



## **Greenhouse gas mitigation strategies in East African pastoral systems: beyond technical solutions**

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**Key words:** pastoralism; methane; climate

### **Abstract**

Prioritizing the support of pastoralists in Kenya through a bottom-up approach, this study focuses on identifying strategies to enhance their livelihoods, with subsequent evaluation of the impact on greenhouse gas emissions. Using the Greenhouse Gas and Air Pollution Interactions and Synergies (GAINS) model and Tier 2 emissions factors, we develop a region-specific emissions inventory and evaluate how supporting pastoralist livelihoods intersect with emissions mitigation. Pastoralism, vital for local economies and ecosystems, has often been misrepresented in climate policy due to the application of industrial-focused emission reduction strategies that do not fit these extensive systems. Our research identifies effective interventions, both institutional and technical, to support pastoralist livelihoods while addressing climate change. Institutional strategies include enhancing public health and education, improving early warning systems, leveraging social capital, and promoting mobility, each of which contributes to resilience and adaptation but requires further exploration of their emissions impacts. Technical measures, such as fodder harvest and storage and disease prevention through vaccination, are shown to reduce enteric fermentation emissions by 22% within pastoral systems. The study emphasizes the need for tailored climate policies that incorporate traditional practices and support pastoral systems effectively, advocating for a holistic approach to emissions reduction that respects and enhances local knowledge and practices.

### **Introduction**

Pastoralism, in particular, has been a silenced perspective in the policy debate (Houzer & Scoones, 2021). Pastoralists are livestock keepers managing cattle, goats, sheep, camels, llamas, yaks, reindeer and other animals on extensive rangelands covering over half of the world's land surface and supports millions of people's livelihoods (ILRI et al., 2021). These extensive livestock systems occur where alternative forms of agriculture do not exist and play a crucial role in providing nutrition to often poor and marginalised populations (Iannotti et al., 2021; Scoones, 2021). Traditional indigenous knowledge is used amongst communities to provide ecosystem services while adapting to variable climates (FAO, 2024). Despite the opportunities offered by pastoralism, their needs in climate change mitigation and adaptation policy have often been neglected (Adesogan et al., 2020; Harrison et al., 2021). A more nuanced, balanced discussion

of livestock sustainability is needed to address this inequality and can only be achieved with more specific research focusing on these regions (Hallström et al., 2015; Johnsen et al., 2019; Nordhagen et al., 2020; Paul et al., 2021).

Previous research has demonstrated that technical emissions abatement solutions typically used in industrialised systems, such as breed and feed optimisation, are not applicable to pastoralists in Africa due to differing priorities (Cheng et al., 2022; Höglund-Isaksson et al., 2020; Houzer & Scoones, 2021). Rather than productivity as a core focus, indigenous breeds and management systems are crucial in supporting cultural practices, nutritional security and risk management as well as providing low emissions per head. Instead, emissions are more closely linked to underpinning institutional factors (Reid et al., 2004). As of current, limited research exists that uses a transdisciplinary approach to identify strategies that support pastoralists in Africa from the bottom-up in climate adaptation while also examining the associated emissions.

Supporting pastoralism in the context of drylands in East Africa while considering emissions is a ‘*wicked problem*’ that requires a transdisciplinary approach introducing complexity (Lawrence et al., 2022). Leveraging the Greenhouse Gas and Air Pollution Interactions and Synergies (GAINS) model from International Institute for Applied Systems Analysis (IIASA), this research aims to provide nuanced insights into region-specific strategies that align with the diverse pastoralist systems, cultural practices, and dietary patterns of East Africa. Drawing on local knowledge from bottom-up social science research (Ash et al., 2024) focused on climate adaptation amongst pastoralists in East Africa, strategies that support livelihoods in climate adaptation are identified.

## Methods

### *Emissions Estimation*

The GAINS model estimates emissions bottom-up, i.e., quantifications of human activities contributing to emissions are multiplied by an emission factor representing the average emissions per unit of activity. This research builds upon existing Tier 1 national inventories of methane (CH<sub>4</sub>) emissions from enteric fermentation in livestock systems in Kenya (Höglund-Isaksson et al., 2020) by using country-specific information to allow for deriving country- and sector/technology- specific emission factors at a Tier 2 level. CH<sub>4</sub> emissions are estimated for enteric fermentation emissions in livestock systems in Kenya spanning a timeframe from 1990 to 2050 in five-year intervals.

Following the general GAINS methodology (Amann et al., 2011), emissions from source  $s$  in region  $i$  and year  $t$  are calculated as the activity data  $A_{its}$  times an emission factor  $ef_{ism}$ . If emissions are controlled through implementation of technology  $m$ , the fraction of the activity controlled is specified by  $Appl_{itsm}$ , i.e.,

$$E_{its} = \sum_m [A_{its} * ef_{ism} * Appl_{itsm}],$$

where

$$\sum_m Appl_{its} = 1,$$

and where  $A_{its}$  is the activity (number of animals)

$ef_{ism}$  is the emission factor for the fraction of the activity subject to control by technology  $m$ ,

$Appl_{itsm}$  is the application rate of technology  $m$  to activity  $s$ .

Hence, for each emission source sector, country-and year- specific sets of application rates for all the possible technologies (including no control) are defined such that application rates always sum to unity.

### Systems Boundary

This study focuses on estimating CH<sub>4</sub> emissions from enteric fermentation of livestock, specifically cattle, sheep, goats, and camels in Kenya (Figure 1). The system boundary is defined to include only methane emissions arising from enteric fermentation processes in these animals. Other potential sources of emissions, such as:

- Methane and nitrous oxide emissions from manure management,
- Carbon sequestration from soils, trees, and plants, and
- Other greenhouse gas emissions from the agricultural sector,

are excluded from this analysis.

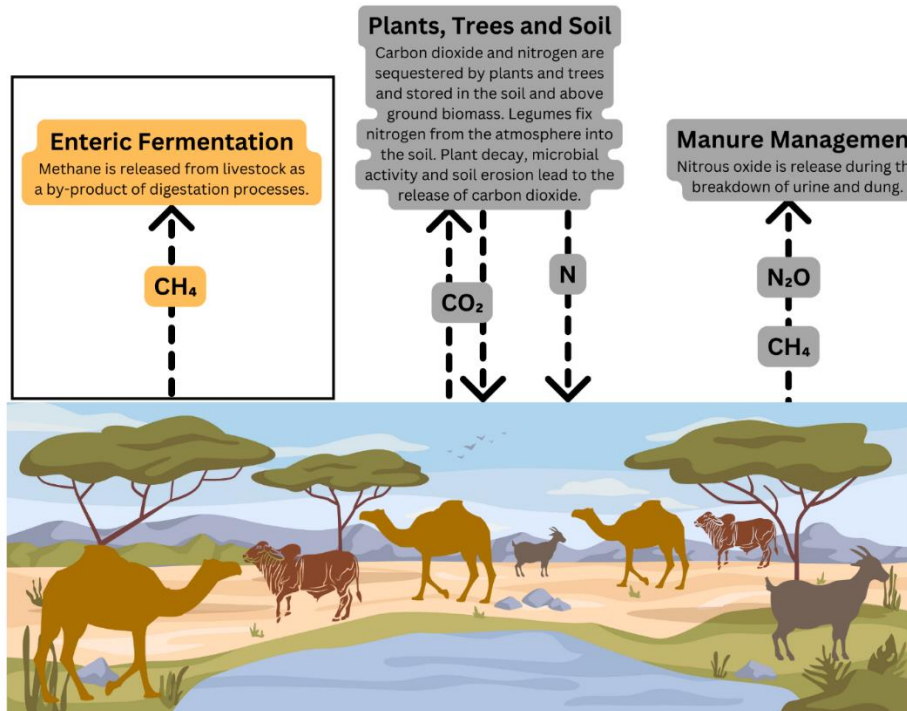


Figure 1: Emission sources and sinks in pastoral livestock systems including cattle, camel, sheep and goats. Enteric fermentation is highlighted as the focus of this study.

### Emission Factors

Emission factors and calculation method (Tier 1 vs. Tier 2) for each sector used in the GAINS modelling are represented in Table 1.

Table 1: Description, emission factor and associated method and source of the sectors used in the GAINS methodology.

<b>Animal Categories</b>	<b>Emission Factor Selection</b>	<b>Emission Factor</b>	<b>Method</b>	<b>Source</b>
<b>Pastoral camels</b>	Tier II data unavailable for camels.	46	IPCC Tier I	IPCC (2006)
<b>Pastoral sheep and goats</b>	Aligned smallholder systems in Kenya.	4	Diet-based IPCC Tier II	Goopy et al. (2021)
<b>Pastoral dairy cows</b>	Smallholder dairy farm in central Kenya using local breeds and aligned milk production levels.	76.4	Diet-based IPCC Tier II	Wilkes et al. (2020)
<b>Pastoral beef</b>	Local breeds in smallholder systems in Kenya.	23.3	Diet-based IPCC Tier II	Goopy et al. (2018)
<b>Agropastoral beef</b>	Mixed grazing systems in Kenya using local breeds.	36.01	Diet-based IPCC Tier II	Ndung'u et al. (2019)
<b>Ranch beef</b>	Local breeds mimicking ranch conditions in Kenya.	62	Direct respiration chamber	Korir et al. (2022)
<b>Feedlot beef</b>	South African systems as Kenya data unavailable. Similar liveweight and species characteristics to feedlot systems in Kenya.	25	Diet-based IPCC Tier II	Tongwane and Moeletsi (2020)
<b>Large scale intensive dairy cows</b>	Zero grazing conditions mimicking intensive dairy production.	78	Diet-based IPCC Tier II	Wilkes et al. (2020)
<b>Small scale intensive dairy cows</b>	Zero grazing conditions mimicking intensive dairy production.	78	Diet-based IPCC Tier II	Wilkes et al. (2020)
<b>Agropastoral dairy cows</b>	Semi-zero grazing conditions mimicking agropastoral dairy production.	74	Diet-based IPCC Tier II	Wilkes et al. (2020)

### ***Interventions***

A number of institutional and technical interventions were assessed including: public health and education, anticipatory action, social capital, mobility, security, pasture enclosures, fodder harvest and storage, species diversification and disease prevention through vaccination. These interventions—whether institutional or technical—have varying impacts on pastoral livelihoods, climate resilience, human health, and food security. Each approach carries both benefits and challenges, which must be carefully balanced to ensure that pastoral systems can adapt effectively to climate change while preserving their cultural and economic importance.

On the basis of literature availability, two strategies were selected for further quantifications of impacts on methane emissions: fodder harvest and storage, and disease prevention (Table 2). While examining the impact of all interventions identified as a welfare package would be of great interest, the literature is not currently advanced enough to make these linkages. In addition, the inherent nature of pastoralism not being constant or linear, but rather adapting to variability, makes the prediction of stock flux variation due to intervention a challenge. However, both fodder harvest and storage as well as disease prevention pathways have a direct impact on methane emissions at the animal level and can therefore be modelled using the GAINS methodology.

Table 2: Interventions and their associated methane reduction mechanisms, removal efficiency (%) and sources.

<b>Intervention</b>	<b>CH<sub>4</sub> Reduction Mechanism</b>	<b>Removal Efficiency (%)</b>	<b>Source</b>
<b>Fodder Harvest and Storage</b>	Increased digestibility and reduced methanogen activity	5-20	(Adesogan et al., 2020; Beauchemin et al., 2011; Hristov et al., 2013)
<b>Disease Prevention</b>	Reduced mortality and replacement rates, improved feed conversion efficiency, reduced methane yield through gastrointestinal interactions	33	(Ezenwa et al., 2020; Fox et al., 2018)
<b>Combination</b>		45	As above.

## Results and Discussion

Figure 2 represents that with implementation of disease control and improved fodder quality at a feasible adoption rate in pastoral systems, annual enteric fermentation CH<sub>4</sub> emissions in 2050 would be 22% less in pastoral systems and 11% less across all livestock systems compared to the BAU approach. This means Kenyan pastoralist systems would emit 3,406kt CH<sub>4</sub> less between 2030 and 2050, nearly double the country's total annual CH<sub>4</sub> emissions in 2020 based on the recent GAINS modelling (Höglund-Isaksson et al., 2020).

Human population growth and increased demand for red meat and milk protein per capita to meet nutritional targets in Kenya underscore the unavoidable increase in emissions even with mitigation strategies. Despite the increase in absolute emissions, milk and red meat protein demand per capita in Africa will still remain 51% and 78% smaller, respectively, when compared to Europe in 2030 (Arndt et al., 2022). On the other hand, enteric CH<sub>4</sub> emissions per capita will be significantly higher than in Europe in 2030 due to the significantly higher emissions intensity of the systems in Africa. This disparity emphasizes the need for tailored approaches: reducing consumption in Europe may be effective for limiting emissions due to low emissions intensity but high demand in consumption, while in Africa, supporting livestock systems to meet nutritional needs while managing emissions is crucial. Understanding the drivers that create change are crucial for this process. The current literature tends to examine animal efficiency and productivity in isolation when discussing how to support pastoralists and climate (Henry et al., 2018; Krätli et al., 2013). However, previous research (Young, 2020) in the pastoral context has shown, for example, that there is no

clear correlation between the immediate drivers of acute malnutrition, diet and disease, but rather, systemic and institutional factors such as livelihood systems, environmental aspects and gender relations. This research offers a region-specific perspective on integrating local context into strategies that balance livestock sustainability and climate goals.

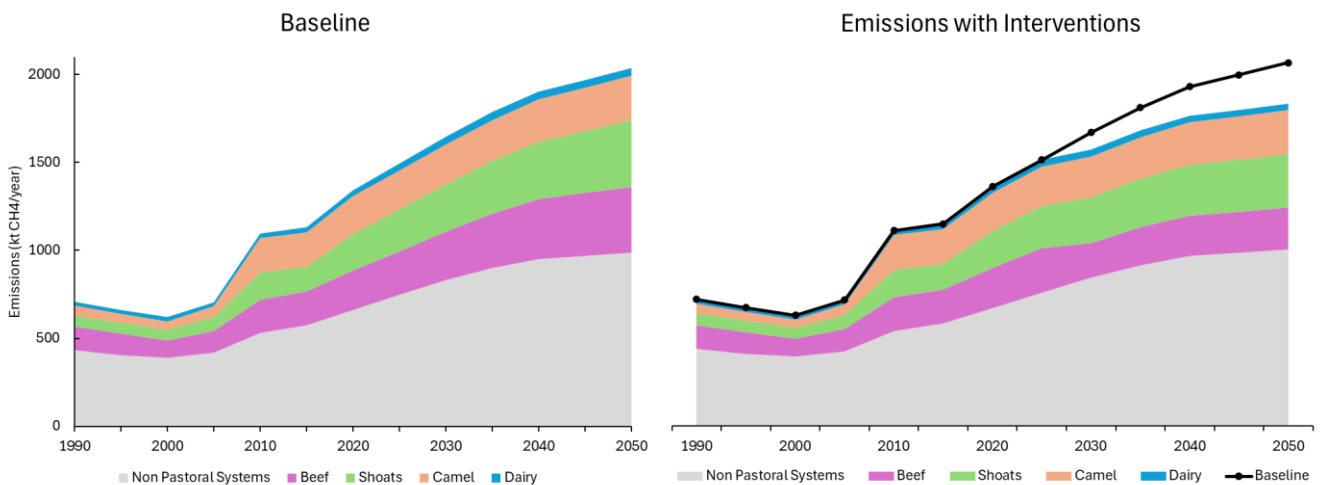


Figure 2: Enteric fermentation CH<sub>4</sub> emissions 1990–2050 in Kenya in the baseline scenario (left panel) and a feasible intervention scenario (right panel) with the enteric fermentation from non-pastoral systems represented in grey.

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