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GIS-Based Estimate of GHG Emission from Livestock in Anambra State of Nigeria

E. C. Chukwuma[1*], C. O. Nwajinka[1], L. C. Orakwe[1] and C. C. Odoh[2]

[1]Department of Agricultural and Bio-Resources Engineering, Nnamdi Azikiwe University, Awka, Anambra State, Nigeria.
[2]Department of Environmental Management, Nnamdi Azikiwe University, Awka, Anambra State, Nigeria.

Authors' contributions

This work was carried out in collaboration between all authors. Authors ECC, LCO and CON designed the study, wrote the protocol, and wrote the first draft of the manuscript. Authors ECC and CCO anchored the field study and gathered the initial data. Authors CON and LCO managed the literature searches. Authors ECC and CCO did the preliminary data analyses of the study. All authors read and approved the final manuscript.

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ABSTRACT

The need for improved livestock waste management in developing countries has been emphasized by various researchers. Consideration has been given globally to advocacy for a transition from fossil energy system to Renewable Energy (RE), based on several socio-economic and environmental advantages. Green House Gas (GHG) from agricultural sector of Anambra State, with appropriate waste management strategy such as Anaerobic Digestion (AD) will definitely mitigate Methane emission hazards and will as well supply the much needed energy for domestic and industrial uses. An investigation was carried out in this study to estimate the Methane Emission Potential (MEP) of the study area as a result of poor livestock waste management system practiced in the area. This was achieved by incorporating Geographical Information System (GIS) capability to the Methane estimation. The result of the study shows that two Local Government Areas (LGA)

**Corresponding author: E-mail: ec.chukwuma@unizik.edu.ng, ecchukwuma12@gmail.com;*

which are Anambra West and Anambra East were the least in MEP with virtually none and 0.000646 Gg/year respectively. Idemili North LGA with MEP of 0.017962 Gg/year was observed to be the highest in Methane emission. On incorporating spatial density mapping on MEP, Onitsha North and Idemili North LGA were identified as the highest risk LGAs, with MEP of 0.00018 Gg/year and 0.000272 Gg/year respectively. The study suggests that an improved livestock waste management system using AD should be incorporated in the study area especially in the high risk zones of Onitsha and Idemili North LGA.

Keywords: Methane emission; GIS; agricultural waste; anaerobic digestion; Anambra State of Nigeria.

1. INTRODUCTION

Associated with population increase is growing demand for meat products. Consequently, the number of slaughterhouses is on the increase with increasing number of animals for slaughter to satisfy the increasing population. This has given way to intensive livestock husbandry system with rapid expansion. As a consequence, the development of the livestock sector has created serious environmental problems including water pollution and GHG emissions since 1979 [1]. It has been reported that in Finland, agricultural sector is the third most significant source of GHG emissions after energy sector and industrial processes [2]. Agricultural sector in China contributes as much as 15–17% of total GHG emissions, mostly through CH_4 and N_2O emissions [3]. Because of the ever increasing impact of GHG emissions from agricultural sector in China, several research concerning GHG emissions from livestock is gaining momentum in the area [4].

A theoretical estimate of methane emissions from both livestock manure in Nigeria and municipal solid waste deposits in some of the country's major cities have been provided [5]. Ten-year data obtained from the United Nations Food and Agricultural Organization (FAO) was used to estimate the methane emissions from animal wastes using a mathematical approach developed by the Intergovernmental Panel on Climate Change (IPCC).The result of the study shows that Onitsha (one of the commercial cities in the study area) is the second to the highest in statistical MEP amongst the South-Eastern mega cities in Nigeria.

There is immense need to adopt sustainable strategy in agricultural production. Agricultural sector presents a substantial potential for climate change mitigation. The global technical mitigation potential is approximately 5500–6000 Mt CO_2-eq./year by 2030 for all land-based emissions, including CH_4 emissions from ruminants, with a further 770 Mt CO_2-eq./year possible for agricultural energy-based emissions [6]. Methane capturing processes and optimization strategies has been suggested as appropriate strategy for mitigating methane emission problem in the study area [7-8]. Biogas production is a current trend within agricultural sector and bio-energy production [2]. It has been observed that one of the ways to successfully deal with manure management and the associated GHG emissions is through AD of manure. AD is an attractive sustainable environmental technology in the agricultural sector considering that it stabilizes the organic wastes and produces renewable energy in the form of biogas (CH_4 and CO_2) and nutrient-rich digestate. The produced CO_2 and CH_4 neutral biogas can be used to replace fossil fuels for heat and/or electricity generation, and/or can be upgraded as vehicle fuel. With the growing interest in exploring renewable energy, GIS has proved to be an effective tool to address issues related to biomass availability and biomass logistics [9].

The objective of this study is to estimate the GHG potential from agricultural sector of Anambra State of Nigeria and hence advocate the use of appropriate waste management strategy such as AD to the relevant authorities. This will be achieved in this study using GIS capability.

2. STUDY AREA

Anambra is the eight most populated State in the Federal Republic of Nigeria and the second most densely populated state after Lagos State. According to National Population Commission in 1991, the study area population is about 2,796,967 with 2.8% annual growth rate. The study area is located in the South-Eastern Nigeria. It is located between Latitudes 05°4215611N and 06°4513411N and Longitude

06°3713011E and 07°2513011E. Its boundaries are formed by Delta State to the West; Imo State and Rivers State to the South; Enugu State to the East and Kogi State to the North. The topography and climatic vegetation of the area makes it very suitable for extensive modern agricultural investment. It is endowed with 60% arable land, thus suitable for large-scale farming. The annual rainfall is about 1300 mm, peak rainfall occurs in June to July while the second peak occurs in September to October. Fig. 1 shows the map of the study area. The study area consists mainly of urban, semi-urban and rural areas. The populate engages in agricultural activities that includes: livestock farming/production, crop production, fisheries etc Livestock such as poultry, goats, and sheep under free range system are kept in the rural areas of the study area. However, the poultry keeping in confirmed system is becoming popular with numerous well established large poultry farms in the urban and semi-urban areas of the state according to statistical report [10].

Fig. 1. Map of Nigeria show Anambra State

3. METHODOLOGY

3.1 Data Collection

The primary data for this study was obtained from Anambra State Bureau of Statistics Awka, Anambra State of Nigeria. Because of lack of data plaguing the state, this study focused on Methane emission from manure management, the Methane emission estimate was based on IPCC criteria for livestock system. The Department of Veterinary Services, Ministry of Agriculture and Rural Development, Awka provided poultry population census in the study area for 2015. There seems to be no data on other livestock like cattle, pigs, goats etc; this could also be attributed to subsistence farming in the region and unwillingness of some farmers to get registered, perhaps because of financial involvement. The data on number of slaughtered animal was used to estimate the number of livestock in the state, thus the data used is conservative.

3.2 GIS Mapping of GHG MEP

To estimate the MEP of the study area, the data of the number of livestock slaughtered in the various markets in the study area was used as a guide to the probable number of livestock in the region. From preliminary studies of abattoirs in the study area, the cattle and goats are supplied majorly from Northern Nigeria (which is known for livestock production). Pig and poultry farms however dominate the study area. The number of standing animals in these markets is usually as much as 10 times in number to the slaughtered ones. Table 1 shows the number of livestock slaughtered in the various LGAs of the state within 2010-2011 for cattle and 2007-2008 for goat and pig.

Population growth rate in the state is given at a rate of 2.83% by the National Population Commission. The Anambra State Bureau of Statistics Awka, observed in their publication of 2011 that there was about 2 percent increase in consumption of cattle from the year 2010 to 2011. Due to the unavailability of data, 2% annual increase (growth rate) projection inference was made and used as estimate for the year 2018. A conservative estimate of livestock in stock made for cattle, goat and pig is shown in the Table 2. The estimate for poultry was made from the publication of Anambra State Bureau of Statistics Awka for the year 2015. A 2 percent compound growth rate was also used to obtain 2018 projection. This is shown in Table 2.

Table 1. Selected Years for Livestock Slaughtered in Registered Markets by L.G. A

S/N		[b]Cattle		[a]Goat		[a]Pig	
	LGA/Year	**2010**	**2011**	**2007**	**2008**	**2007**	**2008**
1.	Aguata	2,000	1,440	1089	2218		
2.	Anambra East	NA	NA	NA	NA	NA	NA
3.	Anambra West	NA	NA	NA	NA	NA	NA
4.	Anaocha	570	600	993	1164	1188	1001
5.	Awka North	NA	2,160	2196	1764	1344	879
6.	Awka South	5,140	3,567	1146	1516	1167	1185
7.	Ayamelum	NA	NA	NA	NA	991	1132
8.	Dunukofia	3,440	3,600	1132	1093	1639	1082
9.	Ekwusigo	194	480	895	1644	1075	1275
10.	Idemili North	5,950	6,480	1867	894	1889	2184
11.	Idemili South	4,050	4,080	898	697	1048	1086
12.	Ihiala	1,200	2,160	844	895	1167	788
13.	Njikoka	990	1,440	1328	1314	1234	1067
14.	Nnewi North	6,010	5,040	1568	2160	980	1581
15.	Nnewi South	1,060	1,080	1995	1733	1081	1104
16.	Ogbaru	NA	NA	987	896	999	895
17.	Onitsha North	3,010	2,880	1088	2437	1205	1138
18.	Onitsha South	2,600	2,440	2019	1189	1267	1184
19.	Orumba North	2,015	1,360	900	884	1375	1086
20.	Orumba South	290	360	1009	1004	1288	1287
21.	Oyi	4,222	4,320	895	NA	NA	1190
	Total	**42,741**	**43,487**	**22,849**	**23,502**	**22,250**	**22,385**

Source: Statistical year book of Anambra 2009[a];2011[b].(NA=Not Available)

Table 2. Estimate of Stock of the various livestock for 2018

S/N	LGA	[b]Cattle	[b]Goat	[b]Pig	[a]Chicken	[b]Chicken
1.	Aguata	1654	2548	-	159407	169164
2.	Anambra East	-	-	-	26480	28101
3.	Anambra West	-	-	-	-	-
4.	Anaocha	689	1338	1149.834	43210	45855
5.	Awka North	2481	2026	1009.695	162,658	172614
6.	Awka South	4097	1741	1361.193	194,130	206012
7.	Ayamelum	0	0	1300.312	6330	6717
8.	Dunukofia	4135	1256	1242.878	18540	19675
9.	Ekwusigo	551	1888	1464.574	53268	56528
10.	Idemili North	7443	1027	2508.729	216132	229361
11.	Idemili South	4687	801	1247.473	28310	30043
12.	Ihiala	2481	1028	905.1643	43373	46028
13.	Njikoka	1654	1509	1225.648	225271	239059
14.	Nnewi North	5789	2481	1816.072	83683	88805
15.	Nnewi South	1241	1991	1268.149	26821	28463
16.	Ogbaru	0	1029	1028.074	348000	369300
17.	Onitsha North	3308	2799	1307.204	55865	59284
18.	Onitsha South	2803	1366	1360.044	19975	21198
19.	Orumba North	1562	1015	1247.473	38385	40734
20.	Orumba South	414	1153	1478.358	25720	27294
21.	Oyi	4962	-	1366.936	86652	91956
	Total	**49953**	**26996**	**25713**	**1844557**	**1,978,210**

Source: *[a]Department of Veterinary Services, Ministry of Agriculture and Rural Development, Awka, Anambra State. [b]Author's Calculations.*

because of lack of data for stock in the state, a conservative estimate was made based on the assumption that the number livestock slaughtered is the same with the number of livesstock available for collection of wastes annually.

By limitation of accessibility to livestock wastes in various homes, restaurant etc for biogas production, the market wastes was used in the assessment criteria for this study. Projected livestock slaughtered in registered markets by LGA for year 2018 was calculated based on 2% increase in the number of slaughtered livestock. The total amount of dung production is calculated by equation (1):

$$Q_p = \sum P_i A_i 365 \quad (1)$$

Where Q_p is the amount of dung produced annually in Kg, P_i is the population of the livestock i, A_i is the availability of the waste for collection for livestock i.

In this study, the mathematical approach developed by IPCC was used for estimating the quantity of Methane emissions [11], the annual Methane emission estimate is shown by equation (2):

$$\text{ATMEP} = \text{EF}_a \times \text{P} \times 10^{-6} \quad (2)$$

Where ATMEP is the Annual Total MEP Value, EF_a is the Emission Factor and P is the population of the livestock.

$$EF_a = [VS_i \times Bo_i] * 0.67 \sum_{jk} MCF_{jk} \times MS_{ijk} \quad (3)$$

EF_a	=	annual CH4 emission factor for livestock category *T*, kg CH4 animal^{-1} yr^{-1}
VS_i	=	daily volatile solid excreted for livestock category T, kg CH_4 animal^{-1} yr^{-1}
365	=	basis for calculating annual VS production, days yr^{-1}
Bo (T)	=	maximum methane producing capacity for manure produced by livestock category *T*, m^3 CH_4 kg^{-1}of VS excreted
0.67	=	conversion factor of m^3 CH_4 to kilograms CH_4
$MCF_{(j,k)}$	=	methane conversion factors for each manure management system j by climate region *k*, %
$MS_{(i,j,k)}$	=	fraction of livestock category i's manure handled using manure management system j in climate region *k*, dimensionless.

In this work, the following emission factors for tropical African countries of pigs = 2, cattle = 1, goat = 0.22, sheep = 0.21 and chickens = 0.023 were used according to Suberu et al., (2013) and IPCC (2006).

The Spatial density of MEP for the LGAs is given as

$$SD_{MEP} = \frac{\text{ATMEP}}{A_l} \quad (4)$$

Where A_l is the area of the LGA.

4. RESULTS AND DISCUSSION

4.1 GIS Map of MEP

The GIS MEP map in Fig. 2 shows that Anambra West and Anambra East emissions have the least environmental danger posed by MEP of Nil and 0.000646 Gg/year respectively. This could be attributed to the nature of the area (wetland) that makes it challenging for livestock rearing. Next to regions of least danger posed by environmental hazards of Methane emission is Ayamelum (0.002755 Gg/year), Orumba South (0.004252 Gg/year), and Aniocha (0.004338 Gg/year) LGAs, this could also be attributed to the level of intensity of livestock farming in the region. Awka North, Dunukofia, Onitsha North and Idemili South LGAs were placed on the same level of risk. Worthy to note is that Idemili North is the highest risk area having 0.017962 Gg/year followed by Ogbaru, Nnewi North, Oyi, Njikoka and Awka South LGAs. The high emission rates of these areas could be attributed to livestock management system and the intensity of livestock production.

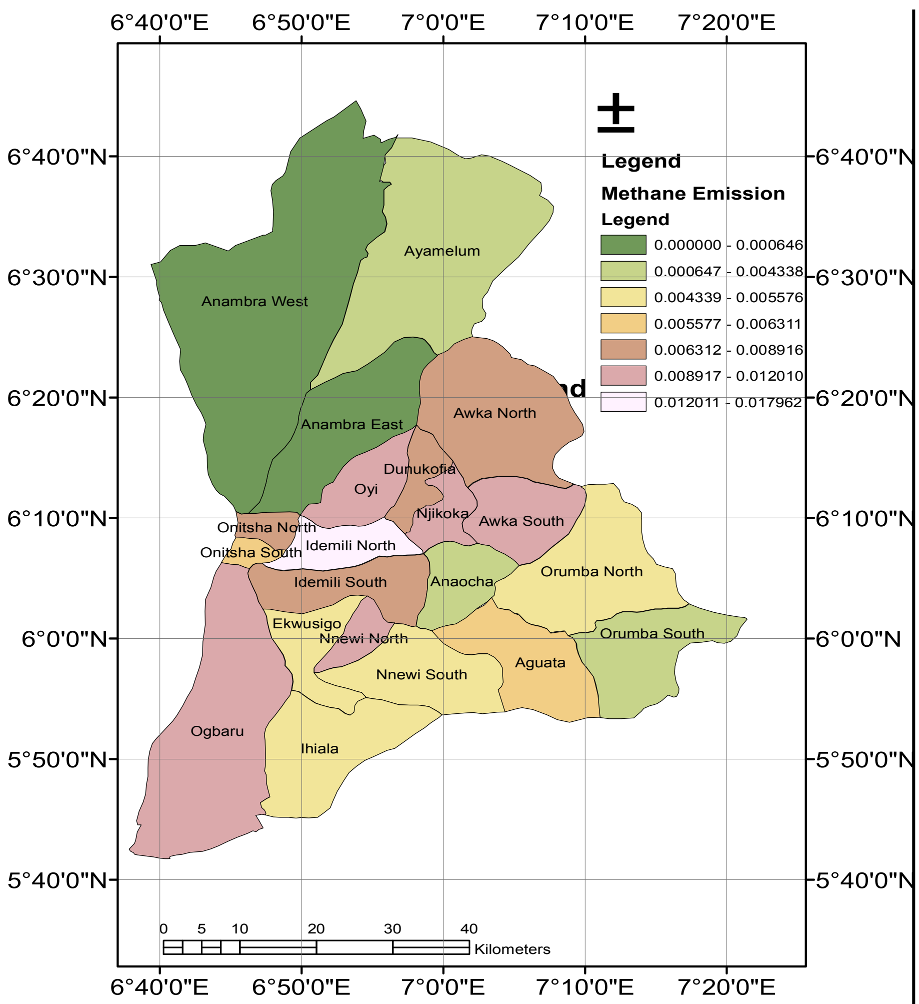

Fig. 2. Methane Emission Potential of Various LGA in the study area

4.2 Spatial Density map of Methane Emission Potential

The Methane emission spatial density map of the study area is designed to show the concentration of livestock farms or Methane emission per unit area of the study area. The result is to demonstrate regions with higher Methane emission capacity as regions that has clustering of livestock farms or higher agriculture based Methane emissive points. Fig. 3 shows spatial density map of MEP of the study area. From the Figure, it could be observed that Onitsha and Idemili North has the highest MEP. This corresponds with previous studies which indicated high level of pollution in the city of Onitsha (Suberu, et al., 2013). This is however made vivid by using spatial density criteria in assessing the MEP. Since Onitsha is the biggest commercial city in the study area, it is not surprising that Idemili North L.G.A being in proximity to the city could be a major site for livestock farming in other to cater for the staggering need for livestock products in Onitsha metropolis. From the result of the study, an improved livestock management system is strongly recommended and the use of AD system for animal waste management will be most appropriate mitigation strategy. Centralized bio-plant for animal waste management have been suggested by various researchers, and should be incorporated in the study area.

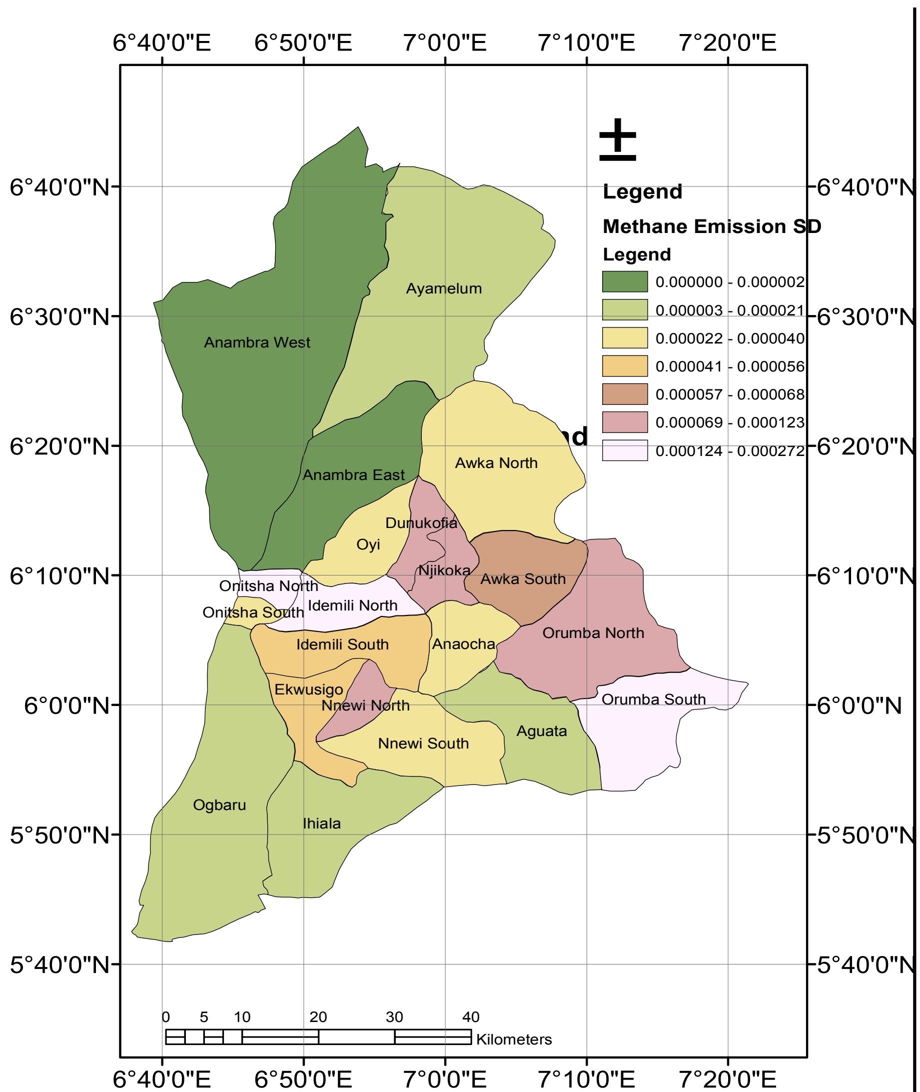

Fig. 3. Methane Emission spatial density map of the study area

5. CONCLUSION

From the study a conservative approach in estimating MEP using GIS capability was presented. The Methane emission factor for various livestock in the study area was obtained using IPCC mathematical model. The result of the study indicates that Anambra West and Anambra East LGAs were classified as lowest in risk assessment while Idemili North was observed to be the highest risk LGA. On incorporating the spatial density of Methane emission sources, Onitsha North and Idemili North LGAs were identified as the highest risk LGAs. This study suggests that improved livestock management system should be incorporated in the study area especially in the high risk zones.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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