2 Livestock Status in India

Livestock plays a critical role in the Indian economy and welfare of India's rural population. As a centuries old tradition, livestock rearing has been an integral part of Indian agricultural system. The importance of livestock in India's economy can be gauged from the fact that 90 million farming families are occupied in cultivating 140 Mha area and rearing 90 million milch animals. Livestock production is an important source of income and employment in the rural sector (Dastagiri, 2004). As a major component of agricultural sector, its share in gross domestic product of the country has been rising gradually. It is estimated that livestock contributes 8% to the country's GDP and employs 8% of the labour force, including small and marginal farmers, women, and landless agricultural workers. This sub-sector provides a flow of essential food products, draught power, manure, employment, income, and export earnings. Livestock also serves as an important part of agriculture diversification and income enhancement, and crucial for nutrition enhancement. Currently, India ranks first with 485 million or 13% of the world's total livestock population sustaining in less than 5% of world's and one-third of Asia's agricultural land area (MOA, 2003). It ranks first with regard to the bovine (cattle and buffalo) and second in goat populations in the world (*http://www.clfmaofindia.org*). A detailed account of the country's livestock status is undertaken at every five years interval by the Department of Animal Husbandry and Dairying under the Ministry of Agriculture, Government of India (MOA). This census provides detailed information on indigenous and cross-breed

population for all livestock categories like cattle, buffalo, goat, etc. along with age, sex and composition etc at district/state level.

Despite having huge livestock population, India stands insignificant in the world trade of livestock products. Increasing globalization of livestock product markets is an opportunity as well as a threat to India's livestock sector. In 2001, India emerged as the world leader in milk production, with a production volume of 84 Mt, closely followed by USA. India has about three times as many 'dairy' animals as the USA, but annual milk yield per dairy animal is about one tenth of that achieved in USA FAO, 2006). The rapid growth in milk production is largely credited to the '*Operation Flood*', the world's largest integrated dairy development program, attempted to establish linkages between rural milk producers and urban consumers by organizing farmer-owned and-managed dairy cooperative societies. It was assisted by many multi-lateral agencies, including the European Union, the World Bank, FAO and WFP (World Food Program). In the Indian context of poverty and malnutrition, milk has a special role to play for its many nutritional advantages as well as providing supplementary income to some 70 million farmers in over 500,000 remote villages (*http://indiadairy.com*).

How can the trade-offs between livestock for food security and possible environmental effects be minimized is a big challenge facing the world. Indian agriculture is particularly vulnerable to impacts of climate change due to its large livestock population. In order to have a strategic plan for developing farmer friendly technologies to reduce livestock contribution to climate change, there is a need to quantify the GHGs emissions from milching animals among the Indian livestock and their contribution to the milk production. This study aims at detailed estimation of methane and nitrous oxide emissions from milching livestock viz. dairy cattle, buffalo and goat) vis-a-vis milk production in the country. The study also attempts at category-wise detailed trend projections of population growth and GHGs emission from Indian livestock. The major objectives of the study include:

➢ Developing a detailed inventory of GHGs (methane and nitrous oxide) emissions from milching livestock.

➢ Deriving the spatial patterns of estimated GHGs emissions at state/district level.

➢ Detailed analysis of estimated methane emissions vis-à-vis milk production for the milching livestock.

➢ Trend projections for future livestock population growth and methane emissions.

2. MATERIAL AND METHODS

2.1 Study Area and Data Used

A detailed inventory for CH_4 and N_2O emissions from Indian livestock was developed at the district and state level, respectively. A detailed statistical database of age, reproductive status, indigenous and cross-breed or exotic population of dairy cattle, buffalo and goat was prepared at all-India, state/union-territory, and district levels using the recent livestock census (MOA, 2003). In case of goat population, the data is available for dairy animals

irrespective of indigenous/exotic species. The adult lactating dairy indigenous cattle and buffalo over 3-years and 1-year and above goats were only considered for the purpose of this study. The country-specific emission coefficients conforming to IPCC good practice guidelines and based on Indian feed standards for dairy indigenous/exotic cattle, dairy indigenous/exotic buffalo and goat were used for estimating methane emissions from enteric fermentation and manure management (adopted from Swamy et al., 2004, MOEF, 2004 and Swamy and Bhattacharya, 2006). The district-level methane emission estimates for enteric fermentation were made under three scenarios viz. maximum, average and minimum for different milching livestock

The N_2O emission coefficients derived using tier-II IPCC emission factors based on the weighted average for the country (Swamy and Bhattacharya, 2006) were adopted. Among the milching livestock, only the dairy cattle (including indigenous and exotic animals) account for N_2O emissions. A long-term database of livestock census, production and per-capita availability of livestock products (viz. milk, meat and eggs) at all-India state/union-territories and district level was also prepared for the study using the data from MOA, 2003.

2.2 Methodology

2.2.1 Milching livestock distribution: A statistical approach was used to study the long-term changes in population growth of milching livestock by categories during the period 1951-2003. The population distribution of milching livestock as estimated by the recent census 2003 was studied in detail and spatial patterns were derived in GIS environment using a spatial framework of district administrative coverage with Albers Conical Equal Area projection in ARCGIS/ARCMAP version 9.3.1.

2.2.2 GHG inventory estimation: The detailed methane emission inventory was estimated for lactating dairy indigenous and exotic cattle, buffalo and goat using the country-specific Indian feed standard based methane emission coefficients for enteric fermentation and manure management. The district-level methane emission inventory was computed as a product of milching livestock population under each category (cattle, buffalo and goat) and its respective methane emission coefficient. The district level estimates were up-scaled to arrive at state/country level emissions.

$$ME_{mLs} = \sum_{d=1}^{N_d} \left\{ \left(\sum_{l=1}^{N_l} P_{dl} * EF_{dl} \right) + \left(\sum_{l=1}^{N_l} P_{dl} * MM_{dl} \right) \right\} * 10^{-9}$$

where, NOEc is the aggregated nitrous oxide emission by milching cattle (expressed in Gg N2O/year, Gg=109 g) at the national level integrated over all the states, Pc is the state-level dairy indigenous and exotic cattle population (in numbers), s is the state, Nc is the country-specific nitrous oxide emission factor (kgN2O/animal/year) for dairy cattle species. The estimated CH_4 and N_2O emissions

were converted to the aggregate CO_2 equivalent GHG emission (expressed in Mt=10^{12}g) by taking into account the GWP of individual GHGs (CH_4=21 and N_2O=310). GWP captures the integrated effect of emissions in CO_2 equivalent emission terms.

2.2.3 Methane emissions vis-à-vis milk production: A long-term analysis of milk production (Mt) and per-capita milk availability (gm/day) was carried out at all-India level for the period 1950/51-2005/06. The livestock category wise-share of milk production was studied at the state level for the recent period (2000-2006). The methane emissions with respect to the milk yield (gm/kg milk produced) were calculated at the state level using the estimated methane emissions (Tg) and category-wise share in milk production (Mt) by non-descript (indigenous) and cross-breed (exotic) cattle/cows, buffaloes and goat for the year 2003. The spatial patterns of CH_4 emissions at the district level and state level CH_4 emissions per kg milk produced were derived in the GIS environment using a spatial framework of district administrative coverage with Albers Conical Equal Area projection in ARCGIS/ARCMAP version 9.3.1. The milching livestock census available for the last more than five decades (1951-2003) and milk production were modelled using a linear regression to make the projected trend of population growth and expected CH_4 emissions.

3. RESULTS AND DISCUSSION

The earlier attempts to estimate methane emission from Indian livestock using different approaches are discussed in detail by Chhabra et al. (2009). These earlier estimates include methane emissions including all livestock categories. Chhabra et al. (2009) also presented a detailed inventory and spatial patterns of livestock based methane emissions in India for the recent period 2003. However, a detailed inventory and estimation of methane emissions from milching livestock vis-à-vis milk production for the recent period has not been attempted earlier. The results of the present study are discussed below:

3.1 Milching Livestock Population

The long-term analysis of livestock census for the period 1951-2003 indicates that total livestock has increased by 192.2 million (~65%) with an annual growth rate of 1.26%. Among the milching livestock (figure 1) cattle have increased steadily by 49.3 million during 1951-1992, followed by a decrease of 19.4 million by the year 2003. However, the number of dairy cattle (considering adult lactating animals only) has increased by 10.1 million only during 1951-2003 with only a marginal increase of 0.15 million in the past one decade (1992-2003). Buffaloes have significantly increased from 43.4 to 98 million during 1951-2003, including 8 million increase during 1997-2003. Goats have significantly increased by 163% during 1951-2003. As the long-term break-up data of dairy and non-dairy goats was not available, the goat here includes both male and female animals.
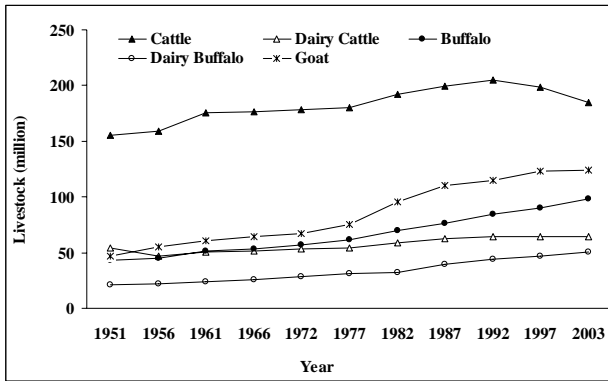
The recent census indicates that milching livestock (including indigenous and exotic dairy animals) constitutes 103.4 million or 21.3% of the total. The milching cattle, goat and buffalo constitute 35%, 33% and 32%, respectively. Of the total 35.8 million milching cattle, the indigenous species constitutes a major fraction with 27.6 million animals (77.2%) as compared to only 8.2 million (22.1%) cross-breed or exotic cattle. Uttar Pradesh, Rajasthan, Madhya Pradesh, Maharashtra and Andhra Pradesh are the top five states with 15.5, 10.4, 9.2, 8.4 and 7.5 million milching livestock, respectively. Dairy buffalo is the major milching livestock constituting ~51% of total in Uttar Pradesh and Andhra Pradesh. Indigenous dairy cattle and goats are dominant in Madhya Pradesh (36%) and Rajasthan (45%), respectively. The spatial distribution of milching livestock at the district level (figure 3) indicates high concentration in few districts of West Bengal (Mednipur: 0.97 million), Rajasthan (Barmer: 0.89 million, Nagaur: 0.82 million, Sikar: 0.73 million, Jodhpur: 0.72 million), Maharashtra (Ahmednagar: 0.75 million), and Karnataka (Belgaum: 0.62 million).

Indigenous dairy cattle is the major milching livestock in Mednipur (~59%), however, goat is the major livestock in Rajasthan-Barmer (64%) and Nagaur, Sikar (60.5%).

3.2 Greenhouse Gas Inventory Estimation

The total CH_4 emission from enteric fermentation and manure management of milching livestock was estimated as 3.16 Tg/yr of which enteric fermentation contributes 2.88 Tg/yr (91.3%) as compared to only 0.28 Tg/yr (8.7%) by manure management. The enteric fermentation methane emission was estimated in the range of 2.2-3.6 Tg/yr with an average emission of 2.88 Tg/yr. The detailed inventory and its spatial analysis in GIS (figure 3) indicate that the districts with high livestock population may not truly correspond to methane emission inventory because the methane emissions depend on livestock category. Dairy buffalo are the highest contributors of CH_4 emission with 1.78 Tg/yr (56.4% of the total) from 33.2% population among the milching livestock. Although goats are the dominant milching livestock with a population share of 33.1%, their contribution to the CH_4 emission is only 0.14 Tg/yr or 4.5%. The spatial analysis identified the districts with high methane emissions viz. 0.025 Tg/yr in Bulandshar (U.P): 0.022 Tg/yr in Prakasham (A.P), Jaipur (Rajasthan), and 0.021 Tg/yr in Kolhapur (Maharashtra) and Mednipur (W.B.). Dairy buffalo with highest CH_4 emission coefficient is the major livestock in Bulandshar, Prakasham, Kolhapur, Belgaum and Guntur, whereas goat and indigenous cattle are dominant in Jaipur and Mednipur, respectively. U.P., Rajasthan and A.P. are the top three states with 0.58 Tg/yr (18.2%), 0.28 Tg/yr (8.9%) and 0.27 Tg/yr (8.6%) methane emissions from enteric fermentation and manure management of milching livestock.
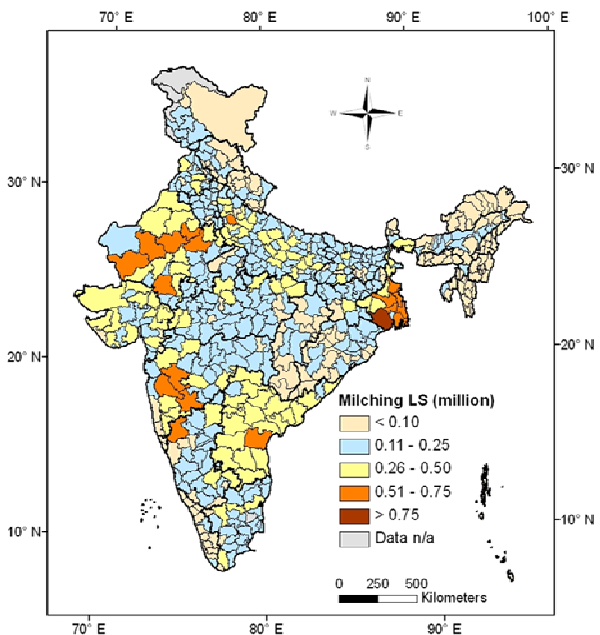

Figure 2. District-level Distribution of Milching Livestock in India for the Year 2003
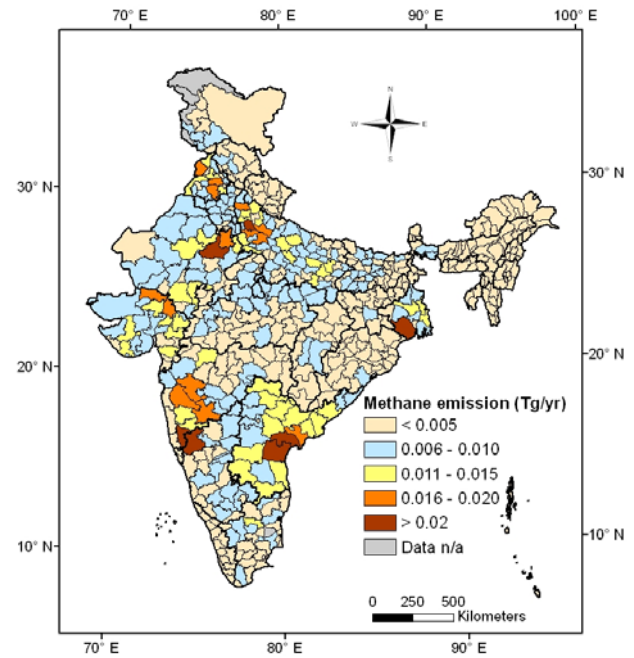

Figure 3. Spatial Distribution of District-Level Methane Emission from Milching Livestock in India (2003)

The total N_2O emission from animal waste management system of dairy milching cattle was estimated at 0.021 GgN_2O/yr, with a share of 0.016 GgN_2O/yr (77.5%) by indigenous cattle and 0.005 GgN_2O/yr (22.5%) by exotic animals. U.P., W.B., and M.P. are the top three states with 0.002 GgN_2O/yr emissions. The total GHG emission (including CH_4 and N_2O) expressed in terms of total CO_2 equivalent from milching livestock is estimated at 66.37 Mt.

Livestock category	Population (million)	CH_4 emission (Tg/yr)				N_2O emission (Gg/yr)	Total CO_2 equivalent (Mt)
		EF	MM	Total	% contribution		
Indigenous cattle	27.63	0.77	0.10	0.86	27.35	0.016	18.06
Exotic cattle	8.18	0.34	0.03	0.37	11.78	0.005	7.77
Total cattle	*35.80*	*1.11*	*0.13*	*1.24*	*39.13*	*0.021*	26.05
Buffalo	33.32	1.64	0.14	1.78	56.36	-	37.38
Goat	34.24	0.14	0.01	0.14	4.51	-	2.94
Total	*103.36*	*2.88*	*0.28*	*3.16*	*100*	*0.021*	*66.37*

Table 1. Category-wise population and GHG emissions from milching livestock* in India for the year 2003

3.3 Methane Emission vis-à-vis Milk Production

The long-term analysis of milk production data for the period 1950-51/2005-06 indicates that India's annual milk production has increased by ~5.8 times, rising from a mere 17 Mt in 1950-51 to 97.1 Mt in the year 2005-06. In 2001, India emerged as the world leader in milk production with a production volume of 84 Mt. The per-capita milk availability has increased from 124-241 gm/day during the study period. Currently, India is one of the world`s largest and fastest growing markets for milk and milk products, getting almost 7.5% growth annually in value terms for milk and milk products. The increase in milk production is largely credited to the significant increase of ~55 million dairy buffalo during 1951-2003. Buffaloes are the major source of milk in our country. Moreover, buffalo's milk also has higher demand due to its higher fat content than cow's milk hence fetches a higher return to the farmer for a given input of fodder/feed.

Considering the total CH_4 emission of 3.16 Tg and total milk yield of 88.1 Mt for the year 2003, the CH_4 emission per kg milk produced amounts to 35.9 $gmCH_4$/kg milk. Among the milching livestock, CH_4 emission is less in exotic/cross-bred cows (23.8 $gmCH_4$/kg milk) having higher productivity as compared to indigenous cows (44.6 $gmCH_4$/kg milk) with low productivity. Goats with a low share of 4.2% in total milk production emit 38.4 $gmCH_4$/kg milk, which is higher than lactating buffaloes emitting 37.1 $gmCH_4$/kg milk and contributing more than half ~54% to the total milk production. The category-wise CH_4 per unit milk produced is in the order of cross-breed cow<dairy buffalo<goat<indigenous cow. There also exist wide variations among the states. Orissa and Assam are the top two states with high CH_4 emission of 80.1 and 77.6 $gmCH_4$/kg milk produced, respectively (figure 4). The lowest CH_4 emission was estimated in Kerala (15.9 $gmCH_4$/kg milk) followed by Punjab (19.1 $gmCH_4$/kg

milk). Singhal et al. (2005) estimated average CH_4 emission for lactating animals as 53.6 $gmCH_4$/kg milk for the year 1994. Swamy and Bhattacharya (2006) indicated that indigenous animals with higher methane/kg milk have lower milk yield/animal owing to their poor nutritional status. Due to poor availability of pasture and grazing lands in India (only 3.4% of total area available), the animals either subsist on poor quality grasses available in the pastures and non-pasture lands or are stall-fed, chiefly on crop by-residues.
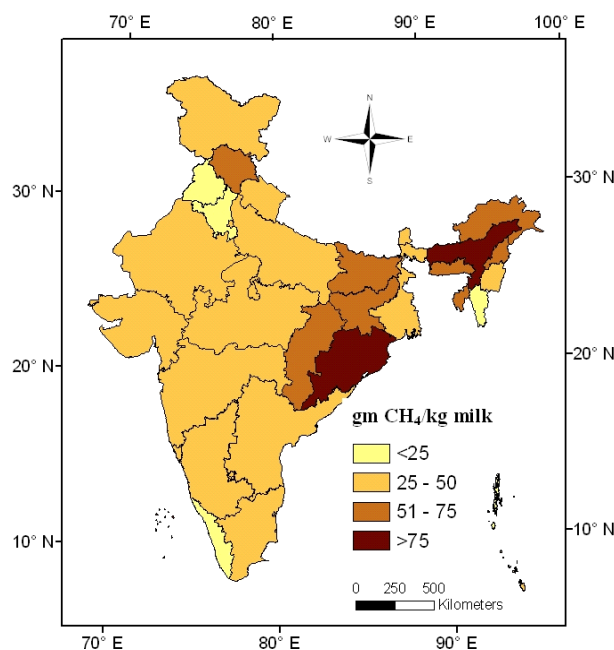

Figure 4. Distribution of Methane Emission per kg Milk Produced by the Milching Livestock in India (2003)

Based on the available long-term census data for dairy cattle and buffalo for last more than five decades (1951-2003), the projected trend of population growth were generated for the year 2021 using linear regression model over 11 data points (n=11). The share of lactating animals in dairy cattle and buffalo population in the year 2003 was used to make projected trend in population growth as the long-term data for milching animals was not available. The results indicate that lactating dairy cattle and buffalo are expected to increase by 3.5 and 5.6 million, respectively by the year 2021. Based on these projections, the CH_4 emissions from dairy lactating cattle and buffalo are expected to increase by 0.12 Tg (~36%) and 0.30 Tg (17%) by the year 2021. These projected estimates of CH_4 emissions are based on population growth only, however methane emission also depends on other factors viz. livestock feed, level of intake, and digestibility of feed etc. These variables also need to be included for detailed studies in future. The increase in CH_4 emissions raises concerns as CH_4 has 21 times higher GWP than CO_2. However, a relatively short life time of CH_4 provides an opportunity for mitigating the impacts of global warming because emissions reductions could lead to stabilization or reduction in CH_4 concentrations within 10-20 years in the atmosphere. Thus, measures and policies that target reductions in CH_4emissions can help mitigate the rate of climate change at a faster rate than those

that target reductions in emissions of CO_2 and other longer-lived GHGs. Improved animal feeds, like Urea Molasses Block (UMB), are slowly being used in some advanced states like Punjab and Gujarat. These coupled with suitable feed digesters; mainly given to enhance milk production also have the potential to reduce average CH_4 emissions from enteric fermentation. The emissions from livestock manure management may be considerably reduced with the advanced technological options (FAO, 2006). However, due to the large population, lack of awareness and access to improved feed, methane mitigation from milching livestock would require substantial efforts and detailed studies.

The animal production system which is a large contributor to global warming through emission of CH_4 and N_2O is also much vulnerable to climate change itself (Sirohi and Michaelowa, 2004). The performance, health and well-being of the livestock are strongly affected by climate both, directly and indirectly. Hot and humid environmental conditions directly stress the lactating dairy cow and reduce intake of the nutrients necessary to support milk yield and body maintenance. The indirect effects include climatic influences on quantity and quality of feed and fodder resources such as pastures, forages, grain and crop by-residues and the severity and distribution of livestock diseases and parasites. Using the remote sensing derived potential feed/fodder area available in each district, Chhabra et al. (2009) estimated an average CH_4 flux of 74.4 kg/ha for Indian livestock. This factor also needs to be considered in long term plan for milk production and GHG emission strategy. Besides the quantum, the type and quality of feed resources also vary across regions. The population growth in each livestock category is also largely influenced by the demand of livestock products etc.

CONCLUSION

Climate change and food security are two emerging issues being faced by people all over the world. While livestock's role in contributing to food security is very well acknowledged, its negative impacts by way of contributing to GHGs in the atmosphere raise criticism. The long-term analysis of livestock census indicates that total livestock has increased with an annual growth rate of 1.26% during the past five decades. Currently, India ranks first with 485 million or 13% of the world's total livestock, of which milching livestock accounts for 21.3%. Among the categories, cattle, goat and buffalo constitute 35%, 33% and 32% of the total milching livestock, respectively. The spatial distribution of milching livestock indicates high concentration of milching animals in few districts of W.B., Rajasthan, Maharashtra, and Karnataka. The total CH_4 emission from enteric fermentation and manure management of milching livestock was estimated at 3.16 Tg/yr of which enteric fermentation contributes 91.3% as compared to only 8.7% by manure management. U.P., Rajasthan and A.P. are the top three states with 18.2%, 8.9% and 8.6% contribution to the total CH_4 emission, respectively. The detailed spatial analysis in GIS identified the districts with high CH_4 emissions viz. Bulandshar, Prakasham and Jaipur. The total N_2O oxide emission from dairy cattle was estimated at 0.021 GgN_2O/yr, with a share of 77.5% by indigenous cattle and 22.5% by exotic animals. The total GHG emission expressed in terms of total CO_2 equivalent is estimated at 66.37 Mt, with a major contribution of 56.3% by dairy buffalo.

The long-term analysis of milk production data indicates that India's annual milk production has increased by ~5.8 times during 1950-51 to 2005-06. The increase in milk production is largely credited to the significant increase of ~55 million dairy buffalo, which is a major source of milk in the country. The CH_4 emission in terms of milk production is less in exotic/cross-bred cows (23.8 gmCH_4/kg milk) having higher productivity as compared to indigenous cows (44.6 gmCH_4/kg milk) with low productivity. An increase in cross-breed/exotic animals with higher productivity may provide a better balance between milk production vis-à-vis methane emissions. Orissa, and Assam are the top two states with high CH_4 emission of 80.1 and 77.6 gmCH_4/kg milk produced, respectively. The projected trend of population growth indicates that lactating dairy cattle and buffalo are expected to increase by 3.5 and 5.6 million resulting to an expected increase of ~36% and 17% CH_4 emissions, respectively by the year 2021. This study has presented a detailed and recent GHG inventory from milching livestock vis-à-vis their role in milk production in India. These estimates are important indicators for studying the future impacts of livestock to climate change.

ACKNOWLEDGEMENTS

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