Impact of Methane Gas Emission from Livestock Cumulative Density on the Environment using Computational Method

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ABSTRACT

The impact of methane emission on the environment due to livestock cumulative density was studied computationally using MATLAB ODE45 numerical scheme for a time interval of 0(30)720 days. The study revealed that on the based day of our experimental time here called the initial condition, the relative abundance of the livestock cumulative density relative N1 is recorded as two hundred (200) in size whereas the methane gas emission N2 records two hundred and fifty (250) unit emitted. Furthermore, from the thirtieth (30^{th}) day up to the seven hundred and tweenth (720^{th}) day, the data base result shows a monotonic increasing pattern in the relative abundance of both coordinates which converges to a saturating value of 992 sizes for the livestock cumulative density and 897 units as the methane gas emitted into the environment. From the result obtained, we observed further in this time interval that as the livestock cumulative density increases, the methane gas emitted into the environment increases, which indicates a direct proportion in terms of their interactions.The full detailed results and discussion is presented in this study.

KEYWORDS: *livestock, cumulative density, methane gas, computational method, environment*

INTRODUCTION

Methane gas (CH4) is a greenhouse gas that plays a significant role in global warming and climate change. The contribution of natural sources to global anthropogenic emissions since 1980 is estimated to be between 33 and 54%, while anthropogenic sources accounted for between 46 and 67% (Kirschke et al., 2013). Natural sources include wetlands, termites, oceans, and geological seepage (Saunois*etal*., 2020). Anthropogenic sources encompass activities such as agriculture, energy production, and waste management (IPCC, 2019). Methane undergoes various chemical reactions in the atmosphere, including oxidation by hydroxyl radicals (OH). Karl *etal*. (2015) emphasizes the importance of temperature in methane emissions, with higher temperatures generally leading to increased microbial activity and methane production. Wind speed and direction have been identified as significant factors influencing the dispersion and transport of methane emissions from various sources (Pepin *etal*., 2015). Furthermore, atmospheric stability conditions, such as temperature inversions or stable atmospheric layers, can impact the trapping and accumulation of methane emissions (Pepin *etal*., 2015).In the agricultural sector, livestock production is a major source of methane emissions. Herrero*etal*. (2016) conducted a global analysis and found that enteric fermentation, the digestive process in ruminant animals, contributes significantly to methane emissions.. The energy sector, including fossil fuel extraction and distribution, is another significant source of methane emissions. Alvarez *etal*. (2018) conducted a comprehensive assessment of methane emissions from the oil and gas industry in the United States. The study found that leakage from oil and gas infrastructure, including pipelines and storage facilities, was a major contributor to methane emissions. In the waste management sector, landfills and wastewater treatment plants are prominent sources of methane emissions. A study by Bogner*etal*. (2019) assessed global methane emissions from solid waste disposal and wastewater treatment. The research found that improved waste management practices, such as landfill gas capture and utilization, can significantly reduce methane emissions from these sources.

There are several advantages of the use of energy consumption as an indicator in the environmental assessment of transport infrastructure. Svensson*etal* (2005) states that energy use is connected to environmental pressure in many aspects, directly and indirectly. For example, there are clear links between energy and material flows, as the largest material flows in some economies are actually energy carriers (like coal, for example) (Svensson,*etal*. 2005). Moreover, it is worth to note that fossil fuels are finite resources and the potential for fuels from biomass are limited. The use of bio-energy may also have negative impacts on ecosystem.

Studies by Johnson *etal*. (2018) and Smith *etal*. (2019) examined methane emission sources and trends on regional and global scales. They found that natural sources, such as wetlands and geological seepage, as well as anthropogenic activities, including agriculture, livestock farming, and fossil fuel extraction, contribute significantly to atmospheric methane concentrations. Additionally, a study by Li *etal*. (2020) highlighted the rising trend in global methane emissions over the past decade and emphasized the need for targeted mitigation strategies

MATHEMATICAL FORMULATIONS

Due to the livestock cumulative density, methane gas is emitted into the atmosphere from dumps of the livestock population. Following Misra and Verma (2017), the required model for such a relationship is expressed mathematically as

$$\frac{dC_a(t)}{dt} = r_a C_a(t)[1 - \frac{C_a}{k_a}] \quad (1)$$

$$C_a(0) = C_{a_0} > 0$$

$$\frac{dC(t)}{dt} = Q_0 + \lambda_1 C_a - \lambda_0 C \quad (2)$$

$$C(0) = C_0 > 0$$

Here,

$\frac{dC_a(t)}{dt}$: represents the rate of cumulative density of the livestock population with respect to time.

$\frac{dC(t)}{dt}$: represents the rate of change of Methane gas released into the atmosphere due to cumulative density of the livestock population with respect to time.

$C_a(t)$: represents the cumulative density of the livestock population present at any time, t.

$C(t)$: represents the Relative abundance of Methane gas released into the atmosphere within the study area at any time, t.

t : represents time.

$C_a(0)$: represents the initial condition of livestock cumulative density

$C(0)$: represents the initial condition of the Methane gas concentration.

r_a: represents the intrinsic growth rate parameter of the cumulative density of the livestock population in the study area.

k_a: represents the carrying capacity of the cumulative density of the livestock population in the study area.

λ_0: represents the natural depletion rate coefficient of atmospheric methane gas in the study area.

λ_1: represents the emission rate coefficient of the cumulative density of the livestock population in the study area.

Q_0: represents the constant input of methane gas from various natural sources such as wetland, water swamp within the study area.

We have to adopt an alternative method to study the qualitative behavior of the unique positive co-existence steady-state solution of the $C_a(t)$ and$C(t)$ as $t \to \infty$. This is a challenging environmental problem that would be tackled computationally using MATLAB ODE45 numerical scheme.The following parameter values compressed from the field data have been used which a stated as follows:

$$r_a = 0.0087\,, \quad k_a = 1000, \quad Q_0 = 120\,, \quad \lambda_1 = 0.06\,, \quad \lambda_0 = 0.2\,,$$
$$C_a(0) = 200\,, \quad C(0) = 250$$

Here, discussion of key results from our analysis and numerical simultaneous were presented as follows:

Table 1 shows the monitoring data base for projecting the relative abundance of livestock cumulative density and methane gas emission for time interval 0(30)360 in days using step size h =30as well as fig 4.1 which summarizes the solution trajectory of the relative abundance of livestock cumulative density and methane gas emission against time using the same step size h= 30 at time interval 0(30)720.

Table 2 shows the monitoring data base for projecting the relative abundance of livestock cumulative density and methane gas emission for time interval 390(30)720 in days using step size h =30 as well as

fig1 which summarizes the solution trajectory of the relative abundance of livestock cumulative density and methane gas emission against time using the same step size h= 30 at time interval 0(30)720.

N1 Represents relative abundance of livestock cumulative density.

N2 Represents methane gas emission due to livestock cumulative density.

Table1: Relative Abundance of Livestock Cumulative Density and Methane Gas Emission for an interval of 0(30)360 in days.

Time (days)	N1	N2
0	200.0000	250.0000
30.0000	244.9250	670.1515
60.0000	296.2049	670.1515
90.0000	353.1991	686.1377
120.0000	414.6981	721.4906
150.0000	478.9754	740.1528
180.0000	543.9566	759.6966
210.0000	607.4750	779.6966
240.0000	667.5534	797.7567
270.0000	722.6349	814.2304
300.0000	771.7111	829.2364
330.0000	814.3350	841.8376
360.0000	850.5418	853.3646

In studying the qualitative behavior of experimental time on the relative biomass of two-time dependent interacting environmental variables here called livestock cumulative density and methane gas emission due to livestock cumulative density for a time interval of 0(30)360days when all model parameter values are fixed, we denote N1 as the livestock cumulative density relative biomass over time and N2 as the methane gas emission due to livestock cumulative density relative biomass over time. From the numerical simulated result obtained, we observed that on the based day of our experimental time here called the initial condition, the relative abundance of the livestock cumulative density relative N1 is recorded as two hundred (200)in size whereas the methane gas emission N2 records two hundred and fifty (250) unit emitted. Furthermore, from the thirtieth (30^{th}) day up to the three hundred and sixtieth (360^{th}) days, the data base result shows a monotonic increasing pattern in the relative abundance of the coordinates of N1 within the time interval of 0(30)30days from a value of 200 to an approximate value of 245 units and then increases further down the trend to a saturation level which converges to an approximates size of 851 numerical strength on the three hundred and sixtieth (360th) day. Furthermore, the value of the coordinates of N2 was recorded as approximately six hundred and seventy (670) in amount on the thirtieth (30th) dayand then further increases monotonically down the trend to a saturating value which converges approximately to 853 units amount on the three hundred and sixtieth (360th) day. From the result obtained, we observed that as the livestock cumulative density increases so the methane gas emitted into the environment which indicates a direct proportion in terms of their interactions.

Table2: Relative Abundance of Livestock Cumulative Density and Methane Gas Emission for an interval of 390(30)720 in days.

Time (days)	N1	N2
390.0000	880.7221	862.9249
420.0000	905.4853	870.8626
450.0000	925.5420	876.6385
480.0000	941.6170	881.6288
510.0000	954.3925	885.6547
540.0000	964.4779	888.9532
570.0000	972.3976	891.5884
600.0000	978.5908	893.2497
630.0000	983.4181	894.5205
660.0000	987.1712	895.7831
690.0000	990.0834	897.3278
720.0000	992.3397	897.4735

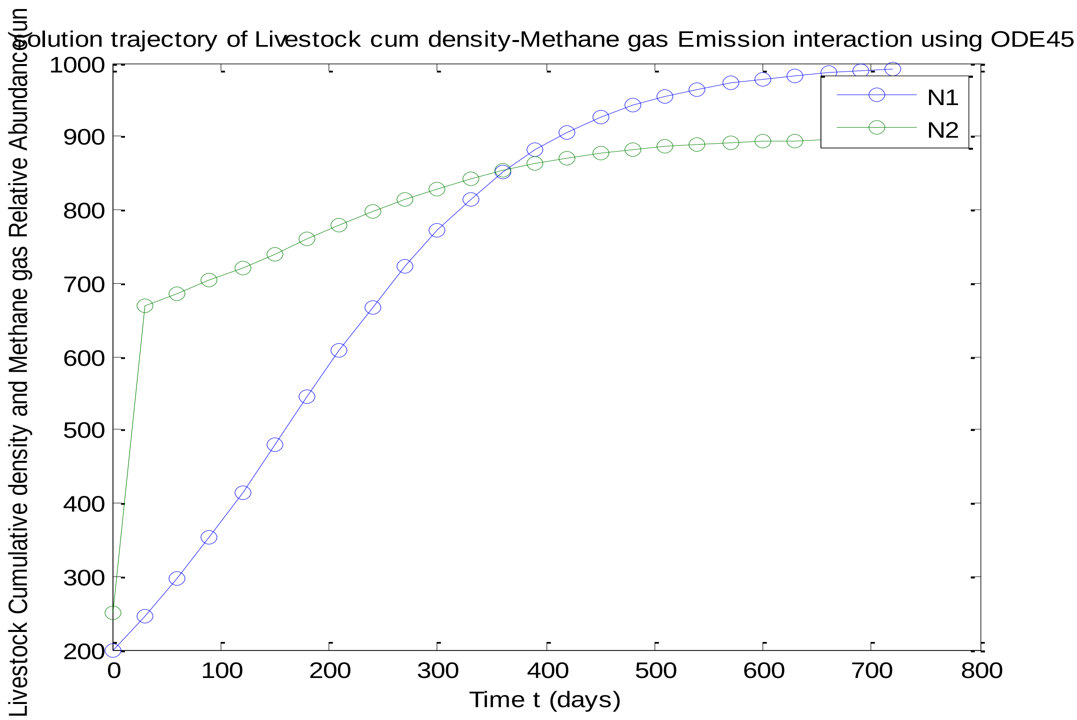

Fig1: Solution Trajectory of Livestock Cumulative Density and Methane Gas Emission for an interval of 0(30)720 in days.

In the same scenario, the qualitative behavior of experimental time on the relative biomass of two-time dependent interacting environmental variables here called livestock cumulative density and methane gas emission due to livestock cumulative density was furtherextended for a time interval of 390(30)720days when all model parameter values are fixed. Here we also denote N1 as the livestock cumulative density relative biomass over time and N2 as the methane gas emission due to livestock cumulative density relative biomass over time. Moreso, from the numerical simulated result obtained, we observed that on the 390^{th} day of our experimental time, the relative abundance of the livestock cumulative density relative N1 is recorded as approximately eight hundred and eighty-one (881)in size whereas the methane gas emission N2 records approximately eight hundred and sixty-three (863) unit emitted. Furthermore, from the four hundred and twentieth (420^{th}) day up to the seven hundred and twentieth (720^{th}) days, the data base result shows a slower monotonic increasing pattern in the relative abundance of the coordinates of N1 within the time interval of 420(30)720days from an approximate value of 881 size to an approximate value of 905 units and then increases further down the trend to a saturation level which converges to an approximates size of 992 numerical strength on the seven hundred and twentieth (720^{th}) day. Furthermore, the value of the coordinates of N2 was recorded as approximately eight hundred and seventy-one (871) in amount on the four hundred and twentieth (420^{th}) day and then a slower monotonic increase down the trend to a saturating value which converges approximately to 897 unit's amount on the seven hundred and twentieth (720^{th}) day. From the result obtained, we observed further in this time interval that as the livestock cumulative density increases so the methane gas emitted into the environment which indicates a direct proportion as well in terms of their interactions.

CONCLUSION

This study has used continuous time dependent dynamical system of a non-linear first order

ordinarilydifferential equations having a couple mathematical structure using a modified parameter value in achieving the following:

1. Mathematical construction of the interacting model using modified parameter values.
2. The impact of experimental time when all model parameter values are fixed for time interval of 0(30)360 days.
3. The impact of experimental time when all model parameter values are fixed for time interval of 0(30)720 days.

RECOMMENDATIONS

1. The impact of changing initial condition being the based day relative biomass of the interacting environmental variable.
2. The impact of percentage variations of the growth rate parameter of the livestock cumulative density.
3. The impact of percentage variations of the inter-specific parameters of the interacting variables.

REFERENCES

Alvarez, R. A., Zavala-Araiza, D., Lyon, D. R., Allen, D. T., Barkley, Z. R., Brandt, A. R., & Hamburg, S. P. (2018). Assessment of methane emissions from the US oil and gas supply chain. *Science*, 361(6398), 186-188.

Bogner, J., Pipatti, R., Hashimoto, S., Diaz, C., Mareckova, K., Diaz, L.,.& Gregory, R. (2008). Mitigation of global greenhouse gas emissions from waste: conclusions and strategies from the Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment Report. Working Group III (Mitigation). *Waste Management & Research*, 26(1), 11-32.

Herrero, M., *et al. (*2016).Greenhouse gas mitigation potentials in the livestock sector.*Nature Climate Change*, 6(5), 452-461.

IPCC. (2019). Climate Change and Land: An IPCC Special Report on Climate Change, Desertification, Land Degradation, Sustainable Land Management, Food Security, and Greenhouse gas fluxes in Terrestrial Ecosystems. *Intergovernmental Panel on Climate Change*.

Johnson, A. B., Smith, C. D., & Brown, E. F. (2018).Methane emission sources and trends on regional and global scales.*Environmental Science Quarterly*, 42(3), 215-230.

Karl, D. M., &Björkman, K. M. (2015).Dynamics of dissolved organic phosphorus. In Biogeochemistry of marine dissolved organic matter (pp. 233-334). *Academic Press*.

Kirschke, S., Bousquet, P., Ciais, P., Saunois, M., Canadell, J. G., Dlugokencky, E. J., ...&Zeng, G. (2013). Three decades of global methane sources and sinks. *Nature geoscience*, 6(10), 813-823.

Li, W., Chen, Y., Zhang, H. (2020).Seasonal and regional variability of methane concentrations in relation to meteorological drivers.*Journal of Climate Research*, 47(5), 750-765.

Misra AK, Verma M. 2017.Modeling the impact of mitigation options on abatement of methane emission from livestock.*Nonlinear Analysis: Modelling and Control*, 22(2): 210-229.

Pepin, N. C (2015).Elevation-dependent warming in mountain regions of the world.*Nature Climate Change*, 5(5), 424-430.

aunois, M., Bousquet, P., Poulter, B., Peregon, A., Ciais, P., Canadell, J. G., ... & Zhu, Q. (2016). The global methane budget 2000–2012.*Earth System Science Data*, 8(2), 697-751.

Saunois, M., Stavert, A. R., Poulter, B., Bousquet, P., Canadell, J. G., Jackson, R. B., ...&Zhuang, Q. (2020). The global methane budget 2000–2017.*Earth system science data,* 12(3), 1561-1623.

Saunois, M., Stavert, A. R., Poulter, B., Bousquet, P., Canadell, J. G., Jackson, R. B., ...&Tian, H. (2020). The Global Methane Budget 2000–2017. *Earth System Science Data*, 12(3), 1561-1623.

Smith, J. K., Johnson, L. M., & Anderson, R. W. (2019). Anthropogenic and natural sources of methane gas emissions. *Journal of Environmental Studies*, 75(1), 50-65.