Research Article

The "Buharinomics" Legacy on the Hoof: Rising Greenhouse Gas Emissions from Nigeria's Livestock Sector and Pathways to Mitigation

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Abstract | The livestock sector is a critical component of Nigeria's agricultural economy but a significant source of greenhouse gas (GHG) emissions, primarily methane (CH_4) and nitrous oxide (N_2O). This study provides a comprehensive analysis of the trends and structure of these emissions during the Buharinomics era (2014-2022), a period defined by policies aimed at agricultural expansion and self-sufficiency. Utilizing secondary data on livestock populations and applying IPCC methodological frameworks, the study quantified emissions from key livestock categories, including cattle, sheep and goats, poultry, and swine. The results reveal a consistent and significant upward trajectory in the sector's carbon footprint, with total GHG emissions increasing by 13.6% over the eight-year period. The emission profile is overwhelmingly dominated by CH_4 from enteric fermentation, accounting for an average of 94.43% of total emissions. Cattle and small ruminants were identified as the primary sources, jointly responsible for over 95% of the total emission burden. While the period saw explosive growth in the poultry sector, the analysis indicates that national policies successfully stimulated herd expansion but failed to implement commensurate climate-smart practices, resulting in a coupled growth of animal stocks and emissions. The study concludes that the Buharinomics approach prioritized extensive production over sustainable intensification, leading to an increase in emission intensity. The findings underscore an urgent need for policy coherence that integrates explicit GHG mitigation targets into national agricultural development strategies, such as the National Livestock Transformation Plan, through improved feed management, manure processing, and incentives for productivity gains to decouple livestock sector growth from its environmental impact.

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Introduction

The global agricultural sector faces the dual challenge of ensuring food security for a growing population while mitigating its significant environmental footprint, with livestock production being a vital component of food systems, livelihoods, and economies worldwide, particularly in developing nations (Anyanwu *et al*., 2024; Ayinde *et al*., 2021; Gerber *et al*., 2013). In Nigeria, Africa's most populous country, livestock rearing is an integral part of the agricultural economy, contributing approximately 17% to the Agricultural GDP and providing income and nutritional security for millions of households (Ogunsakin, 2024; Tyohen and Mbakpenev, 2023). However, this essential sector is also a major source of anthropogenic greenhouse gas (GHG) emissions (Okafor *et al*., 2024; Okedere *et al*., 2021), primarily methane (CH_4) from enteric fermentation in ruminants and nitrous oxide (N_2O) from manure management, gases with a global warming potential 28 and 265 times that of carbon dioxide (CO_2) over a 100-year period, respectively (Olujobi, 2024; IPCC, 2019). The period from 2014 to 2022, characterized by the economic policies of President Muhammadu Buhari's administration (Buharinomics), witnessed significant shifts in Nigeria's agricultural landscape through initiatives like the Anchor Borrowers' Programme and the National Livestock Transformation Plan (NLTP), aimed at boosting domestic production and self-sufficiency.

Despite the critical role of livestock in Nigeria's economy, its growth has been largely extensive, relying on increasing animal numbers rather than enhancing productivity per animal, a model that carries a heavy environmental price through the release of potent GHGs. While Nigeria has committed to mitigating climate change through its Nationally Determined Contributions (NDCs) under the Paris Agreement, a significant gap exists in policy-relevant, temporally-specific data on emission sources. The problem is threefold: first, there is an insufficient understanding of how specific national policies under Buharinomics have directly influenced the livestock sector's emission profile; second, preliminary data suggests a continuous rise in emissions, but the precise rate, composition, and species-specific contributions have not been systematically documented; and third, the sector's low productivity suggests high emission intensity, undermining its long-term sustainability and resilience to climate change.

The imperative for this research is therefore grounded in its significant contributions to national policy, academic knowledge, and global commitments. It provides a crucial, time-bound evidence base to inform the development of specific mitigation targets for Nigeria's NDCs and national climate policies like the National Climate Change Policy and Action Plan. The findings offer critical insights for policymakers in the Ministry of Agriculture and Rural Development, enabling the prioritization of interventions and guiding the implementation of the NLTP towards more climate-smart pathways. Academically, this research adds to the literature on agricultural emissions in West Africa by providing a detailed, multi-year, species-specific dataset. Furthermore, by highlighting systemic inefficiencies, the study makes a case for sustainable intensification, which can reduce emissions per unit of output, lower production costs, increase farmers' incomes, and enhance overall food security a core tenet of the Buharinomics agricultural agenda. It also supports Nigeria's capacity to fulfill its global reporting obligations under the United Nations Framework Convention on Climate Change (UNFCCC) by contributing to more accurate national GHG inventories.

The primary aim of this study was to comprehensively analyze the trends and structure of greenhouse gas emissions from the Nigerian livestock sector during the Buharinomics period. To achieve this aim, the study quantified the absolute emissions and annual growth trends of methane (CH_4), nitrous oxide (N_2O), and total GHG emissions; determine the relative contribution of different livestock categories to the total national livestock GHG emissions; analyze the composition of total livestock emissions by gas type (CH_4 vs. N_2O) and assess their trends over the study period; and discuss the findings in the context of Nigeria's national policies under Buharinomics and existing scientific literature to derive implications for climate-smart livestock policy and future research. By fulfilling these objectives, this study provides a holistic and actionable understanding of the environmental dimensions of Nigeria's livestock sector during a defining period of its economic history.

Theoretical framework

This analysis was guided by an integrated theoretical framework that interprets the emission trends through multiple lenses. The Environmental Kuznets Curve (EKC) hypothesis (Grossman and Krueger, 1995) positions Nigeria's livestock sector within an extensive growth phase (Khan and Bin, 2020; Gerber *et al*., 2013), where policy-driven expansion has led to a proportional increase in environmental degradation. The related concept of Decoupling (UNEP, 2011) highlights the observed failure to delink economic growth in the sector from its environmental impact, underscoring the need for sustainable intensification. The persistence of this high-emission trajectory is explained by Policy Feedback Theory (Pierson, 1993), which illustrates how prevailing policies entrenched existing practices, creating a state of carbon lock-in (Amaefule *et al*., 2023; Unruh, 2000) that resisted transition. From an economic standpoint, the Polluter Pays Principle (Borowy, 2017) frames the emissions as a negative externality, justifying interventions to internalize these costs. Finally, the Sustainable Livelihoods Approach (Scoones, 1998) ensures a nuanced perspective by centering the analysis on livestock as a critical asset for millions, thereby grounding mitigation strategies in principles of equity and climate justice (Abdulraheem *et al*., 2023). Together, these theories provide a robust foundation for discussing the results and formulating feasible policy recommendations.

Conceptual framework

The conceptual framework for this study illustrates the cause-and-effect relationships driving livestock emissions (Figure 1). It begins with the Driving Forces, including the Buharinomics policy environment, economic factors, and socio-cultural practices, which directly shape the Livestock Production System (comprising ruminants, monogastrics, and other animals). This system, through its inherent Emission Processes namely enteric fermentation and manure management generates the Output of greenhouse gases (CH_4 and N_2O). These emissions lead to negative Outcomes and Impacts, such as contributing to climate change and creating national policy dilemmas. In response, Mitigation Responses (technical interventions and policy measures) form a critical feedback loop, aiming to influence the original production practices and driving forces to create a more sustainable and lower-emission system.

Empirical review

Empirical evidence consistently identifies the livestock sector as a major source of GHG emissions globally, with enteric fermentation in ruminants being the primary contributor (Nwokolo, 2024; Solomon *et al*., 2023; Gerber *et al*., 2013). This pattern was confirmed in Africa, where studies note rising emissions linked to growing animal populations and higher emission intensities due to low productivity (Ntinyari and Gweyi-Onyango, 2020; Opio *et al*., 2013). In Nigeria, research such as that by Adeyemi and Akinfala (2021) in the North Central region has documented significant annual increases in emissions, directly correlating them with rising cattle and small ruminant populations, a finding corroborated at the national scale by this study.

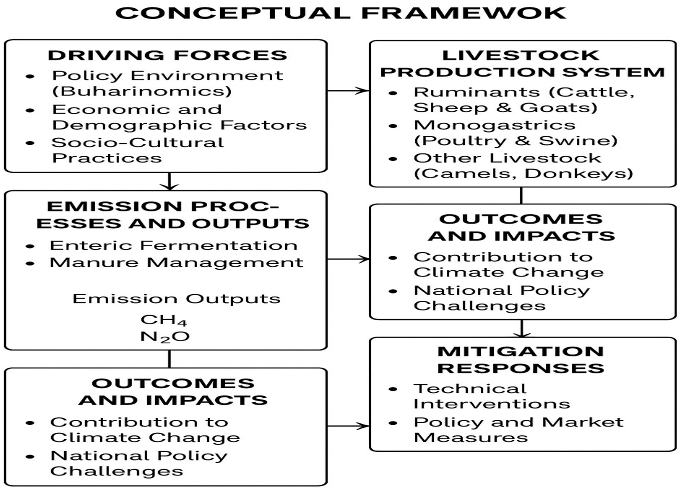

Figure 1: *Conceptual framework.*

Species-specific analyses consistently pinpoint cattle as the dominant emission source, though their exact share can vary by region (Onyeneke *et al*., 2023; Iyiola-Tunji *et al*., 2020). The significant and growing role of small ruminants is also emerging in the literature (Kannan, 2025), which aligns with this study's finding of their substantial contribution. For monogastrics, the poultry sector's rapid growth presents a dual environmental challenge, involving both direct emissions and a substantial embedded carbon footprint from feed production (Bawa *et al*., 2023). The partitioning of emissions by gas type is well-established, with studies confirming that manure management from monogastrics like swine is a disproportionately large source of N_2O (Menghistu *et al*., 2021; Oenema *et al*., 2005), a result reflected in the national data, which shows a consistent rise in N_2O (Dioha and Kumar, 2020).

Regarding policy, empirical work highlights the implementation challenges of initiatives like the National Livestock Transformation Plan, including funding gaps and conflicts (Kelechi, 2024), and identifies barriers to adopting climate-smart practices, such as high costs and limited information (Sakha and Gweyi-Onyango, 2024). This study addresses key gaps in the empirical literature by providing a temporally-specific, policy-linked, and comprehensive species-level analysis of emissions for the Buharinomics era, thereby offering an updated baseline for measuring future mitigation efforts.

Materials and Methods

This section outlines the methodological approach employed to quantify, analyze, and discuss the greenhouse gas (GHG) emissions from the Nigerian livestock sector from 2014 to 2022. The study adopted a quantitative, descriptive, and trend-analysis research design, utilizing secondary data and established international accounting protocols to ensure scientific rigor and reproducibility.

Research design

This study employed a longitudinal trend analysis research design. This design is appropriate for investigating changes and patterns in variables over a specific period (Babbie, 2020). In this case, the variables were livestock populations, methane (CH_4) emissions, nitrous oxide (N_2O) emissions, and their respective shares, tracked annually across the eight-year period of the Buharinomics administration (2014-2022). This design allows for the observation of pre-existing trends without manipulation of variables, facilitating a robust description of the emission trajectory and its correlation with the prevailing policy environment.

Data sources and collection

The study relied exclusively on secondary data sourced from FAO statistics. The primary data source, as provided in the results section, is a comprehensive data set detailing livestock emissions in Nigeria. It is inferred that this data set was constructed using the following foundational sources:

Livestock population data: The annual stock numbers for different livestock categories (cattle, sheep, goats, poultry, etc.) are typically sourced from FAO statistics. In Nigeria, these are primarily compiled by the National Bureau of Statistics (NBS) and the Federal Ministry of Agriculture and Rural Development (FMARD) through surveys and projections.

Emission factors: The conversion of animal population data into GHG emissions requires country-specific or default emission factors. The most authoritative source for these factors is the Intergovernmental Panel on Climate Change (IPCC). This study aligns with the IPCC's Guidelines for National Greenhouse Gas Inventories (2006) and its 2019 Refinement, which provide Tier 1 methodological defaults for estimating emissions from enteric fermentation and manure management. The use of these internationally recognized protocols ensures the comparability of the Nigerian data with global and regional estimates.

The data collection method was therefore documentary analysis, involving the systematic retrieval and organization of pre-existing quantitative data from the aforementioned sources into a structured dataset for analysis.

Data analysis techniques

The collected data were analyzed using both descriptive and analytical statistics. The analysis was conducted using spreadsheet software (such as Microsoft Excel) capable of handling complex formulas and generating summary tables. The specific techniques included:

- Descriptive statistics: These were used to summarize the central tendency and variability of the data. This involved calculating:
- Means (Averages): To determine the average annual emissions, stocks, and percentage shares across the study period for each livestock category and gas type.
- Totals: To aggregate emissions and stocks for each year and category.
- Trend analysis: This was the core of the analytical process. It involved:
- Calculation of annual percentage change: The year-on-year growth rate for emissions and stocks was calculated using the formula: [(Value in Yeart - Value in Yeart-1) / Value in Yeart-1] * 100 … (1)
- This metric was crucial for understanding the pace of emission growth and identifying periods of acceleration or deceleration.
- Visual inspection of time-series data: The tabulated data was examined for consistent upward or downward trends over the nine-year period.
- Compositional analysis (Share Calculation): To understand the structure of the livestock emission profile, the percentage contribution of each component was calculated.
- Species contribution to total emissions: (Total Emission from Speciesi/ Total Livestock Emission) * 100 … (2)
- Gas share in total emissions: (Total CH_4 or N_2O emission/ total livestock emission)* 100 …. (3)

- Species Contribution to Specific Gases: (CH_4 or N_2O from Speciesi / Total Livestock CH_4 or N_2O) * 100 …. (4)
- These calculations were repeated for each year to track the evolution of the emission structure.

Analytical framework

The processed data was interpreted within a structured analytical framework to move from mere description to meaningful discussion:

- Emission hotspot identification: The species and gases with the largest absolute contributions and growth rates were identified as priority areas for mitigation.
- Policy contextualization: The observed trends were critically discussed in relation to the key agricultural and economic policies of the Buharinomics era (e.g., the Anchor Borrowers' Programme, the National Livestock Transformation Plan). The analysis questioned whether the data reflected a policy success (in production expansion) or a policy failure (in environmental sustainability).
- Comparative analysis with literature: The findings were consistently juxtaposed with previous empirical studies (as cited in the Empirical Review) to establish consistency, highlight novelties, or identify discrepancies.

Ethical considerations

As the study utilized exclusively publicly and anonymously available secondary data on national statistics, it did not involve direct interaction with human or animal subjects. Therefore, issues of informed consent and confidentiality were not applicable. However, the research adhered to principles of academic integrity by explicitly acknowledging all data sources and methodological references (e.g., FAO), ensuring transparency through detailed descriptions of the calculation methods to enable replication, and maintaining objectivity by presenting the analysis in an unbiased manner, avoiding any misinterpretation to support a preconceived narrative.

Limitations of the methodology

While rigorous, the methodology has certain limitations:

- Dependence on secondary data: The accuracy of the analysis is contingent on the accuracy and reliability of the underlying data from the FAO. Potential errors in livestock census data would propagate through the emission calculations.
- Use of IPCC default factors: The study employs Tier 1 IPCC emission factors, which are generalized defaults. Country-specific (Tier 2 or 3) emission factors, which account for local variations in animal diet, weight, and management systems, would provide a more accurate estimate but require data that is often unavailable or incomplete for Nigeria.
- Attribution of policy impact: The research design establishes correlation, not causation, between Buharinomics policies and emission trends. While a strong temporal association and logical link can be argued, other confounding factors (e.g., climate variability, international market prices, and insecurity) may have also influenced livestock populations and management practices during this period.

In conclusion, this methodology provides a transparent, systematic, and internationally aligned approach for assessing the GHG emissions from Nigeria's livestock sector. By combining quantitative trend analysis with qualitative policy discussion, it yields actionable insights for policymakers and contributes meaningfully to the scholarly discourse on agriculture and climate change in Nigeria.

Results and Discussion

Introduction to the context and overall emission trends

The agricultural sector is a cornerstone of the Nigerian economy, contributing significantly to employment and livelihoods. However, it is also a major source of greenhouse gas (GHG) emissions, primarily methane (CH_4) and nitrous oxide (N_2O), which have a global warming potential 28 and 265 times that of carbon dioxide (CO_2) over a 100-year period, respectively. The period from 2014 to 2022, coinciding with the administration of President Muhammadu Buhari, herein referred to as the "Buharinomics" era, was characterized by specific economic policies, population growth, and attempts at agricultural modernization. This section provides a comprehensive analysis of the trends, composition, and sources of livestock-derived GHG emissions during this pivotal period, drawing upon the detailed data provided and contextualizing it within the broader spectrum of national and international research.

The overarching trend from 2014 to 2022 reveals a consistent and significant increase in total livestock

GHG emissions in Nigeria. As shown in Table 1, total emissions rose from 1,380.37 kt CO_2-eq in 2014 to 1,567.77 kt CO_2-eq in 2022, marking a 13.6% increase over the eight-year period. This represents an average annual growth rate of 1.60% in total emissions. This persistent upward trajectory aligns with the findings of the Food and Agriculture Organization (FAO), which has consistently highlighted Sub-Saharan Africa as a region with rapidly growing livestock emissions due to increasing demand for animal protein driven by population growth and urbanization. The annual percentage changes, which peaked at 1.72% in 2020, suggest that the sector's carbon footprint was expanding relentlessly, largely unchecked by mitigation strategies integrated into national agricultural policies.

The composition of these emissions is overwhelmingly dominated by methane (CH_4), which constituted an average of 94.43% of total livestock emissions throughout the period, while nitrous oxide (N_2O) accounted for the remaining 5.57% (Table 1). This predominance of methane is a classic feature of livestock emissions in developing countries with predominantly ruminant-based systems, such as Nigeria's. Methane is primarily produced through enteric fermentation in the digestive systems of ruminants like cattle, sheep, and goats. The near-constant share of CH_4 and N_2O over the years indicates a stable, yet inefficient, production system where changes in herd size and composition have a more significant impact on emission levels than changes in production efficiency or manure management practices that could alter the gas ratio.

This steady growth in emissions is a direct function of increasing animal stocks to meet the protein demands of a burgeoning population. Studies, such as those by Opio *et al.* (2013) in their comprehensive report for the FAO, have established a strong positive correlation between livestock population growth and GHG emissions in Africa. The data under Buharinomics provides a clear national case study confirming this global and regional pattern. The lack of a noticeable decline, even amidst global economic shifts and local policy changes, underscores the immense challenge of decoupling agricultural production from environmental impact in the absence of targeted, widespread intervention strategies focused on emission intensity reduction.

Species-specific contributions to total emissions

A disaggregated analysis of emissions by livestock category is crucial for identifying hotspots and prioritizing mitigation efforts. The data reveals a stark hierarchy in contributions, with cattle being the undisputed largest contributor, followed by sheep and goats.

Cattle: The dominant source

Cattle are the single most significant source of livestock emissions in Nigeria, contributing an average of 48.75% to the total livestock emission burden during the Buharinomics era (Table 2). Although their percentage share showed a slight decreasing trend from 50.50% in 2014 to 46.68% in 2022, their absolute emissions grew from 698.76 kt to 734.97 kt. This paradox of a growing absolute contribution alongside a declining share indicates that while other sectors (like poultry) were growing faster in percentage terms, the cattle population remained the bedrock of the sector's emissions. The average annual emission from cattle was 714.59 kt, dwarfing all other categories.

Table 1: *Livestock total emission of methane (CH_4), nitrous oxide (N_2O) and the overall emission.*

Year	Methane CH_4 (kt)	N_2O (kt)	Total emission (kt)	Share of CH_4 from total emission (%)	Share of N_2O from total emission (%)	Percentage change of methane CH_4 (kt)	Percentage change of N_2O (kt)	Percentage change of total emission
2014	1304.67	75.69	1380.36	94.51	5.48			
2015	1320.95	76.66	1397.61	94.51	5.48	1.24	1.27	1.24
2016	1340.28	78.54	1418.83	94.46	5.53	1.46	2.46	1.51
2017	1362.65	80.12	1442.77	94.44	5.55	1.66	2.00	1.68
2018	1385.24	81.88	1467.12	94.41	5.58	1.65	2.20	1.68
2019	1408.88	83.44	1492.32	94.40	5.59	1.70	1.89	1.71
2020	1433.26	85.28	1518.54	94.38	5.61	1.73	2.20	1.75
2021	1457.73	87.08	1544.81	94.36	5.63	1.70	2.11	1.72
2022	1479.20	88.56	1567.76	94.35	5.64	1.47	1.70	1.48
Average	1388.09	81.92	1470.01	94.42	5.57	1.58	1.98	1.60

Source: *FAO, 2025.*

Table 2: *Percentage share distribution of total livestock emission across selected livestock groups.*

Year	Total emission by Camel (kt)	Total emission by Cattle (kt)	Total emission by Chicken (kt)	Total emission by Donkey (kt)	Total emission by Poultry (kt)	Total emission by Sheep and Goat (kt)	Total emission by Swine (kt)
2014	13.78	698.76	5.45	14.85	5.45	626.09	19.26
2015	13.80	709.77	5.44	14.96	5.44	631.16	20.30
2016	13.79	699.31	6.35	15.13	6.35	661.00	21.06
2017	13.81	705.33	6.73	15.30	6.73	677.53	21.90
2018	13.82	711.74	7.28	15.45	7.28	693.89	22.76
2019	14.29	717.61	7.60	15.58	7.60	711.44	23.62
2020	14.40	723.78	8.18	15.74	8.18	729.62	24.64
2021	14.51	730.04	8.72	15.87	8.72	747.86	25.62
2022	14.62	734.97	9.02	16.00	9.02	764.76	26.20
% share of camel emission in total livestock emission	**% share of cattle emission in total livestock emission**	**% share of chicken emission in total livestock emission**	**% share of donkey emission in total livestock emission**	**% share of poultry emission in total livestock emission**	**% share of sheep and goat emission in total livestock emission**	**% share of swine emission in total livestock emission**	
0.99	50.50	0.39	1.07	0.39	45.24	1.39	
0.98	50.66	0.38	1.06	0.38	45.05	1.44	
0.96	49.14	0.44	1.06	0.44	46.45	1.48	
0.95	48.73	0.46	1.05	0.46	46.81	1.51	
0.93	48.34	0.49	1.04	0.49	47.13	1.54	
0.95	47.91	0.50	1.04	0.50	47.50	1.57	
0.94	47.47	0.53	1.03	0.53	47.85	1.61	
0.93	47.05	0.56	1.02	0.56	48.20	1.65	
0.92	46.67	0.57	1.01	0.57	48.56	1.66	

Table 3: *Cattle total emission of methane (CH_4), nitrous oxide (N_2O) and the overall emission.*

Year	CH_4 (kt)	N_2O (kt)	Total emission (kt)	Stocks	Share of CH_4 from total emission (%)	Share of N_2O from total emission (%)	Percentage change of Methane CH_4 (kt)	Percentage change of N_2O (kt)	Percentage change of Total emission	Percentage change of stocks
2014	667.80	30.95	698.76	19753249	95.56	4.43				
2015	678.31	31.46	709.77	20184763	95.56	4.43	1.57	1.63	1.57	2.18
2016	668.31	30.99	699.31	19884104	95.56	4.43	-1.47	-1.47	-1.47	-1.48
2017	674.06	31.26	705.33	20057095	95.56	4.43	0.85	0.86	0.85	0.86
2018	680.19	31.55	711.74	20240605	95.56	4.43	0.90	0.91	0.90	0.91
2019	685.80	31.81	717.61	20408427	95.56	4.43	0.82	0.82	0.82	0.82
2020	691.70	32.08	723.78	20585153	95.56	4.43	0.86	0.86	0.86	0.86
2021	697.68	32.36	730.04	20764244	95.56	4.43	0.86	0.86	0.86	0.87
2022	702.39	32.58	734.97	20905254	95.56	4.43	0.67	0.67	0.67	0.67
Average	682.91	31.67	714.59	20309210.44	95.56	4.43	0.63	0.64	0.63	0.71

Source: *FAO, 2025.*

This dominance is attributable to two primary factors: their large population size and their status as ruminants. Cattle have a high individual methane yield due to enteric fermentation. The steady increase in cattle stocks, from approximately 19.75 million in 2014 to 20.91 million in 2022 (Table 3), directly fueled this emission trend. Research by Onyeneke *et al*. (2023) in Nigeria corroborates this, identifying cattle as the leading emitter per livestock unit and highlighting the extensive grazing systems as a key

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driver. The manure management practices common in Nigeria, often involving pasture-based systems and simple storage, also contribute to the N_2O emissions from this sector, which averaged 31.67 kt annually. The slight decline in the relative share of cattle emissions could be attributed to the more rapid expansion of monogastric sectors like poultry, rather than any successful efficiency gains within the cattle industry itself.

Sheep and goats: The second major pillar

Small ruminants (sheep and goats) collectively represent the second-largest source of livestock GHG emissions, with an average contribution of 46.92% to the total (Table 2). Their share actually increased from 45.25% in 2014 to 48.57% in 2022, while their absolute emissions surged from 626.09 kt to 764.77 kt a 22.1% increase over the period. This category also exhibited the highest average annual growth rate in total emissions among the major ruminants at 2.54% (Table 4). The stock of sheep and goats grew from 113.24 million to 138.32 million, reflecting their crucial role in rural livelihoods as a source of readily liquidable assets and meat.

The high emissions from this sector are due to their vast numbers and, like cattle, their ruminant physiology. They are often managed in extensive systems with low productivity per animal, meaning more animals are required to produce a given amount of meat or milk, leading to higher aggregate emissions. A study by Bawa *et al.* (2023) emphasized the significant contribution of small ruminants to the agricultural economy and, by extension, its environmental footprint in West Africa. The increasing share of small ruminants in total emissions under Buharinomics suggests that their populations may have been growing at a faster rate than cattle, possibly due to their shorter gestation periods, lower capital requirements, and their perceived resilience to climate variations, making them an attractive option for smallholder farmers in a changing climate.

The "Other" categories: Swine, poultry, donkeys, and camels

The remaining emissions are distributed among swine, poultry, donkeys, and camels, whose collective contribution, while small in percentage terms, provides insights into the diversification of the livestock sector.

- Swine: Pigs contributed an average of 1.56% to total emissions, with a steady increase in both absolute terms (from 19.27 kt to 26.21 kt) and percentage share (Table 2). Swine emissions are unique because they are almost entirely derived from manure management, not enteric fermentation. The N_2O share from swine is consequently much higher, averaging 27.42% of their total emissions (Table 5), compared to just around 5% for cattle. This aligns with studies like that of Gerber *et al.* (2013), who note that for monogastrics, manure handling is the primary emission source. The growth in the swine population under Buharinomics indicates an expansion of commercial and small-scale pig farming, likely in response to urban demand.

Table 4: *Sheep and goat total emission of methane (CH_4), nitrous oxide (N_2O) and the overall emission.*

Year	CH_4 (kt)	N_2O (kt)	Total emission (kt)	Stocks	Share of CH_4 from total emission (%)	Share of N_2O from total emission (%)	Percentage change of methane CH_4 (kt)	Percentage change of N_2O (kt)	Percentage change of total emission	Percentage change of stocks
2014	590.29	35.79	626.09	113242235	94.28	5.71				
2015	595.08	36.08	631.16	114159849	94.28	5.71	0.81	0.80	0.81	0.81
2016	623.20	37.80	661.00	119554273	94.28	5.71	4.72	4.75	4.72	4.72
2017	638.78	38.74	677.53	122543129	94.28	5.71	2.49	2.50	2.50	2.49
2018	654.21	39.68	693.89	125502693	94.28	5.71	2.41	2.40	2.41	2.41
2019	670.76	40.68	711.44	128677404	94.28	5.71	2.52	2.52	2.52	2.52
2020	687.90	41.72	729.62	131965547	94.28	5.71	2.55	2.56	2.55	2.55
2021	705.09	42.77	747.86	135264686	94.28	5.71	2.50	2.50	2.50	2.50
2022	721.03	43.73	764.76	138321403	94.28	5.71	2.25	2.25	2.25	2.25
Average	654.04	39.66	693.71	125470135.4	94.28	5.71	2.53	2.53	2.53	2.53

Source: *FAO, 2025.*

Table 5: *Swine total emission of methane (CH_4) , nitrous oxide (N_2O) and the overall emission.*

Year	CH_4 (kt)	N_2O (kt)	Total emission (kt)	Stocks	Share of CH_4 from total emission (%)	Share of N_2O from total emission (%)	Percentage change of Methane CH_4 (kt)	Percentage change of N_2O (kt)	Percentage change of Total emission	Percentage change of stocks
2014	13.98	5.28	19.26	6991989	72.57	27.42				
2015	14.73	5.56	20.30	7368216	72.57	27.42	5.38	5.38	5.38	5.38
2016	15.28	5.77	21.06	7643563	72.57	27.42	3.73	3.73	3.73	3.73
2017	15.89	6.00	21.90	7949306	72.57	27.42	4.00	3.99	3.99	4.00
2018	16.51	6.24	22.76	8259938	72.57	27.42	3.90	3.90	3.90	3.90
2019	17.14	6.47	23.62	8572832	72.57	27.42	3.78	3.78	3.78	3.78
2020	17.88	6.75	24.64	8941888	72.57	27.42	4.30	4.30	4.30	4.30
2021	18.59	7.02	25.62	9299563	72.57	27.42	3.99	4.00	3.99	3.99
2022	19.01	7.18	26.20	9509551	72.57	27.42	2.25	2.25	2.25	2.25
Average	16.56	6.25	22.82	8281871.77	72.57	27.42	3.92	3.92	3.92	3.92

Source: *FAO, 2025.*

Table 6: *Chicken total emission of methane (CH_4), nitrous oxide (N_2O) and the overall emission.*

Year	CH_4 (kt)	N_2O (kt)	Total emission (kt)	Stocks	Share of CH_4 from total emission (%)	Share of N_2O from total emission (%)	Percentage change of Methane CH_4 (kt)	Percentagechange of N_2O (kt)	Percentage change of Total emission	Percentage change of Stocks
2014	2.74	2.70	5.45	137240000	50.34	49.65				
2015	2.85	2.58	5.44	142895000	52.46	47.53	4.12	-4.35	-0.08	4.12
2016	3.35	3.00	6.35	167509775	52.69	47.30	17.22	16.16	16.72	17.22
2017	3.60	3.12	6.73	180073008	53.50	46.49	7.50	4.04	5.86	7.49
2018	3.85	3.43	7.28	192525312	52.85	47.14	6.91	9.74	8.22	6.91
2019	4.13	3.47	7.60	206507286	54.31	45.68	7.26	1.15	4.38	7.26
2020	4.47	3.71	8.18	223704000	54.66	45.33	8.32	6.82	7.64	8.32
2021	4.80	3.91	8.72	240481000	55.13	44.86	7.49	5.46	6.57	7.49
2022	4.97	4.04	9.02	248991777	55.15	44.84	3.53	3.46	3.50	3.53
Average	3.86	3.33	7.20	193325239.8	53.45	46.54	7.79	5.31	6.60	7.79

Source: *FAO, 2025.*

Table 7: *Poultry total emission of methane (CH_4), nitrous oxide (N_2O) and the overall emission.*

Year	CH_4 (kt)	N_2O (kt)	Total emission (kt)	Stocks	Share of CH_4 from total emission (%)	Share of N_2O from total emission (%)	Percentage change of Methane CH_4 (kt)	Percentage change of N_2O (kt)	Percentage change of Total emission	Percentage change of Stocks
2014	2.74	2.70	5.45	137240000	50.34	49.65				
2015	2.85	2.58	5.44	142895000	52.46	47.53	4.12	-4.35	-0.08	4.12
2016	3.35	3.00	6.35	167509775	52.69	47.30	17.22	16.16	16.72	17.22
2017	3.60	3.12	6.73	180073008	53.50	46.49	7.50	4.04	5.86	7.49
2018	3.85	3.43	7.28	192525312	52.85	47.14	6.91	9.74	8.22	6.91
2019	4.13	3.47	7.60	206507286	54.31	45.68	7.26	1.15	4.38	7.26
2020	4.47	3.71	8.18	223704000	54.66	45.33	8.32	6.82	7.64	8.32
2021	4.80	3.91	8.72	240481000	55.13	44.86	7.49	5.46	6.57	7.49
2022	4.97	4.04	9.02	248991777	55.15	44.84	3.53	3.46	3.50	3.53
Average	3.86	3.33	7.20	193325239.8	53.45	46.54	7.79	5.31	6.60	7.79

Source: *FAO, 2025.*

- Chicken and poultry: The data for "Chicken" (Table 6) and "Poultry" (Table 7) are identical, suggesting the latter is an aggregate that is dominated by chickens. This sector, while a minor contributor to total GHG emissions (averaging 0.48%), exhibited the most explosive growth. Total emissions from poultry skyrocketed by 65.6%, from 5.45 kt in 2014 to 9.02 kt in 2022. This was accompanied by a staggering growth in stocks, from 137.24 million to 248.99 million. The average annual growth rate for poultry emissions was a massive 6.60% (Table 7). This phenomenal expansion reflects the success of the poultry sector in Nigeria, which has been a focus of both private investment and government initiatives to boost animal protein production. However, from a GHG perspective, poultry's impact is dual: while its direct GHG footprint is low, its feed supply chain (involving crop cultivation and land-use change) can have significant embedded carbon and N_2O emissions, an aspect not captured in this direct emission inventory. The work of Bawa *et al*. (2023) on the environmental impact of Nigeria's poultry sector echoes this, highlighting the sustainability challenges associated with its rapid, feed-intensive growth.
- Donkeys and camels: These animals contribute minimally to national livestock emissions (averaging 1.04% and 0.96%, respectively) and their emissions remained relatively stable throughout the period (Tables 8 and 9). Their primary role is for draught power and transportation, not meat production, which explains their low and stable populations and emissions. Their consistent but minor share underscores the diversity of Nigeria's livestock assets, serving socio-economic functions beyond mere meat and milk provision.

Table 8: *Donkey total emission of methane (CH_4), nitrous oxide (N_2O) and the overall emission.*

Year	CH4 (kt)	N2O (kt)	Total emission (kt)	Stocks	Share of CH4 from total emission (%)	Share of N2O from total emission (%)	Percentage change of Methane CH4 (kt)	Percent-agechange of N2O (kt)	Percentage change of total emission	Percentage change of stocks
2014	14.22	0.62	14.85	1270000	95.76	4.23				
2015	14.33	0.63	14.96	1279505	95.76	4.23	0.74	0.74	0.74	0.74
2016	14.49	0.64	15.13	1294377	95.76	4.23	1.16	1.16	1.16	1.16
2017	14.65	0.64	15.30	1308540	95.76	4.23	1.094	1.09	1.09	1.09
2018	14.80	0.65	15.45	1321441	95.764	4.23	0.98	0.98	0.98	0.98
2019	14.92	0.66	15.58	1332543	95.76	4.23	0.84	0.84	0.84	0.84
2020	15.07	0.66	15.74	1346116	95.76	4.23	1.01	1.01	1.01	1.01
2021	15.20	0.67	15.87	1357162	95.76	4.23	0.82	0.82	0.82	0.82
2022	15.3239	0.67	16.00	1368207	95.76	4.23	0.81	0.81	0.81	0.81
Average	14.78	0.65	15.43	1319765.66	95.76	4.23	0.93	0.93	0.93	0.93

Source: *FAO, 2025.*

Table 9: *Camel total emission of methane (CH_4) , nitrous oxide (N_2O) and the overall emission.*

Year	CH_4 (kt)	N_2O (kt)	Total emission (kt)	Stocks	Share of CH_4 from total emission (%)	Share of N_2O from total emission (%)	Percentage change of Methane CH_4 (kt)	Percentage change of N_2O (kt)	Percentage change of Total emission	Percentage change of Stocks
2014	13.55	0.23	13.78	279215	98.32	1.67				
2015	13.57	0.23	13.80	279534	98.32	1.67	0.11	0.08	0.11	0.11
2016	13.56	0.23	13.79	279397	98.32	1.67	-0.04	-0.04	-0.04	-0.04
2017	13.58	0.23	13.81	279677	98.32	1.67	0.100	0.12	0.100	0.10
2018	13.59	0.23	13.82	280009	98.32	1.67	0.11	0.08	0.11	0.11
2019	14.05	0.23	14.29	289370	98.32	1.67	3.34	3.36	3.34	3.34
2020	14.15	0.24	14.40	291595	98.32	1.67	0.76	0.75	0.76	0.76
2021	14.26	0.24	14.51	293860	98.32	1.67	0.77	0.78	0.77	0.77
2022	14.37	0.24	14.62	296120	98.32	1.67	0.76	0.78	0.76	0.76
Average	13.85	0.23	14.09	285419.66	98.32	1.67	0.74	0.74	0.74	0.74

Source: *FAO, 2025.*

Methane vs. nitrous oxide: A tale of two gases

The distinct sources and drivers of methane and nitrous oxide emissions warrant a separate discussion, as they imply different mitigation pathways.

Methane (CH_4): The enteric fermentation behemoth

As established, methane was the dominant gas, accounting for over 94% of total emissions. The source distribution of CH_4 (Table 10) mirrors that of total emissions, given its overwhelming share. Cattle were responsible for 49.41% of all livestock methane, followed by sheep and goats at 46.96%. This means that these two ruminant categories together accounted for over 96% of all livestock methane emissions in Nigeria under Buharinomics. This is a critical finding, as it pinpoints enteric fermentation in ruminants as the single most important process to target for GHG mitigation in the Nigerian livestock sector.

The annual growth rate of methane emissions averaged 1.58% (Table 1), slightly lower than that of N_2O. The continuous rise in CH_4 emissions is a direct proxy for the growing ruminant population. Mitigating these emissions is challenging, as it requires interventions that improve feed quality and digestibility, which can reduce methane produced per unit of feed intake. Strategies such as the use of dietary additives, improved forages, and better herd management have been suggested by researchers like Amaefule *et al.* (2024); Gerber *et al.* (2013). However, the widespread adoption of such technologies in Nigeria's predominantly extensive and low-input systems remains limited, explaining the unabated rise in methane emissions during the period under review.

Nitrous oxide (N_2O): The manure management challenge

Nitrous oxide emissions, though smaller in volume, are more potent and are primarily linked to manure management. The source profile for N_2O is markedly different from that of CH_4 (Table 11). While cattle were still the largest source (37.28% of N_2O), their dominance is less pronounced than for CH_4. Sheep and goats were the second-largest source (46.41% of N_2O),

Table 10: *Percentage share distribution of total livestock methane emission across selected livestock groups.*

Year	Total CH_4 by camel (kt)	Total CH_4 by cattle (kt)	Total CH_4 by chicken (kt)	Total CH_4 by donkey (kt)	Total CH_4 by poultry (kt)	Total CH_4 by sheep and goat (kt)	Total CH_4 by swine (kt)
2014	13.55	667.80	2.74	14.22	2.74	590.29	13.98
2015	13.57	678.31	2.85	14.33	2.85	595.08	14.73
2016	13.56	668.31	3.35	14.49	3.35	623.20	15.28
2017	13.58	674.06	3.60	14.65	3.60	638.78	15.89
2018	13.59	680.19	3.85	14.80	3.85	654.21	16.51
2019	14.05	685.80	4.13	14.92	4.13	670.76	17.14
2020	14.15	691.70	4.47	15.07	4.47	687.90	17.88
2021	14.26	697.68	4.80	15.20	4.80	705.09	18.59
2022	14.37	702.39	4.97	15.32	4.97	721.03	19.01
Percentage share of camel emission in total livestock emission	**Percentage share of cattle emission in total livestock emission**	**Percentage share of chicken emission in total livestock emission**	**Percentage share of donkey emission in total livestock emission**	**Percentage share of poultry emission in total livestock emission**	**Percentage share of sheep and goat emission in total livestock emission**	**Percentage share of swine emission in total livestock emission**	
1.03	51.15	0.21	1.08	0.21	45.22	1.07	
1.02	51.31	0.21	1.08	0.21	45.02	1.11	
1.01	49.81	0.24	1.08	0.24	46.45	1.13	
0.99	49.41	0.26	1.07	0.26	46.82	1.16	
0.98	49.03	0.27	1.06	0.27	47.16	1.19	
0.99	48.60	0.29	1.05	0.29	47.53	1.21	
0.98	48.17	0.31	1.05	0.31	47.91	1.24	
0.97	47.77	0.32	1.04	0.32	48.27	1.27	
0.97	47.39	0.33	1.03	0.33	48.64	1.28	

Table 11: *Percentage share distribution of total livestock nitrous oxide emission across selected livestock groups.*

Year	Total N_2O by camel (kt)	Total N_2O by cattle (kt)	Total N_2O by chicken (kt)	Total N_2O by donkey (kt)	Total N_2O by poultry (kt)	Total N_2O by sheep and goat (kt)	Total N_2O by swine (kt)
2014	0.23	30.95	2.70	0.62	2.70	35.79	5.28
2015	0.23	31.46	2.58	0.63	2.58	36.08	5.56
2016	0.23	30.99	3.00	0.64	3.00	37.80	5.77
2017	0.23	31.26	3.12	0.64	3.12	38.74	6.00
2018	0.23	31.55	3.43	0.65	3.43	39.68	6.24
2019	0.23	31.81	3.47	0.66	3.47	40.68	6.47
2020	0.24	32.08	3.71	0.66	3.71	41.72	6.75
2021	0.24	32.36	3.91	0.67	3.91	42.77	7.02
2022	0.24	32.58	4.04	0.67	4.04	43.73	7.18
Percentage share of camel emission in total livestock emission	**Percentage share of cattle emission in total livestock emission**	**Percentage share of chicken emission in total livestock emission**	**Percentage share of donkey emission in total livestock emission**	**Percentage share of poultry emission in total livestock emission**	**Percentage share of sheep and goat emission in total livestock emission**	**Percentage share of swine emission in total livestock emission**	
0.29	39.53	3.45	0.80	3.45	45.70	6.74	
0.29	39.74	3.27	0.80	3.27	45.58	7.03	
0.28	38.05	3.69	0.78	3.69	46.40	7.09	
0.27	37.59	3.76	0.77	3.76	46.59	7.22	
0.27	37.01	4.02	0.76	4.029	46.55	7.32	
0.27	36.63	4.00	0.76	4.00	46.86	7.46	
0.27	36.09	4.17	0.75	4.17	46.93	7.60	
0.26	35.60	4.30	0.73	4.30	47.05	7.73	
0.26	35.21	4.37	0.73	4.37	47.26	7.76	

and notably, swine emerged as a significant contributor, providing 7.39% of total livestock N_2O despite constituting only 1.56% of total emissions. This highlights swine production as a disproportionately large source of this potent gas.

The average annual growth rate of N_2O was 1.98% (Table 1), higher than that of CH_4. This suggests that the practices leading to N_2O emissions particularly the handling and storage of manure from all livestock, but especially from the rapidly expanding poultry and swine sectors were intensifying. When manure is stored or deposited on pastures in conditions that are neither fully aerobic nor fully anaerobic, it facilitates nitrification and denitrification processes, leading to N_2O release. The work of Oenema *et al.* (2005) has long established the strong connection between manure management and N_2O fluxes. The data from the Buharinomics era indicates a growing N_2O problem, potentially exacerbated by the concentration of animals in peri-urban areas and the lack of advanced manure processing facilities.

Emission intensity and the paradox of productivity

A crucial aspect of sustainable livestock development is improving productivity, which can lead to a reduction in emission intensity that is, emissions per unit of product (e.g., kg of meat or milk). While the provided data does not include production figures, the stock numbers and emission trends allow for some inferences.

The steady increase in animal stocks (e.g., cattle stocks grew by ~6%, while sheep and goat stocks grew by ~22%) to achieve a 13.6% increase in total emissions suggests that the underlying productivity of the system may not have improved significantly. If productivity (e.g., milk yield per cow, meat offtake rate) had increased, one would expect a slower growth in stocks for the same level of output, potentially flattening the emission curve. The consistent growth in both stocks and emissions points towards an extensive growth model, where output is increased by simply adding more animals, rather than an intensive model that focuses on improving the efficiency of each animal.

This reflects the findings of several studies on African agriculture. For instance, a report by the International Livestock Research Institute (ILRI) has consistently argued that low animal productivity is a key driver of high emission intensities in Sub-Saharan Africa. Under Buharinomics, the data suggests that policies may have successfully expanded the livestock population (a goal in itself for food security and economic reasons) but did not concurrently drive a widespread shift towards more efficient, lower-intensity production systems. The spectacular growth of the poultry sector, which is inherently more efficient at converting feed to protein than ruminants, is a step in the right direction. However, the continued dominance and growth of the ruminant sectors, without a corresponding breakthrough in productivity, locked the country into a high-emission trajectory.

Policy implications and the buharinomics context

The term "Buharinomics" encompasses the economic policies of the Buhari administration, which included a strong emphasis on agricultural self-sufficiency through initiatives like the Anchor Borrowers' Programme and restrictions on food imports. The livestock emission trends from 2014 to 2022 must be interpreted within this policy framework.

The overarching goal of boosting domestic agricultural production appears to have been successful in terms of expanding livestock populations, as evidenced by the growing stocks across all major categories. However, the environmental cost, as detailed in this analysis, was a significant and steady rise in GHG emissions. The policies seem to have prioritized expansion over efficiency, focusing on quantity rather than the environmental efficiency of production.

There is little evidence in the emission data to suggest that climate-smart livestock practices were mainstreamed at a scale capable of altering the sector's emission trajectory. While the government's Economic Recovery and Growth Plan (ERGP) and later the National Livestock Transformation Plan (NLTP) acknowledged the need for sustainability, the implementation appears to have been overshadowed by more immediate concerns like farmer-herder conflicts and food price inflation. The continuous annual growth in emissions indicates a policy gap in integrating meaningful GHG mitigation measures into core agricultural development strategies.

For future policy, this analysis underscores several urgent needs:

- Target ruminants: Mitigation efforts must prioritize cattle, sheep, and goats, focusing on improving feed quality, veterinary services, and genetics to enhance productivity and reduce methane emission intensity.
- Manage manure: The growing N_2O emissions, particularly from swine and poultry, call for policies that promote better manure management practices, such as composting, biogas production, and controlled application as fertilizer.
- Support sustainable intensification: Policy should incentivize a shift from extensive to more efficient production systems, where more output is derived from fewer, more productive animals. This includes supporting the dairy and beef fattening sectors with improved technologies.
- Integrated planning: Livestock development planning must be integrated with environmental and climate change policies. The Nationally Determined Contributions (NDCs) of Nigeria under the Paris Agreement should have specific, actionable, and funded targets for the livestock sector.

Conclusions and Recommendations

This study concludes that the Buharinomics era (2014-2022) left a legacy of significant growth in Nigeria's livestock sector coupled with an environmentally unsustainable rise in its greenhouse gas emissions. Total emissions increased by 13.6%, driven by an extensive production model that prioritized expanding animal numbers over enhancing efficiency. The emission profile is overwhelmingly dominated by methane from enteric fermentation in ruminants, with cattle and small ruminants jointly responsible for over 95% of the total burden. The analysis reveals a critical policy failure: While initiatives successfully stimulated herd expansion, they failed to implement commensurate climate-smart practices, resulting in a locked-in coupling between sector growth and environmental impact.

To reverse this trend, targeted actions are imperative. Policymakers must urgently revise the National Livestock Transformation Plan (NLTP) to integrate explicit GHG mitigation targets and mainstream climate-smart agriculture, focusing on improved feed strategies to reduce enteric fermentation. Sustainable manure management, particularly through biogas technology for swine and poultry operations, should be incentivized. Concurrently, investment in country-specific emission factor research is needed for accurate accounting. Agricultural extension services must promote integrated ruminant management that bundles productivity gains with emission reduction, while the private sector should be encouraged to invest in sustainable value chains and green markets, such as carbon credit projects.

These findings carry profound policy implications, chief among them the imperative for coherence between agricultural development and climate goals. Future policy must aggressively incentivize a shift from extensive production to sustainable intensification, ensuring more output is derived from fewer, more productive animals with a lower emission footprint. Economic instruments, such as redirecting subsidies towards verified climate-smart practices, should be explored to internalize the environmental costs of production. Finally, leveraging the success of the poultry sector must be done responsibly, and all mitigation strategies must be designed through a lens of climate justice to secure the livelihoods of the millions who depend on livestock, ensuring a just transition to a resilient and low-emission future.

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Novelty Statement

We gratefully acknowledge the Food and Agriculture Organization (FAO) for providing the secondary livestock emission data that made this research possible.

Author's Contribution

All authors jointly conceived the study, contributed to data analysis and interpretation, and participated in drafting, reviewing, and approving the final manuscript.

Generative AI and AI-assisted technology statement

Generative AI tools were used only to support language editing and formatting, while all analysis, results, and conclusions were produced solely by the authors.

Conflict of interest

The authors have declared no conflict of interest.

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