Quantifying greenhouse gas emissions attributable to smallholder livestock systems in Western Kenya: cradle to farm gate life cycle assessment

P. W. Ndung’u a, b, T. Takahashi c, d, C.J.L. du Toit a, M. Robertson-Dean e, K. Butterbach-Bahl b, f, G. McAuliffe c, L. Merbold b, J. P. Goopy a, b

a Department of Animal and Wildlife Sciences, University of Pretoria, 0002, South Africa.
b Mazingira Centre, International Livestock Research Institute, P.O. Box 30709, Nairobi, Kenya.
c Rothamsted Research, North Wyke, Okehampton, Devon, EX20 2SB, UK.
d University of Bristol, Langford House, Langford, Somerset, BS40 5DU, UK.
e School of Mathematics, University of New England, Armidale, NSW, Australia.
f Institute for Meteorology and Climate Research, Atmospheric Environmental Research, Karlsruhe Institute of Technology, D-82467 Garmisch-Partenkirchen, Germany
Livestock are important assets in Africa, helping improve the nutritional status of their owners, and contributing to economic growth.

Livestock mostly kept in smallholding enterprises but are characterized by low productivity due to:
- Poor feeding - poor feed quality and quantity
- Poor animal husbandry practices

Livestock production systems have a substantial contribution to greenhouse gas emissions in the Agricultural sector.
Background

- African countries use Tier 1 estimates - they are **CRUDE** and have **HIGH** uncertainties.

- Tier 2 emission factors alone will not explain the reasons for emissions efficiency variability across smallholder farms (*Goopy et al.*, 2018; *Ndung’u et al.*, 2019).

- Calculating the total direct and indirect GHG emissions associated with the livestock products (also know as **emission intensity**) has been demonstrated to better inform on the **resource use efficiency and sustainability** of livestock systems (*Moran & Wall, 2011*).
Background

- Emission intensity is measured by using the life cycle assessment (LCA) method.

- LCA has a unique way of quantifying GHG emissions throughout the life cycle of a product.

- In LCAs, GHG emissions must be referenced to a functional unit (FU) which is the quantity of a value associated with the purpose of a system.

- The aim was to develop baseline information on the emission intensities of smallholder livestock systems in western Kenya.
Research questions

1. Do emissions intensities vary between smallholder farms in a similar locality?

2. What is the carbon hotspot in smallholder livestock systems?

3. What are the drivers of emissions intensities in smallholder livestock systems?
Study Sites

- **Study site**: Nyando, Nandi and Bomet in Western Kenya.

- **Farm sample size**: 313 smallholding farms located across different agro-ecological zones defined by altitude, rainfall and temperature.

- **Herd sample size**: >3000 cattle of varied age groups.

- **Type of data**: Animal production and feed basket data measured on a seasonal basis in order to capture, seasonal effects, movement of animals in and out of farms and start and end of lactation(s).
Life Cycle Assessment: Cradle to Farm Gate

System Boundary

Pasture
- Napier Grass
- Maize stover
- Rhodes grass
  Enclosure
  Pile

Manure management

Farm Outputs
- Milk & Meat (Crude Protein)

Farm Inputs
- Fertilizer, Agrochemicals & Live animals

Feed - Basket

Emission sources
- Enteric fermentation - Methane
- Manure management - Methane, Nitrous oxide
- Feed production - Carbon dioxide

Emission intensity = Total GHG emission
Total CP Output

50%
Materials and Methods

- Enteric methane emissions estimates were calculated using metabolizable energy requirement (MER) approach.

- Manure emissions were calculated following IPCC guidelines.

- Emissions were initially calculated on an animal-by-animal basis and subsequently summed for each farm.

- The functional unit was set as kg Crude Protein (CP), encompassing both meat and milk production.
Data Source

A new approach for improving emission factors for enteric methane emissions of cattle in smallholder systems of East Africa – Results for Nyangao, Western Kenya

J.P. Gospy1,a, A.A. Oyengo1,b, U. Dickhout1,c, K. Butterbach-Bahl1,d
1Max-Planck-Institut für Breitenbiologie, Mülheim, Germany
2University of Agriculture, Nairobi, Kenya
3University of Mombasa, Mombasa, Kenya
4Institute for Hydrobiology and.flink Research, University of Bayreuth, Germany

Abstract

In Africa, the agricultural sector is the largest sector of the domestic economy, employing between 70% and 90% of the total labor force (CGAP, 2017). Cattle and sheep, whether based on pastoralism or as part of mixed crop–livestock systems, are a crucial component of agriculture and it is estimated that livestock contribute to about 40% of the gross domestic product (CGAP, 2017). The impact of livestock on the environment in Africa is high and it is estimated that 70% of the gross domestic product of Africa is due to livestock production, determined by the emission of greenhouse gases (Kerstens et al., 2014).

Introduction

Methane emissions from enteric fermentation have been identified as a key source of greenhouse-gas emissions (GHG) from livestock systems from agricultural sources in developing countries (Tran et al., 2011). This is because most developing countries depend largely on the agricultural sector for economic production and development, specifically enteric fermentation, dominating national GHG emissions inventories. The Intergovernmental Panel on Climate Change (IPCC) has developed three different approaches for estimating enteric methane (CH4) emissions. Tier 1 estimates are default emission factors (EFs) developed to represent the GHG emissions from livestock systems in different geographic regions on the basis of livestock census data and assumptions regarding the systems themselves (Spiering et al., 2012). It is recognised that Tier 1 estimates have shortcomings, both because they are derived from data from livestock systems in developed economies ("adapted") to the conditions of developing countries and by their nature, as the approach cannot accommodate changes to emissions brought about by changes to livestock production systems. Tier 2 estimates can represent a substantial increase in the precision of CH4 emissions from livestock because they better define animals, productivity, and feed through using actual measurements of these characteristics (Table 2016).

Keywords: African cattle, dry matter digestibility, feed basket, greenhouse gas, livestock.

Received 13 November 2017, accepted 2 May 2018, published online 1 August 2018

Introduction

Methane emissions from enteric fermentation have been identified as a key source of greenhouse-gas emissions (GHG) from livestock systems from agricultural sources in developing countries (Tran et al., 2011). This is because most developing countries depend largely on the agricultural sector for economic production and development, specifically enteric fermentation, dominating national GHG emissions inventories. The Intergovernmental Panel on Climate Change (IPCC) has developed three different approaches for estimating enteric methane (CH4) emissions. Tier 1 estimates use default emission factors (EFs) developed to represent the GHG emissions from livestock systems in different geographic regions on the basis of livestock census data and assumptions regarding the systems themselves (Spiering et al., 2012). It is recognised that Tier 1 estimates have shortcomings, both because they are derived from data from livestock systems in developed economies ("adapted") to the conditions of developing countries and by their nature, as the approach cannot accommodate changes to emissions brought about by changes to livestock production systems. Tier 2 estimates can represent a substantial increase in the precision of CH4 emissions from livestock because they better define animals, productivity, and feed through using actual measurements of these characteristics (Table 2016).

Keywords: African cattle, dry matter digestibility, feed basket, greenhouse gas, livestock.
Results: Emissions Intensities Distribution

• There was substantial variation in the frequency of low, intermediate, and high EI farms between the sites with Nyando having the greatest proportion of high EI farms.

• The differences between farms at the extremes of EI were attributable to differences in farm (CP) output.

• Because of the skewed data, median was used as the measure of central tendency and Nyando (128 kg CO₂-eq/kg CP) had almost twice the emission intensity as Nandi (67 CO₂-eq/kg CP) and Bomet (66 CO₂-eq/kg CP)
Results: Contribution of Emission Sources

• Enteric fermentation drove emissions on all farms in all regions, with up to 95% of the total GHGs being from this source.

• The livestock systems in this study were low input in terms of fertilizers, off-farm feeds and mechanization. Fertilizer and agro-chemicals were <1% of total emissions.

• Emissions from manure management were low ( <3% of total emissions) as a result of using emission factors derived from local management conditions.
Effect of Herd Management on Emissions Intensities

- Having more animals was shown not to be the most efficient.

- Emissions efficiency was driven by:
  a) high (per cow) milk yield;
  b) high sale of animals for meat;
  c) having high proportions of (productive and fertile) females in the herd.

- Pursuing focused management objectives have the potential to move low input smallholder farms towards:
  - reducing GHG emissions per unit of milk and meat produced,
  - potentially lowering GHG emissions from ruminant production.
Take home message

• This work has shown that there are highly emission efficient farms even at low input levels.

• There is a presence of farms of very high and very poor efficiencies.

• Improve the productivity on per animal basis and restructure the herds to have more productive animals in the herd and primarily females who would increase milk output.
Conclusion

• This LCA is first of its kind that accounts for direct emissions from smallholder livestock systems in Kenya and it provides a benchmark for further LCAs.

• Focus on increasing on-farm output while constraining further increases in enteric methane emissions by moving towards an “efficient frontier”.

• Benefits of reducing farm EIs in smallholder farms are;
  i. Move smallholder farms toward a low carbon future,
  ii. Increasing household incomes and,
  iii. Food secure world
What next?

• Provide guidance for sustainable livestock sector development in sub-Saharan Africa e.g. improved feeding regimes.

• Explore the potential of improving individual animal productivity to reduce emissions intensities.

• Build on the existing database by collecting more activity data and for longer periods-reduce uncertainty levels.

• Conduct more comprehensive and national smallholder LCA with indirect emissions and carbon offsets accounted for.
Acknowledgement

Thank you to our sponsors and partners!
About 620 ILRI staff work in Africa and Asia to enhance incomes and livelihoods, improve food security, and reduce disease and environmental degradation. Australian animal scientist and Nobel Prize laureate Peter Doherty serves as ILRI’s patron. Organizations that fund ILRI through their contributions to CGIAR make ILRI's work possible. Organizations that partner ILRI in its mission make livestock research for development a reality.

THANK YOU

Thank You!........“Happy Cow, Happy Farmer”

Any questions?