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Estimation of Methane Emission From Livestock Through Enteric Fermentation Using System Dynamic Model in India

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Abstract

Enteric fermentation is one of the most important parts of the livestock mainly from livestock like cattle, buffalo, sheep and goat. The process of enteric fermentation emits methane in large fraction due to anaerobic fermentation in their digestive system. The present work is focused on the estimation of methane emission from livestock through enteric fermentation using system dynamic approach and mitigate policy have been suggested. Livestock have been divided into different category into cattle, buffalo, goat and sheep. Using their compound annual growth rate population projected and their emissions are estimated. System dynamic model is based on the dynamic interaction between the variables like different category of livestock and their emission coefficient to estimate methane emission from them.

Keywords- Enteric fermentation; livestock; system dynamic model

1. Introduction

The livestock sector is one of the most dynamic parts of the agricultural economy. The sector has expanded rapidly in recent decades and demands for livestock products is expected to continue growing due to rising population growth and urbanization. Livestock includes cattle, buffaloes, goats, sheep, pigs, horses, mules, donkey, camels, and poultry. Livestock contribute 40% of the global value of agricultural output and support the livelihoods and food security of almost a billion people. At the global level, livestock contribute 15% of total food energy and 25% of dietary proteins and also essential micronutrients that are not easily available from plant based food FAO 2009 (Terri Raney, 2009). Hence, livestock plays multifunctional activity.

Livestock production caused for emission of three major greenhouse gases like methane (CH_4) from enteric fermentation and manure management, nitrous oxide (N_2O) from manure, and carbon dioxide (CO_2) from land use change. N_2O emissions from soils and CH_4 from enteric fermentation constitute the largest sources 38% and 32% of total non-CO_2 emissions from agriculture in 2005, respectively. Biomass burning (12%), rice production (11%), and manure management (7%) account for the rest (McCarthy 2001). If demands for food increases then annual emissions of GHGs from agriculture may increase further. GHG emission from livestock has mainly two components: (a) Methane emission from enteric fermentation and manure management. (b) Nitrous oxide from animal waste management system. The emission per unit of livestock and livestock products vary by animal type and seem to be higher in beef, sheep and dairy than in pig and poultry farming.

1.1. Methane Emission

Atmospheric methane (CH_4) is one of the most important trace gases for the global environment and climate change. It affects the radiative budget of the earth and also plays an important role in the atmospheric photochemistry of the troposphere and stratosphere. Currently, methane contributes about 20% of anthropogenic radiative forcing second after carbon dioxide at 60% (Lassey, 2007). Methane remains in the atmosphere for nearly 9–15 years and is about 21 times more effective in trapping heat in the atmosphere than CO_2. It is very likely that the observed increase in methane concentration is due to human-related activities; predominantly agriculture and fossil fuel use (McCarthy, 2001) . The amount of methane produced depends on the type of animal, the amount, the kind of feed it consumes and the type of animal waste management. Methane emitted mainly by two processes, they are enteric fermentation and manure management. These animals possess rumen or fore stomach, which allows them to digest large quantities of cellulose and other roughages found in plant material. A small fraction of symbiotic microorganisms (3–10%) is methanogenic bacteria, which produce methane while removing hydrogen from the rumen. Methane is released mainly through eructation and normal respiration and a small quantity as flatus (Swamy and Bhattacharya, 2006) CH_4 produced from manure stores is estimated with the help of Methane Conversion Factors (MCF).

2. **System Dynamic Methodological Approach**

System dynamics is a methodology for analyzing complex systems and problems over time with the help of complex simulation software. It is different from other for studying complex system with the use of positive feedback loop (reinforcing loop) and negative loop (balancing loop), stocks and flows. The steps in the simulation are to defining the problem, Causal loop diagram making, developing mathematical formulation in the flow diagram, Scenario development and validation and sensitivity analysis of model.

2.1. Causal loop diagram:

A causal loop diagram was developed by using key elements which captures overall system dynamics behavior and performance. It serves as preliminary sketches of causal hypothesis during model development and also simplifies the representation of model. Causal diagram shows causal relations between variables which forms feedback loop. If they are connected by a plus sign (+) indicate that change in one variable change the other in the same direction while a negative sign (-) indicates that the variables are counteracting as shown in the fig. 1.

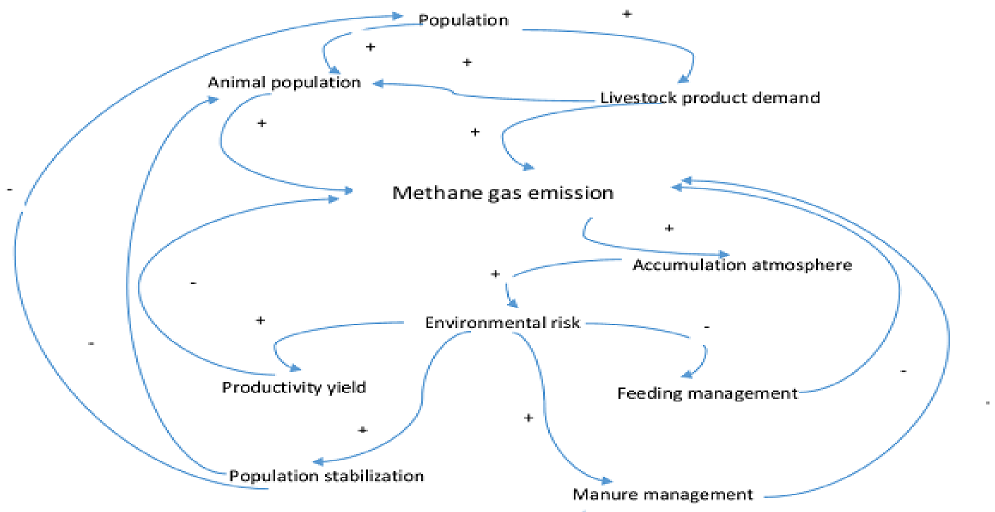

Figure .1. Causal loop diagram for the greenhouse gas emission from livestock and its mitigation methods.

2.2 Stock-flow diagram

In SD model simulation done by using stock and flow diagram. Flow diagram contains three types of variables- stock, flow and converter. Stock represented by rectangle box is used for accumulations whatever flows into them. The flow variable symbolized by double lined arrow with valves is used to fill or drain accumulation in stock. Flows determine the rate of changes in stock. The third variable is converter symbolized by circles, serves a useful role in the software. It holds values for constants, defines external inputs to the model, calculates algebraic relationships, and serves as the repository for graphical functions. In general, it converts inputs into outputs. The single arrow is use to represents the cause and effect links within the model structure known as connectors. In this method population projected using the last census year data for the coming years and on the basis of that emission from animals calculated using specific emission coefficient.

Animal population projected with the help of compound annual growth rate using the following equation are given below and these equation were used in the stock flow diagram as shown in the fig 2. Population is projected using the dynamic equations given below

$$P_t = P_{t-1} + dt \times m_g \quad (1)$$

$$m_g = P_{t-1} \times m_{cg}, \quad (2)$$

where, P_t is the current population at time t, P_{t-1} is the population in previous year, m_g is growth multiplier and m_{cg} is compound annual growth rate. For this purpose livestock category divided into different category on the basis of age, gender and breeding type and then their population projection made. Different category of livestock is cattle indigenous and crossbred, buffalo sheep crossbred and indigenous and goat. They are divided into male and female category also.

For estimation of methane gas emission from livestock specific emission factor obtained from IPCC guidelines was used and the equations are given below.

$$E\ (\text{Tg/year}) = \frac{\left[P \times 10^3 \times EF\left(\frac{\text{kg}}{\text{head}-\text{year}}\right)\right]}{10^9\ \text{kg/year}}\ \text{Tg/year}$$

where E is the emission emitted by livestock and EF is the specific emission factor from different category of livestock.

2.2. Scenario development

Population projection and estimation of methane from livestock made for the starting base line year 2007 using the existing condition this is known as business as usual scenario (BAU). On the basis of BAU, certain modification has been made in the existing condition and then the results are compared to know the results. The results obtained for different scenarios developed in the SD model are discussed to decide the impact of alternative policy option on CH_4 emission from the livestock mainly cattle, buffalo, goat and sheep in India. In case of the purpose of work several mitigation policy like population growth stabilization, feeding management, increase of production yield may be policy option to decrease the emission from livestock.

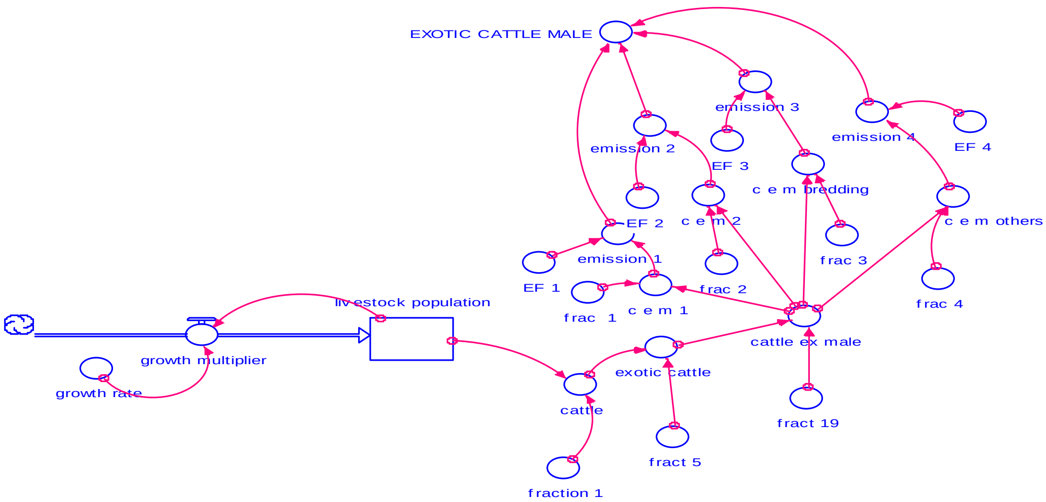

Figure.2. Stock-flow diagram for methane gas emission from livestock using system dynamics approach in this model livestock divided into cattle which is divided into exotic cattle and then in male and female, which is again divided into their different age groups represented by circles in the diagram.

2.3. Model validation

Model validation is the most important step to identify the validation of results. This can be done by historical validation, structural validation and sensitivity analysis of model. This also identifies the robustness of model. These changes in the variables is use to assure that any changes in the variable in the model can lead to change in the model simulation and their results. Once the robustness in the model is assured, the model can be used for policy making and scenario generation.

3. Conclusion

Methane emission from livestock estimated by different works such as Chhabra et al.(2013) for the year and found that enteric fermentation from livestock like cattle, buffalo, sheep and goat is 10.65 Tg/year in the year 2003. While in Singh et al. (2012) found that it is about 9.09 for the year 2003. Many factor affects the methane emission from livestock which include level of feed intake, type of carbohydrate in the diet, manipulation of these factors can reduces methane emission from livestock.

4. References

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