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Enteric methane emissions and their response to agro-ecological and livestock production systems dynamics in Zimbabwe

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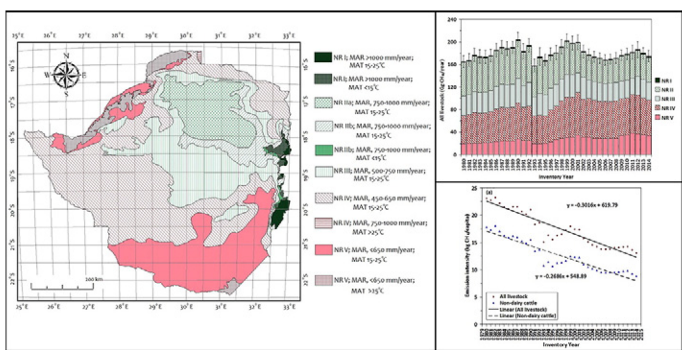
HIGHLIGHTS

- *Per capita* emissions are decreasing at −0.3 kg CH_4 per year.
- Domestic meat export was not a significant emissions driver.
- Emissions were responsive to climate variables in drought years.

GRAPHICAL ABSTRACT



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ABSTRACT

Without disregarding its role as one of the key sources of sustainable livelihoods in Zimbabwe and other developing countries, livestock production contributes significantly to greenhouse gas (GHG) emissions through enteric fermentation. For the livestock sector to complement global efforts to mitigate climate change, accurate estimations of GHG emissions are required. Methane emissions from enteric fermentation in Zimbabwe were quantified over 35 years under four production systems and five agro-ecological regions. The Intergovernmental Panel on Climate Change emission factor methodology was used to derive CH_4 emissions from seven livestock categories at national level. Emission intensities based on human population, domestic export of livestock meat and climate variables were used to assess emission drivers and predict future emission trends. Over the past 35 years, enteric fermentation CH_4 emissions from all livestock categories ranged between 158.3 and 204.3 Gg year^{-1}. Communal lands, typified by indigenous livestock breeds, had the highest contribution of between 58% and 75% of the total annual emissions followed by livestock from large scale commercial (LSC) farms. The decreasing livestock population on LSC farms and consequent decline in production could explain the lack of a positive response of CH_4 emissions to human population growth, and decreasing emissions *per capita* over time at −0.3 kg CH_4 *capita*$^{-1}$ year^{-1}. The emissions trend showed that even if Zimbabwe's national livestock population doubles in 2030 relative to the 2014 estimates, the country would still remain with similar magnitude of CH_4 emission intensity as that of 1980. No significant correlations ($P > 0.05$) were found between emissions and domestic export of beef and pork. Further research on enhanced characterisation of livestock

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species, population and production systems, as well as direct measurements and modelling of emissions from indigenous and exotic livestock breeds were recommended.

1. Introduction

Feed production and processing and enteric fermentation from domesticated ruminants constitute 45 and 39% of total global agriculture greenhouse gas (GHG) emissions, respectively (Gerber et al., 2013). In Zimbabwe, the livestock sector is a notable primary industry responsible for emitting over 60% of agricultural GHG emissions (4000 Gg of carbon dioxide (CO_2) equivalents) annually in the past two decades through enteric fermentation (MMET, 1998; MENRM, 2012; MEWC, 2016). In this period, the contribution of livestock enteric fermentation to national GHG emissions increased from about 12% to 19%. However, in view of the livestock sector's high vulnerability to climate change, particularly in southern Africa (Jury, 2013), the livestock industry stands to benefit considerably from climate change mitigation. The sector must therefore complement global efforts to reduce methane (CH_4) emissions in the long-term. Some researchers have argued that livestock hold as much as 50% of the technical mitigation potential of the combined forestry, land-use and agricultural sectors, through dietary changes and other interventions (Hristov et al., 2013; Herrero et al., 2016). In order to evaluate this mitigation potential at national level, a better understanding of the GHG emission dynamics and their drivers in the livestock sector is required.

Under the provisions of the Paris Agreement (UNFCCC, 2015), Zimbabwe has set a 33% GHG emission intensity reduction target in its Nationally Determined Contributions (MEWC, 2015). This target was specifically intended for the energy sector that contributes the highest GHG emissions. Emissions from energy uses in the manufacturing and construction category contributed 36% of the national emissions in 2000 (MENRM, 2012), but this contribution dropped to about 7% in 2006 (MEWC, 2016). This reduction in GHG emissions from the manufacturing and construction category was due to the closing of some industries due to economic challenges, and may explain why the enteric fermentation category was ranked the second highest emitter of GHGs in Zimbabwe, after the energy industries category. However, before setting up any mitigation targets for the livestock sector, the country requires more location-specific GHG inventories for its livestock systems. This would allow for the targeting of livestock systems and regions with relatively high mitigation potentials.

Zimbabwe has reported its national GHG emissions from the livestock sector using a 'Tier 1' approach based on livestock populations, emission factors and other relevant parameters using the Revised 1996 Intergovernmental Panel on Climate Change (IPCC) Guidelines (IPCC, 1997). However, the reported emissions do not adequately incorporate the dynamics in livestock production systems and the geographical distribution of livestock population (MMET, 1998; MENRM, 2012; MEWC, 2016). Livestock systems and their specific agro-ecological regions are critical factors in predicting the biochemical processes leading to CH_4 emissions from livestock. Incorporation of these factors in GHG inventories permits the use of updated and more region-specific emission factors. It is also a starting point in establishing country-specific emission factors and related parameters.

The objective of this study was to quantify CH_4 emissions from livestock enteric fermentation at national level under different livestock production systems and agro-ecological regions. The annual dynamics in CH_4 emissions were hypothesized to be a reflection of human population growth, climate variability, changes in livestock ownership, livestock geographical re-distribution and domestic export trends of livestock products in the past three-and-half decades. This study was intended to complement global efforts towards GHG mitigation through identification of possible drivers of CH_4 emissions in the livestock sector.

2. Materials and methods

2.1. Agro-ecological regions and livestock production systems in Zimbabwe

Zimbabwe's land area was subdivided into five Natural Regions (NRs) on the basis of mean annual rainfall, temperature and other agro-ecological factors (Vincent and Thomas, 1961) (Fig. 1). Up to 65% of the country's total land area is covered by NRs IV and V that are suitable for semi-extensive and extensive livestock production due to palatable, sweet grass, while about 17% forms the high grain-producing NRs I and II that are suitable for intensive livestock production (ZIMSTAT, 2015). The remaining area falls under NR III that is suitable for semi-intensive livestock production. Beef cattle (hereinafter referred to non-dairy cattle) and indigenous pigs and chicken are raised on natural pastures across all NRs, but predominantly in NRs III, IV and V. Dairy cattle and exotic pigs and chicken are produced from grain- and cereal- based feedstuffs. Natural rangeland (veld) do not only cover more than two-thirds of total land area, but also provide the relatively high-quality sweet-veld that promote higher live weight gains than the sour-veld in the high rainfall regions (Gambiza and Nyama, 2006). While a decline in land areas under NR II and III in favour of the relatively dry NRs IV and V has been reported (Mugandani et al., 2012), evidence to support these changes is still limited. As a result, the current study was based on the five NRs classified by Vincent and Thomas (1961).

Livestock production in Zimbabwe is classified into four major production systems (Table 1) and all production systems were considered in this study. The Communal Lands consist of farmers in a village setting with individual cropping areas, but common grazing areas. About 74% of Communal Lands are in the semi-arid NRs IV and V (ZIMSTAT, 2015). The majority of farmers in this category are considered to be smallholder farmers. FAO (2004) defined smallholder farmers as those farmers with relatively limited resources, cultivating from <1 up to 10 ha, and managing up to 10 head of livestock. Included in this definition are farms under the 'A1' communal resettlement model. The 'A2' resettlement model, with crop and livestock production on the same farm, has relatively large farm sizes of above 100 ha on average. The 'A1' and 'A2' Farms started in 2000 and were considered separately from the Old Resettlement Schemes that were established between 1982 and 1998, except for the period 2000 to 2008. For this period the 'A1' and 'A2' Farms were combined under 'Resettlement Schemes' (RS) due to lack of disaggregated data.

2.2. Data gathering and management

The key data for computation of CH_4 emissions from enteric fermentation was livestock population from four major data sources and covering dairy cattle, non-dairy cattle, goats, sheep, pigs, donkeys and horses. The first data source was the Zimbabwe National Statistics Agency (ZIMSTAT), a semi-autonomous agency of the Government of Zimbabwe, formally called the Central Statistics Office (from 1948 to 2007). The livestock surveys data collected at national level and published at each year ending 31 March by ZIMSTAT was obtained for the period 1980 to 2014. The data was disaggregated according to the identified livestock production systems (Table 1) and according to NRs. In the cases were there was missing data or aggregated data, interpolation