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Projection of methane emissions from livestock through enteric fermentation: A case study from India

Shilpi Kumari [a], R.P. Dahiya [b,*], S.N. Naik [c], Moonmoon Hiloidhari [d], Indu Shekhar Thakur [d], Isha Sharawat [a], Nisha Kumari [b]

[a] *Centre for Energy Studies, Indian Institute of Technology, Delhi, New Delhi 110016, India*
[b] *Deenbandhu Chhotu Ram University of Science and Technology, Murthal 131039, Haryana, India*
[c] *Centre for Rural Development and Technology, Indian Institute of Technology, Delhi, New Delhi 110016, India*
[d] *School of Environmental Sciences, Jawaharlal Nehru University, New Delhi 110067, India*

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ABSTRACT

Livestock is one of the major sources of anthropogenic methane (CH_4) emissions. India has the world's largest number of livestock and thus CH_4 emissions from the Indian livestock sector are very significant. Any long-term CH_4 emissions mitigation strategies would require the precise projection of livestock growth, followed by implementation of appropriate policy mechanisms. However, livestock related long-term CH_4 emissions projection studies are currently lacking in India. In this study, a dynamic approach based on the STELLA software in combination with mathematical models was developed to assess livestock population growth and CH_4 emissions in India for a 25 year period (2007–2032) under baseline (BS: BS-I, BS-II, BS-III) and modified (MS: MS-I, MS-II, MS-III) scenarios. Standard Indian livestock database and IPCC emission guidelines were followed to estimate CH_4 emissions. The results indicate that under the baseline scenarios, CH_4 emissions range from 14.08 Tg (296 Tg CO_2e CH_4) in 2007 to 68.49 Tg (1438 Tg CO_2e CH_4) in 2032 and for modified scenarios, emissions range from 13.85 Tg (291 Tg CO_2e CH_4) in 2007 to 16.62 Tg (349 Tg CO_2e CH_4) in 2032. At the state level, the highest CH_4 emissions from livestock has been observed in Uttar Pradesh (15% of total emissions in India) followed by Madhya Pradesh (9.41%) and Andhra Pradesh (9.20%). The lowest emission per head livestock has been observed in goats and sheep (105 kg CO_2e CH_4 head^{-1} yr^{-1}) followed by cattle (672 kg CO_2e CH_4 head^{-1} yr^{-1}) and buffalo (1155 kg CO_2e CH_4 head^{-1} yr^{-1}) in all the scenarios. However, while considering livestock populations, cattle contribute the highest CH_4 emissions (more than 50%) trailed by buffalo, goat, and sheep. Substantial reduction in emissions would be possible if livestock population growth could be stabilized according to the modified scenarios. Different approaches (like dietary management, livestock product demand optimization, and population stabilization) for CH_4 emissions reduction are also discussed in this paper. A comparison of modeled v/s estimated emissions using actual recent livestock census data from year 2012 has also been presented in this paper. The findings of the present study are expected to help policy makers to adopt appropriate policy mechanisms to reduce CH_4 emissions from the Indian livestock sector.

* Corresponding author.
E-mail address: rpdahiya@gmail.com (R.P. Dahiya).

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1. Introduction

Livestock farming is one of the largest anthropogenic sources of greenhouse gas emissions (GHGs) (Casey and Holden, 2005; Garnet, 2009; Kumari et al., 2014). The total global GHGs emission from livestock is 7.1 gigatonnes $CO_2e\ yr^{-1}$, which accounts for 14.5% of all anthropogenic emissions (Gerber et al., 2013b). Methane (CH_4) is the second most abundant GHG after CO_2 and contributes nearly 9% to global GHGs emissions (EPA, 2013). Approximately 35% of the anthropogenic CH_4 emissions come from the livestock sector, equivalent to 2.2 billion tonnes of carbon dioxide equivalents (CO_2e) (Ingale et al., 2013). With increasing global demand for livestock products, GHGs emissions from livestock are projected to increase substantially by 2050 (Kristensen et al., 2011). As reported by Food and Agricultural Organization (FAO, 2003), unless the growth of livestock populations is controlled, an increase in livestock population will result in 60% more CH_4 emissions in 2030.

Emissions of GHGs from livestock occur mainly through two processes: (i) enteric fermentation, and (ii) manure management practices. CH_4 and N_2O are the two GHGs emitted from livestock, with CH_4 being emitted in significant quantity. Almost 90% of CH_4 emissions are the result of enteric fermentation (Chhabra et al., 2013; Pathak et al., 2013). Globally, enteric fermentation causes ~37% of anthropogenic CH_4 emissions (Chhabra et al., 2013; Koneswaran and Nierenberg, 2008). Emissions of GHGs from ruminant animal production systems are an emerging topic of interest due to their contribution to global climate change. Ruminants contribute significantly more to GHGs emissions than monogastric livestock, and emissions due to cattle are substantially higher than buffalo or sheep and goats (Ripple et al., 2014). Major regional contributions of this flux come from India, China, Brazil and the USA (IPCC, 2013). Globally, GHGs emissions from livestock range from 87 to 94 Tg yr^{-1} (IPCC, 2013). India, having the largest size of livestock, contributes 11.8 Tg yr^{-1} of CH_4 through enteric fermentation (Chhabra et al., 2013). Ruminant livestock possess a fore stomach, commonly known as the rumen where a group of methanogenic bacteria produce CH_4 from anaerobic digestion of cellulose and other macromolecules present in their feed by utilizing H_2 and expelling it through eructation from the mouth and nose (Lassey, 2007; Jha et al., 2011; Shrestha et al., 2013). CH_4 emissions are affected by the age of the animal, its body type, weight of the animal, and feed. CH_4 has an energy content of 55.22 MJ kg^{-1}, therefore, its production represents a significant loss of gross energy (Johnson and Johnson, 1995; Eckard et al., 2010). Its emissions cause a loss of about 5–7% of dietary gross energy, approximately 16–26 g kg^{-1} of dietary dry matter intake (DMI) (Hristov et al., 2013). On the basis of body weight, size, and DMI, sheep and goats can produce about 10–16 kg CH_4 yr^{-1} and cattle 60–160 kg yr^{-1} (Hristov et al., 2013). CH_4 production by enteric fermentation in the rumen of livestock also influences the performance of ruminants.

1.1. Global significance of CH_4 emissions from the indian livestock sector

India's livestock sector is one of the largest in the world. According to GOI (2007), India had a total of 529 million livestock, which makes India the largest contributor to global CH_4 emissions (FAO, 2007). However, approximately 90% of cattle and buffalo are indigenous breeds and have low productivity. According to a 2003 estimate, the Indian livestock sector emits nearly 12 Tg of CH_4 annually, of which more than 90% is released through enteric fermentation (Chhabra et al., 2013). This is much higher than CH_4 emissions from the US livestock sector (7.85 Tg yr^{-1}) (Hristov et al., 2014). The livestock sector of India accounts for 78% of total CH_4 emissions from the agriculture sector and about 50% of CH_4 emissions from all sectors in India (Swamy and Bhattacharya, 2006). Therefore, reduction of CH_4 emissions from livestock is a crucial step for India to achieve its GHGs emissions reduction goals.

Understanding the current trend, as well as future projections of CH_4 emissions is very important to identify policy gaps and to implement long-term policy mechanisms to reduce CH_4 emissions. Although baseline emission data for Indian livestock are available in the literature (Chhabra et al., 2013; Singh et al., 2012; Pathak et al., 2013; Yamaji et al., 2003; Swamy and Bhattacharya, 2006; ALGAS, 1998), studies concerning future projections are very limited. Furthermore, India does not have a statewide database of emission projections. Due to the large geographical extent and variations in the size of livestock among the states of India, statewide projections are important to design region-specific policy mechanisms to reduce CH_4 emissions. Considering these research gaps, the present study is conducted in India aiming to project livestock population growth and CH_4 emissions from Indian livestock for a 25 year period (from 2007 to 2032) under different modeling scenarios.

2. Methodology

System dynamics modeling approaches were applied in this study to project livestock population growth and CH_4 emissions from the Indian livestock sector. System dynamics are computer-based approaches to study, analyze, and solve complex problems. This modeling approach can assist decision makers to develop policies in the livestock sector (Sharawat et al., 2014; Anand et al., 2005; Georgiadis et al., 2005). Projections of livestock population and CH_4 emissions were carried out using STELLA 9.0.1 and mathematical models under baseline (BS) and modified (MS) scenarios. Both the scenarios were further sub-divided as BS-I, BS-II, BS-III and MS-I, MS-II, and MS-III. A database of livestock growth and emission factors was collected from standard sources (Government of India and IPCC). Four livestock categories (cattle, buffalo, goat, and sheep) were considered for the projection since they represent more than 95% of the livestock population in India.