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An Estimation of Greenhouse Gas Emission from Livestock in Nepal

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ABSTRACT

This study estimates and projects livestock-related greenhouse gas (GHG) emissions in Nepal between 2002 and 2022, providing crucial insights for climate change mitigation strategies. The latest secondary data on livestock population was collected from the Ministry of Agriculture and Livestock Development (MoALD) Nepal. The IPCC tier 1 methods were used to estimate emissions and forecast future trends. Studies reveal that Nepal livestock-related GHG emissions reached 28,603Gg CO_2 e /year in 2022,with buffalo accounting for 39 % of the total emissions followed by cattle and goats. In 2022, the primary sources of emissions were direct nitrous oxide (48.2%), enteric methane (44.7%), manure methane (4.5%), and indirect nitrous oxide (0.6%). Future projections indicate a potential increase in total GHG emissions by 3.06 % and 3.56% up to 2050, suggesting a growing environmental impact if current practices continue. The provincial (regional) analysis identified Koshi province as the highest emitter in 2022. This research underscores the need for effective management strategies to mitigate emissions from the livestock sector in Nepal. Further, it also recommends transitioning to the IPCC Tier 2 approach when sufficient national-level data becomes available to enhance the accuracy of future inventories.

Keywords: Climate change, enteric methane fermentation, greenhouse gas, manure methane, nitrous oxide

INTRODUCTION

Climate change is a major global challenge, and although Nepal contributes less than 0.1% of global emissions, it faces severe impacts (Herrero et al., 2016). Globally, livestock accounts for 14.5% of total GHG emissions, mainly from ruminants (Gerber et al., 2013). Major GHGs include CO_2, CH_4, N_2O, and CFCs, with CO_2 emissions from cattle considered negligible (IPCC, 2001). Methane, contributing about 15% to global warming, is mainly produced through enteric fermentation and manure management in livestock (IPCC, 2001; Wu et al., 2024). Methane has a lifespan of 12.4 years and a global warming potential 28 times that of CO_2 over 100 years (Balcombe et al., 2018). Improper manure management, such as anaerobic storage, can further increase methane emissions.

Livestock also contributes nearly two-thirds of anthropogenic N_2O emissions and 75–80% of agricultural N_2O, which is expected to rise (FAO, 2006). In Nepal, livestock contributes 24.01% to the national GDP (MoALD, 2023). Nepal ranked 10th on the 2021 Global Climate Risk Index and could lose 2.2% of GDP annually due to climate change by 2050 (German watch, 2021; Asian Development Bank, 2021). Historical warming in Nepal between 1900–1917 and 2000–2017 was estimated at 1.0–1.3°C (World Bank, 2021).Within Nepal's agriculture sector, 54% of emissions were from enteric fermentation in 2014 (USAID, 2019). Total livestock emissions rose from 12,308 Gg CO_2-eq in 2001 to 17,665 Gg CO_2-eq in 2011 (MoFE, 2021). Country-specific enteric methane emission factors for cattle were 33 ± 7 kg CH_4/head/year for local crossbreeds and 46 ± 9 kg CH_4/head/year for international crossbreeds (Thakuri et al., 2020). Annually, Nepal produces 42,312 metric tons of CH_4, primarily from cattle (52.23%) and buffalo (36.35%) (Upreti et al., 2018).Manure is also an important source of methane, contributing about 9.3 Tg per year globally (Scheehle & Kruger, 2006). In India, enteric fermentation contributes roughly 91% of livestock methane emissions, with dairy buffalo and indigenous cattle responsible for 60% of the total (Chhabra et al., 2012). China has shown a decline in livestock-related GHG emissions from 2002–2020 due to improvements in efficiency and economic factors, and future strategies aim to promote low-carbon livestock systems (He et al., 2023). In contrast, GHG emissions in Bangladesh have increased, with methane making up the majority and enteric fermentation accounting for about 80% of emissions (Jahan, Abdul & Azad, 2013). Large ruminants can produce 200–500 liters of methane per day, and small ruminants 20–40 liters (Abdulrahman, 2020). Mitigation options include improved manure management, better feed efficiency, and optimized husbandry and genetics.

Across Asia, agriculture is increasingly affected by climate change, and Nepal faces similar challenges. Livestock are a major source of the country's GHG emissions, primarily through enteric fermentation and manure management. Accurate estimation of these emissions is crucial for understanding environmental impacts and planning

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mitigation measures. Although the Ministry of Forests and Environment has been assigned to prepare Nepal's National GHG Inventory, the work has not yet begun. The goal of this study is to estimate GHG emissions from Nepal's livestock sector using the Tier 1 method. The findings will support the development of country-specific emission factors, enhance national GHG reporting, and guide climate mitigation efforts for a more sustainable livestock sector.

MATERIALS AND METHODS

Study area

GHG emission was assessed for the whole nation, Nepal, using the recent animal population as reported by the MoALD (2023) census.

Data Collection

Population data from 2002 to 2022 were used for this study were obtained from the MoALD (2023) livestock census. The main livestock categories in Nepal include cattle, buffalo, goats, sheep, pigs, and poultry.

Calculations

The IPCC Tier 1 approach was used to estimate GHG emissions. The IPCC (2006) guidelines provided the necessary parameters, including nitrogen excretion rates, emission factors for enteric fermentation and manure management, manure management systems, direct and indirect N_2O emission factors, live animal weights, and nitrogen volatilization rates. Emission factors for the warm climatic zone were applied in the analysis. Methane and nitrous oxide emissions were converted to CO_2 equivalents using global warming potentials of 25 and 298, respectively. Statistical analysis was conducted to assess long-term trends in livestock populations over the past 20 years across major categories at the national level. All calculations and analyses were performed in Excel.

Enteric methane emission

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The enteric CH_4 emission of ruminants was calculated according to the following equation (Dong *et al.*, 2006).

$$\mathbf{CH_{4\,Enteric}} = \sum_T \frac{N_{(T)} * EF_{(E,T)}}{10^6} * 25, \frac{Gg}{year} Co_2e$$

Where, $CH_{4\ Enteric}$ = the total CH_4 emissions for enteric fermentation of ruminants, Gg/yearCO_2e, N_T = the heads of livestock species/category T in the country, $EF_{(E,T)}$ = emission factor for the enteric fermentation of the livestock category "T," kg CH_4/head/year. The default $EF_{(E,T)}$ values for different livestock categories are presented in Table 1, according to the IPCC.

Table 1. Methane emission factors and nitrogen excretion rate of different livestock categories

Parameters	Livestock species/category (T)						
	Dairy cattle	**Other cattle**	**Buffalo**	**Goat**	**Sheep**	**Poultry**	**Pig**
$EF_{(E,T)}$	58	27	55	5	5		1
$EF_{(M,T)}$	5	2	5	0.22	0.2	0.02	6
LW	275	110	295	30	28	1.5	28
Nex	0.47	0.34	0.32	1.37	1.17	0.82	0.4

Source: U.S. Environmental Protection Agency (2006)

EF= enteric methane emission factor (kg/head/year CH4); $EF_{(M,T)}$= methane emission factor for manure management (kg/head/year CH4); Nex = nitrogen excretion in manure of different livestock categories (kg/1,000 kg animal mass/day), LW= live weight.

Methane emission from the manure of animals

The manure management that contributes to CH_4 emission was calculated by the equation (Dong *et al.*, 2006):

$$\mathbf{CH_{4\,Manure}} = \sum_T \frac{N_{(T)} \times EF_{(M,T)}}{10^6} \times 25, \frac{Gg}{year} Co_2e$$

.

where, $CH_{4\ Manure}$ – total CH_4 emissions from the different manure management systems of different livestock categories, Gg/year CO_2e; $EF_{(M,T)}$ – the emission factor of CH_4 for the manure management systems of varying livestock categories "T," kg CH_4/head/year; and N_T – heads of livestock species/category "T."

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Nitrous oxide emission

The direct N_2O emission was calculated by the equation (Dong *et al.*, 2006):

$$\mathbf{N_2O_{D(mm)}} = \sum_S\left[\left\{\sum_T\left(\mathbf{N_T} \times \mathbf{N_{ex(T)}} \times \mathbf{MS_{S,T}}\right)\right\} \times \mathbf{EF_{3(S)}}\right] \times \mathbf{298} \times \frac{44}{28} \times \frac{1}{10^6}\,\frac{\mathbf{Gg}}{\mathbf{year}}\ \mathbf{CO_2e}$$

where, $N_2O_{D(mm)}$ – total direct N_2O emission for the different manure management systems of different livestock categories (kg/year); $N_{(T)}$ – heads of livestock species/category "T;" $N_{ex(T)}$ – average nitrogen excretion rate of different livestock species/categories "T," kg/head/year; $MS_{(S,T)}$ – the proportion of manure managed by a manure management system "S," dimensionless; $EF_{3(S)}$ – direct N_2O-N emission factor from a manure management system "S," kg/kg N; S – manure management system; and 44/28 – conversion of N_2O-N to N_2O.

The default manure management systems ($MS_{S,\,T}$) and their emission factors (EF_3) are presented in Table 2 and default live weight of different livestock and N_{ex} values for Asia in Table 1 (Eggleston *et al.*, 2006). The manure management systems of goats, sheep, and poultry were taken as reported by Huque *et al.* (2017).

The indirect N_2O emission

The indirect N_2O emission was calculated by the equation (Dong *et al.*, 2006):

$$\mathbf{N_2O_{G(mm)}} = \sum_T\left(\mathbf{N_{Volatalization-MMS(T)}} \times \mathbf{EF_4} \times \mathbf{298} \times \frac{44}{28} \times \frac{1}{10^6}\right)\frac{\mathbf{Gg}}{\mathbf{year}}\ \mathbf{CO_2e}$$

, where,$N_2O_{G(mm)}$ – total indirect N_2O emission from different manure management of livestock, Gg/year CO_2e; $Nv_{olatilizations\ -MM\ S(T)}$ – the loss of manure nitrogen of a livestock species/category "T," kg/year; EF_4 – N_2O emission factor for the deposition of nitrogen on soils and water surfaces, kg N_2O-N/kg NH_3-N and NO_x-N volatilized; and 44/28 – conversion of N_2O-N to N_2O emission.

The $N_{volatilizations-MMS(T)}$ was calculated by the following equation (Dong *et al.*, 2006):

$$\mathbf{N_{Volatalization-MMS(T)}} = \sum_S\left[\sum_T\left(\mathbf{N_T} \times \mathbf{N_{ex(T)}} \times \mathbf{MS_{S,T}}\right) \times \left(\frac{\mathbf{Frac_{GasMS}}}{\mathbf{100}}\right)\right]\frac{\mathbf{kg}}{\mathbf{year}}$$

where, $N_{(T)}$ – heads of livestock species/category "T;" $N_{ex(T)}$ – nitrogen excretion of a livestock species/category "T," kg/head/year; $MS_{(T,\,S)}$ – proportion of manure under a manure management system "S," dimensionless; and $Frac_{GasMS}$ – the proportion of manure nitrogen of a livestock category "T" that volatilizes as NH_3 and NO_x under a manure management system "S" (%). The default values of EF_4 and $Frac_{GasMS}$ are presented in Table 2 and Table 3.

Table 2. Manure management system (%) and their N2 O-N emission factors

Manure management system (MS, %)	**Livestock species/category**							**EF3**	**EF4**
	Dairy cattle	**Other cattle**	**Buffalo**	**Sheep**	**Goat**	**Poultry**	**Pig**		
Uncovered anaerobic lagoon	0	0	0	0	0	0	9	0	0.01
Liquid/slurry	1	1	0	0	0	0	22	0	0.01
Solid storage	0	0	0	100	100	0	16	0.005	0.01
Dry lot	0	4	4	0	0	0	30	0.02	0.01
Pasture	27	22	19	0	0	0	0	0.02	0.01
Daily spread	19	20	21	0	0	0	9	0	0.01
Anaerobic digester	1	1	1	0	0	25.5	8	0	0.01
Burn for fuel	51	53	55	0	0	0	0	0	0.01
Pit storage	0-	0-	0-	0	0	0	3	0.002	0.01
Poultry manure (without litter)	0-	0-	0-	0	0	74.4	0	0.001	0.01
Others	0	0	0	0	0	0	3	-	0.01

Source: 2006 (IPCC) Guidelines for National Greenhouse Gas Inventories, Chapter 10: Emissions from Livestock and Manure Management.

EF3 = direct N2O-N emission factor (kg/kg nitrogen excreted); EF4 = indirect N2O-N emission factor (kg N2O-N/kg NH3-N and NOx-N volatilized); and - = not reported.

Table 3. Default values of nitrogen volatilization in different manure management system usages

Manure management systems	FracGasMS (%)						
	Dairy cattle	Other cattle	Buffalo	Sheep	Goat	Poultry	Pig
Uncovered anaerobic lagoon	35	-	-	-	-	40	40
Liquid/slurry	40	-	-	-	-	-	48
Solid storage	30	45	-	12	12	-	45
Dry lot	20	30	-	-	-	-	
Daily spread	7	-	-	-	-	-	
Pit storage	28	-	-	-	-	-	25
Poultry manure (without litter)	-	-	-	-	-	55	
Poultry manure (with litter)	-	-	-	-	-	40	

Source: IPCC (2006) Guidelines for National Greenhouse Gas Inventories, Chapter 10: Emissions from Livestock and Manure Management.

RESULTS AND DISCUSSION

Methane emission from livestock

Tables 4 and 5 present the GHG emissions from different livestock categories through enteric fermentation and manure management. Between 2002 and 2022, buffalo contributed the highest methane emissions, followed by other cattle, goats, milking cattle, pigs, sheep, and poultry. In 2022, total emissions from enteric fermentation and manure management were estimated at 14,892 Gg CO_2e /year and 1,444 Gg CO_2e /year, respectively.

Nitrous Oxide Emission in Nepal

Table 8 presents total N_2O emissions from different livestock categories. Between 2002 and 2019, buffalo contributed the highest direct N_2O emissions from manure management, but after 2019, goats became the largest direct N_2O emitters, followed by buffalo, cattle, poultry, and sheep. Indirect N_2O emissions were highest in goats, followed by poultry, pigs, sheep, and cattle, while buffalo had zero indirect emissions. In 2022, total N_2O emissions from all livestock were 15,582 Gg CO_2e/year, with 15,582 Gg CO_2e/year from direct and 198.2 Gg CO_2e/year from indirect emissions (Tables 6-8).

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Table 4. Enteric methane emission from different livestock categories

Year	Milking cow	Other cattle	Buffalo	Sheep	Goat	Pig	Total
2002	1237	4135	5089	105	826	23	11414
2003	1262	4106	5280	104	849	23	11624
2004	1288	4103	5435	103	872	23	11824
2005	1308	4112	5612	102	894	24	12053
2006	1310	4117	5782	102	928	24	12262
2007	1318	4142	6004	102	981	25	12571
2008	1327	4168	6183	101	1017	25	12822
2009	1353	4214	6436	100	1059	26	13188
2010	1384	4215	6651	100	1106	27	13483
2011	1412	4220	6866	101	1148	28	13775
2012	1448	4216	7058	101	1189	28	14041
2013	1487	4218	7208	101	1223	29	14266
2014	1486	4198	7121	99	1272	30	14205
2015	1488	4196	7106	99	1281	30	14199
2016	1488	4237	7107	100	1373	32	14337
2017	1493	4265	7120	100	1396	33	14406
2018	1507	4277	7257	100	1456	36	14634
2019	1564	4257	7299	100	1535	37	14793
2020	1691	4248	7229	101	1601	38	14908
2021	1753	4224	7095	99	1680	40	14891
2022	1773	4178	7058	96	1749	38	14892

FracGasMS = percentage of nitrogen volatilization from managed manure of different livestock categories in different manure management systems; and - = not reported

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Table 5. **Manure methane emission from different livestock categories**

Year	Milking cow	Other cattle	Buffalo	Sheep	Goat	Pig	Poultry	Total
2002	107	306	463	4.2	36.3	140	10.7	1067
2003	109	304	480	4.1	37.4	140	11.1	1085
2004	111	304	494	4.1	38.4	140	11.5	1103
2005	113	305	510	4.1	39.3	142	11.4	1125
2006	113	305	526	4.1	40.8	144	11.6	1144
2007	114	307	546	4.1	43.2	148	12.0	1174
2008	114	309	562	4.0	44.7	152	12.3	1198
2009	117	312	585	4.0	46.6	157	12.2	1233
2010	119	312	605	4.0	48.6	160	12.9	1261
2011	122	313	624	4.0	50.5	166	20.0	1299
2012	125	312	642	4.0	52.3	171	22.6	1328
2013	128	312	655	4.0	53.8	174	24.0	1352
2014	128	311	647	3.9	56.0	179	24.0	1349
2015	128	311	646	3.9	56.4	180	25.1	1351
2016	128	314	646	4.0	60.4	194	34.3	1381
2017	129	316	647	4.0	61.4	199	35.0	1391
2018	130	317	660	4.0	64.1	215	36.1	1426
2019	135	315	664	4.0	67.6	223	37.9	1446
2020	146	315	657	4.0	70.5	228	41.3	1461
2021	151	313	645	4.0	73.9	238	36.7	1462
2022	153	310	642	3.9	76.9	226	33.4	1444

Greenhouse gas emission

The estimated GHG emissions from livestock in Nepal for 2022 totaled 28,630 Gg CO_2e, with buffalo contributing the highest share (39%), followed by other cattle (21%), goats (23.7%), dairy cattle (10.9%), poultry (3.8%), pigs (2.8%), and sheep (1.5%). The contribution by emission type was 46.7% from enteric methane, 4.5% from manure methane, 48.2% from direct nitrous oxide, and 0.6% from indirect nitrous oxide. The provincial GHG emissions from livestock in Nepal in 2022 showed that Koshi province had the highest contribution (6,626 Gg CO2e), followed by Lumbini

(6,194 Gg), Bagmati (5,581 Gg), Madhesh (4,993 Gg),Sudurpaschim (3,273 Gg), Gandaki (2,853 Gg), and Karnali (2,399 Gg) .

Table 6. Indirect Nitrous oxide emission from different livestock categories

Year	Milking cow	Other cattle	Buffalo	Sheep	Goat	Pig	Poultry	Total
2002	3.3	4.7	0	5.6	55.7	5.0	18.4	92.7
2003	3.3	4.7	0	5.6	57.3	5.0	19.2	95.0
2004	3.4	4.7	0	5.5	58.8	5.0	19.8	97.3
2005	3.4	4.7	0	5.5	60.3	5.1	19.6	98.6
2006	3.5	4.7	0	5.5	62.6	5.1	20.0	101.3
2007	3.5	4.7	0	5.5	66.2	5.3	20.6	105.7
2008	3.5	4.7	0	5.4	68.6	5.4	21.2	108.9
2009	3.6	4.8	0	5.4	71.4	5.6	21.1	111.9
2010	3.6	4.8	0	5.4	74.6	5.7	22.2	116.3
2011	3.7	4.8	0	5.4	77.4	5.9	34.5	131.8
2012	3.8	4.8	0	5.4	80.2	6.1	38.9	139.2
2013	3.9	4.8	0	5.4	82.5	6.2	41.3	144.2
2014	3.9	4.8	0	5.3	85.8	6.4	41.4	147.6
2015	3.9	4.8	0	5.3	86.4	6.4	43.2	150.1
2016	3.9	4.8	0	5.4	92.6	6.9	59.1	172.8
2017	3.9	4.8	0	5.4	94.1	7.1	60.3	175.7
2018	4.0	4.9	0	5.4	98.2	7.7	62.2	182.3
2019	4.1	4.8	0	5.4	103.6	8.0	65.2	191.1
2020	4.5	4.8	0	5.4	108.0	8.1	71.2	202.0
2021	4.6	4.8	0	5.3	113.3	8.5	63.2	199.8
2022	4.7	4.7	0	5.2	117.9	8.1	57.5	198.2

Table 7. Direct Nitrous oxide emission from different livestock categories

Year	Milking cow	Other cattle	Buffalo	Sheep	Goat	Pig	Poultry	Total
2002	1063	2254	3404	268	2646	122	261	10018
2003	1085	2239	3532	264	2720	122	271	10233
2004	1107	2237	3635	263	2795	122	281	10441
2005	1125	2242	3754	261	2864	124	278	10648
2006	1126	2245	3867	259	2972	126	283	10878

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2007	1133	2258	4016	260	3142	130	292	11230
2008	1141	2273	4135	258	3258	133	301	11499
2009	1163	2297	4305	256	3393	137	299	11849
2010	1190	2298	4449	256	3541	139	314	12188
2011	1214	2301	4593	257	3678	145	488	12676
2012	1245	2299	4721	258	3809	149	551	13032
2013	1279	2300	4821	258	3919	152	585	13313
2014	1277	2289	4763	252	4075	156	586	13398
2015	1279	2288	4753	252	4105	158	612	13446
2016	1279	2310	4754	256	4399	169	837	14004
2017	1283	2325	4762	256	4471	174	854	14125
2018	1296	2332	4854	256	4664	188	881	14470
2019	1345	2321	4882	255	4919	195	923	14840
2020	1454	2316	4835	257	5130	199	1007	15199
2021	1507	2303	4746	253	5383	208	895	15295
2022	1525	2278	4721	246	5602	197	815	15384

Table 8. Total Nitrous oxide emission from different livestock categories (Gg/year CO_2e)

Year	Milking cow	Other cattle	Buffalo	Sheep	Goat	Pig	Poultry	Total
2002	1066	2259	3404	274	2701	127	279	10111
2003	1089	2243	3532	270	2777	127	291	10328
2004	1111	2242	3635	269	2854	127	301	10538
2005	1128	2247	3754	266	2925	129	298	10746
2006	1130	2249	3867	265	3034	131	303	10979
2007	1136	2263	4016	265	3209	135	312	11336
2008	1145	2277	4135	264	3326	138	322	11608
2009	1167	2302	4305	262	3464	142	320	11961
2010	1194	2303	4449	261	3616	145	336	12304
2011	1218	2306	4593	262	3756	151	522	12808
2012	1249	2303	4721	263	3889	155	590	13171
2013	1282	2304	4821	264	4001	158	626	13457
2014	1281	2294	4763	257	4161	162	628	13546

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2015	1283	2292	4753	257	4191	164	655	13596
2016	1283	2315	4754	261	4492	176	896	14176
2017	1287	2330	4762	261	4565	181	914	14301
2018	1300	2337	4854	261	4762	196	943	14653
2019	1349	2326	4882	260	5022	203	988	15031
2020	1458	2321	4835	263	5238	207	1078	15401
2021	1512	2308	4746	259	5496	217	958	15495
2022	1529	2283	4721	251	5720	205	872	15582

Table 9. Total Greenhouse gas emissions from different livestock categories (Gg/year CO_2e)

Year	Milking cow	Other cattle	Buffalo	Sheep	Goat	Pig	Poultry	Total
2002	2410	2410	8955	383	3563	291	290	18301
2003	2460	2460	9292	378	3663	290	302	18844
2004	2510	2510	9564	376	3765	291	312	19327
2005	2549	2549	9876	372	3858	295	309	19809
2006	2552	2552	10175	370	4003	299	315	20267
2007	2568	2568	10566	371	4233	308	324	20937
2008	2586	2586	10880	369	4388	315	334	21460
2009	2636	2636	11325	366	4570	325	332	22190
2010	2697	2697	11704	365	4770	331	349	22915
2011	2752	2752	12083	367	4955	345	542	23797
2012	2823	2823	12421	368	5131	354	612	24531
2013	2898	2898	12684	369	5278	361	650	25138
2014	2895	2895	12531	360	5489	370	652	25192
2015	2899	2899	12504	360	5529	375	680	25246
2016	2899	2899	12507	365	5925	402	930	25928
2017	2909	2909	12529	366	6022	413	949	26097
2018	2937	2937	12771	365	6282	447	979	26718
2019	3048	3048	12845	364	6625	463	1026	27421
2020	3295	3295	12722	367	6910	473	1120	28182

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2021	3416	3416	12486	362	7250	495	995	28420
2022	3456	3456	12420	352	7546	468	906	28603

Future Trend of GHG in Nepal

An emission trend has been estimated up to 2050 for Nepal (Table 11). The rate of increase in annual total GHG emissions from 2002 to 2008 was 2.24% (22,592 and 25,628 Gg/year, respectively). There is a decline in GHG emissions from the year 2008-2018 by 1.98% and from 2018-2022 by 0.79%. The rate of total GHG emissions may increase to 2.77%, 3.06%, and 3.56% in the next three decades (2030–2050).

Table 10. GHG emissions from different livestock categories in different provinces of Nepal for the year 2022 *(Gg/year CO_2e)*

Provinces	Dairy cattle	Other cattle	Buffalo	Sheep	Goat	Poultry	Pig	Total
Koshi	959	1859	2029	26	1456	108	189	6626
Madhesh	554	1249	2119	3	954	81	32	4993
Bagmati	516	992	2134	41	1399	447	52	5581
Gandaki	226	280	1175	42	997	81	53	2853
Lumbini	540	1028	2975	60	1350	126	115	6194
Karnali	208	451	733	139	833	22	13	2399
Sudurpaschim	453	912	1255	43	557	40	14	3273

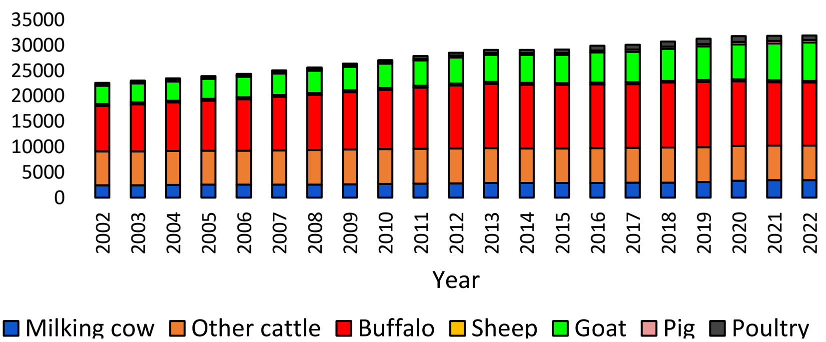

Figure *3*. Total greenhouse gas emissions from livestock categories in Nepal (Gg/year CO_2e)

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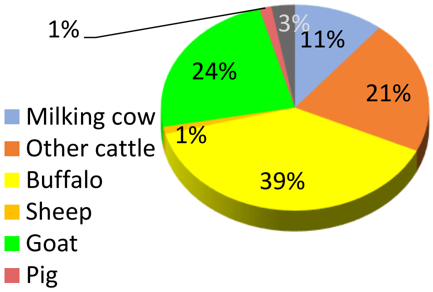

Figure 2. Share of Livestock categories in GHG emission (% CO_2e) in 2022

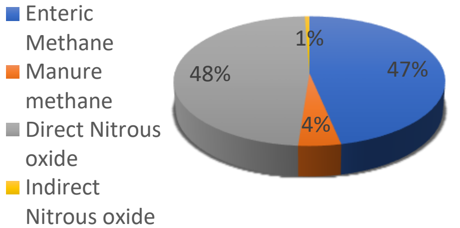

Figure 3. Share of different gases in the total GHG emission (% CO_2e) in 2022.

Table 11. GHG emissions and emission trends from different livestock categories *(Gg/year CO_2e)*

Year	2002	2008	2018	2022	2030	2040	2050
Dairy cattle	2410	2586	2937	3456	4067	4950	6025
Other Cattle	6700	6754	6931	6771	6799	6835	6871
Buffalo	8955	10880	12771	12420	14375	17156	20476
Sheep	383	369	365	352	340	326	313
Goat	3563	4388	6282	7546	11084	17278	26933
Poultry	290	334	979	906	1747	3604	7436
Pig	291	315	447	468	586	764	998
Total	22592	25628	30712	31918	38999	50915	69051
Increase		2.24	1.98	0.79	2.77	3.06	3.56

This study identified buffalo as the largest contributor to methane and GHG emissions in Nepal, reflecting the country's reliance on buffalo for dairy and meat, consistent with Bajagai (2012). While Upreti et al. (2080) reported cattle (52.2%) and buffalo (36.35%) as the main CH_4 emitters, our findings show buffalo as the highest emitter, likely due to methodological differences and Nepal's larger buffalo population. Goats and cattle are the next significant sources, similar to patterns in Bangladesh, where goats later became the leading emitters (Das et al., 2020). Nepal's annual GHG increase from livestock (2008–2018) was 1.98%, higher than Bangladesh (1.16%) and India (0.92%) (Das et al., 2020; FAO, 2021). Although total GHG emissions in Bangladesh (66,586 Gg CO_2e/year) exceed Nepal's, the difference reflects livestock population disparities. Direct N_2O emissions (48%) dominate in Nepal due to unmanaged manure, contrasting with Europe's lower proportions (FAO, 2021). Regionally, Koshi, Lumbini, and Bagmati provinces contributed most to emissions due to high livestock density, mirroring trends in northern India and Southeast China (FAO, 2020). In 2022, enteric fermentation accounted for 47% of emissions, while direct N_2O led at 48%, a shift from 2014 (USAID, 2019) likely caused by poor manure management. Projected GHG growth in Nepal (2.77–3.56% per decade) aligns with global trends of rising emissions in developing countries due to increasing livestock demand (Herrero et al., 2016; FAO, 2023). Opportunities exist for mitigation through improved manure management, livestock feeding, and adoption of IPCC Tier 2 approaches for more accurate assessments.

CONCLUSION

Using the IPCC Tier 1 approach, the total GHG emissions from Nepal's livestock were estimated at 28,603 Gg CO_2e in 2022. The contributions of enteric CH_4, manure CH_4, direct N_2O, and indirect N_2O to total emissions were 47%, 4%, 48%, and 1%, respectively. Projected GHG emissions are expected to increase at rates of 3.06% and 3.56% per year up to 2050. At the provincial level, Koshi province contributed the highest emissions (6,626 Gg CO_2e), followed by Lumbini (6,194), Bagmati (5,581), Madhesh (4,993), Sudurpaschim (3,273), Gandaki (2,853), and Karnali (2,399). Developing country-specific emission factors is essential for accurately estimating GHG emissions from the livestock sector.

SUGGESTIONS

In Nepal, strategies such as extended lactation, improved nutrition, and genetic selection can reduce emissions. Implementing a robust monitoring system will help track livestock emissions and integrate mitigation measures into national climate policies. Farmer training on sustainable practices, including efficient feeding and manure management, is vital. Advanced manure management methods, such as anaerobic digestion, can capture methane for biogas production, reducing environmental impact and providing energy. These measures will support Nepal in addressing livestock emissions and achieving global climate goals, while further research on livestock GHG emissions is recommended.

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