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Feed-based dairy system intensification scenario development and national-level biophysical impact assessment

Final technical report of CSIRO's contribution to the Climate Smart Dairy Project

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Executive summary

The Livestock Masterplans for Tanzania and Rwanda project an increase of the number of reproductive females by 10% and 7% and an increase in the national milk production from 2016/17 to 2021/22 of 80% and 65%, respectively.

If improved feeding systems alone were to deliver the increases in milk production and milk yields as envisioned by the two Livestock Master Plans, methane emissions from enteric fermentation and manure management are projected to increase while the amount of land and water required to produce feed for the national cattle population is mostly projected to increase:

- **Methane emissions** from enteric fermentation and manure management are projected to increase by 11% to 4.6 MtCO2-eq in Tanzania and 30% to 0.24 MtCO2-eq in Rwanda.
- **Emission intensity**, the amount of methane emissions from enteric fermentation per l of milk produced, decreases from 2.5 to 1.9 kg CO2-eq per l milk in Tanzania and 1.7 to 1.3 kg CO2-eq per l milk in Rwanda for improved breeds but cannot compensate for the projected increase in the cattle population that drives the increase in emissions overall.
- The **land required to produce feed** is projected to increase by 12% to 33.3 million ha land in Tanzania and to decrease by 13% to 667,000 ha land in Rwanda. The amount of **water required to produce feed** is projected to increase by 9% to 28.2 billion litre in Tanzania and 3% to 690 million litre in Rwanda.
- The increase in land and water needed is driven by increases in the national cattle population. In some cases, improvements in feed quality in improved breed cattle systems can lead to an overall decrease of water and land needed even as milk yields increase.

With feed interventions the **efficiency of the dairy system** overall increases and the environmental impacts per unit of milk produced decreases. The **feed interventions** considered include that low-quality feed such as from crop residues is replaced with improved Brachiaria species, Desmodium legumes or hay from Rhodes grass and the amount of high-quality feed is increased and differ by season, agroecological zone and cattle breed.

Dry matter feed required to produce one unit of milk for improved breeds decreases from an average of 4.8 to 3.6 kg DM per kg of milk in Tanzania and from 3.3 to 2.6 kg DM per kg of milk in Rwanda. **Land required to produce one unit of milk** for improved breeds decreases from 0.6 to 0.4 ha per t milk in Tanzania and 0.4 to 0.2 ha per t milk in Rwanda. **Water required to produce one unit of milk** for improved breeds decreases from 0.5 to 0.4 l per l milk in Tanzania and 0.4 to 0.2 l per l milk in Rwanda.

We here assume that the national milk production increase and increase in animal productivity is achieved only by improvements in the feed quantity and quality in the dairy herds of improved breeds as feed is the biggest constraint to animal productivity improvements in Tanzania and Rwanda. Other relevant interventions for increasing milk production are genetic improvements in the dairy crossbreeds and animal health interventions for vaccinations and parasite controls.

1 Introduction

The Ministries of Agriculture in Tanzania and Rwanda have commissioned Livestock Masterplans (LMPs) that include 'Dairy Development Roadmaps' laying out key interventions with their respective costs and benefits for increasing animal health and milk production. A central intervention envisioned in the LMPs, fully in line with the Climate Smart Dairy research project, are feed intensification strategies. There is a need to complement this recommendation by farm scale and national scale biophysical impact assessments – the impacts that such an intensification of the dairy sector can have on land use, water use and greenhouse gas emissions and the potential constraints from feed availability. In this report, we aim at quantifying biophysical impacts for potential increases in national milk production as specified in the LMPs using the CLEANED Excel Tool developed by CIAT and the Feed Assessment Tool (FEAST) developed by ILRI. CLEANED provides methods for ex-ante impact assessments with a minimum data approach and measures the environmental impact of a livestock enterprise. FEAST provides a method to assess local feed resource availability and use and can be used to describe baseline feed baskets in different livestock production zones. The LMPs provide data on milk yield and number of reproductive females in the base year (2016/17) and future (2021/22) in three production zones per country. A central element of the analysis is upscaling farm scale interventions and environmental impacts to the national level, and this is done by working with representative farms per production zone in CLEANED and upscaling by multiplying with the number of dairy cows and the total cattle population.

2 Methods and Data

2.1 Livestock feed

Livestock feed baskets are specified for three livestock production zones in each country that are defined by rainfall, altitude and potential for intensification (Figure 1) and for commercial systems that can be located anywhere in the country except for the commercial grazing system in Rwanda. The baseline feed baskets are based on FEAST assessment reports and local expert knowledge. FEAST is a tool for feed assessment to characterize feed quality in selected villages and households. Of the available FEAST assessments, one to two per livestock production zone were selected as representative of the feeding system for local and improved breed cows in Rwanda and Tanzania (in brackets are the names of the villages where interviews for FEAST have been conducted).

In Tanzania:

- Highlands: Rungwe district, Mbeya Region (Rungwe)
- Coastal & Lake: Mvomero district, Morogoro Region (Manyinga, Wami Sokoine) and Babati district, Manyara Region (Long, Seloto)
- Central: Kilosa district, Morogoro Region (Mwade)

In Rwanda:

- Low rain low altitude: Nyagatare district, Eastern Province (Gacundezi)
- Medium rain medium altitude: Nyanza district, Southern Province (Rwotso)
- High rain high altitude: Rutsiro district, Western Province (Remera)

The livestock systems are mostly agro-pastoral systems in Kilosa and Nyagatare districts, mostly open-grazing to semi-intensive mixed crop-livestock systems in Mvomero, Babati and Rwotso districts, and mostly zero-grazing dairy systems in Rungwe and Rutsiro districts.

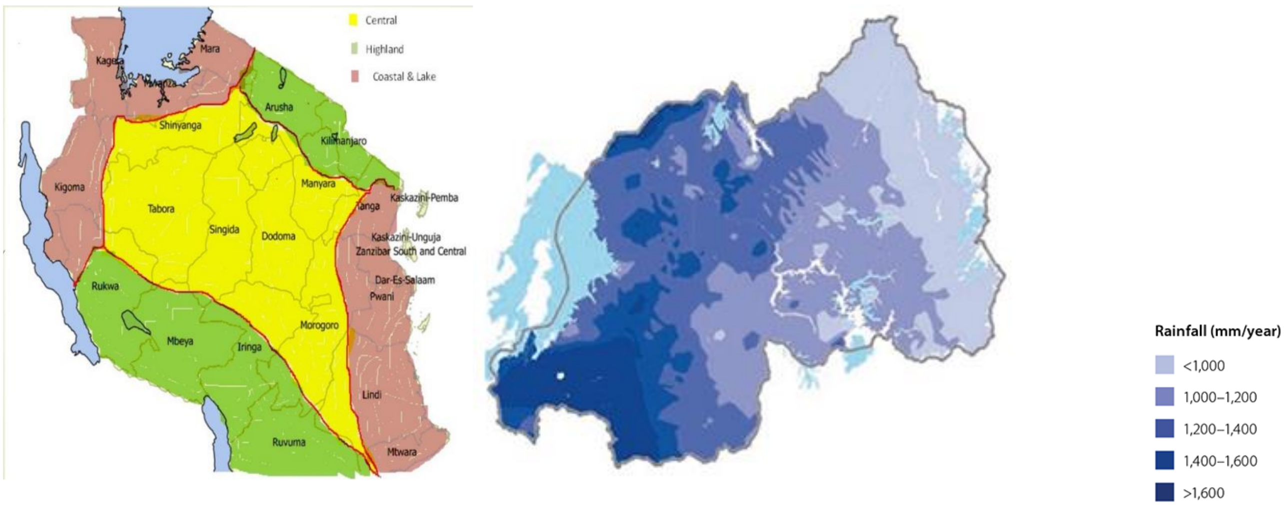

Figure 1 The three livestock production zones as defined in LMPs. Rwanda's three production zones are defined as: 800-1000mm rainfall (low rainfall), 1000-1400mm (medium rainfall) and 1400-1800mm (high rainfall).

The feed baskets in these six zones vary by breed (local vs. improved) and by season (dry / wet). In addition, we define feed baskets for improved breed cattle for one commercial system in Tanzania and two commercial systems in Rwanda (grazing and non-grazing) so in total we define 14 baseline feed baskets in Tanzania and 16 baseline feed baskets in Rwanda. Figure 2 shows an example feed basket in the wet season for an improved breed dairy cow. Dry season feed baskets are adjusted by assuming lower feed availability from grazing and higher shares of crop residues. Feed baskets for local cows are adjusted by assuming higher shares of lower quality feed such as from local grass and in some cases are assumed to be the same as the feed baskets for improved breeds. If FEAST indicates that concentrates or crop by-products such as distillers' grain are part of the livestock diet than this is assumed to be used for improved breeds only.

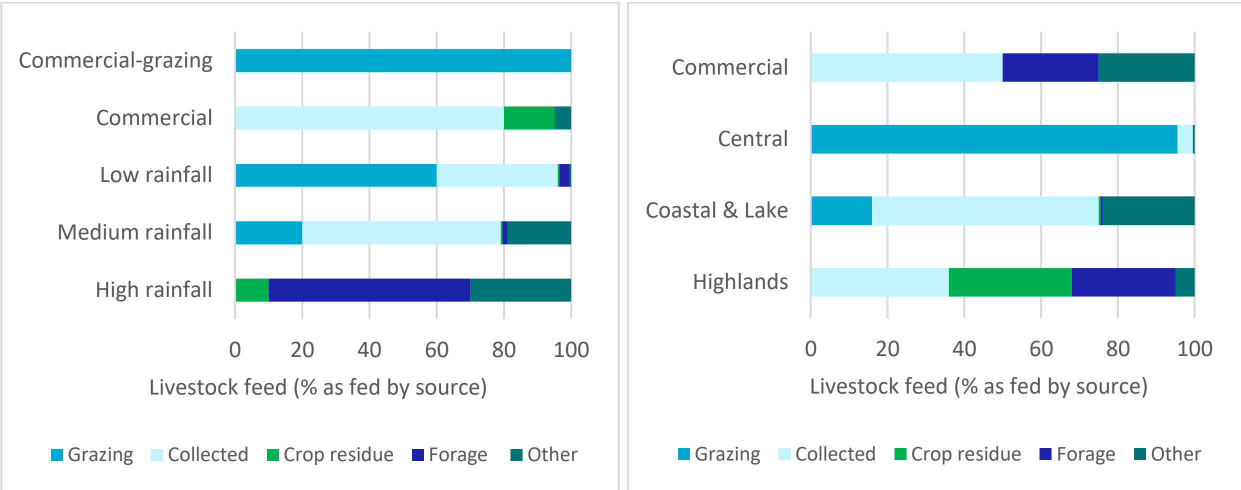

Figure 2 Baseline feed basket in the wet season for improved dairy cows in different production zones in Rwanda (left) and Tanzania (right). The 'Other' category for Tanzania represents purchased sugarcane molasses in the Coastal & Lake zone and a mix of maize bran, sunflower seed cake, common salt and minerals in the commercial system. The "Other" category for Rwanda represents purchased maize stover in the medium rainfall zone, roadside grass in the high-rainfall zone in and maize distillers' grain in the commercial system in Rwanda.

As feed interventions are not described in detail in the LMPs, we here assume that low quality feed such as from crop residues and local grass will be replaced with high quality feed such as from planted forages or purchased feed. Either the share of higher quality feed in the feed basket is increased or higher quality feed is introduced to the feed baskets. The grass and legume species and their respective share in the feed basket are chosen based on pers. comms. with a group of project team members from RAB and CIAT in the following way:

Tanzania

- Low-quality feed in the wet season is replaced with improved *Bracharia* spp. (Brachiaria hybrid) taking 10% of the feed basket and low-quality feed in the dry season replaced with *Chloris gayana* (Rhodes grass) hay taking 40% of feed basket
- If concentrates or crop by-products are part of the baseline feed basket in the wet season, doubling the amount to a maximum of 10% of the feed basket
- In mixed crop-livestock systems in the Highlands, introduce or increase amount of *Desmodium intortum* (Greenleaf desmodium) in the wet and dry season taking a maximum of 5% of the feed basket

Rwanda

- Low-quality feed in the wet season is replaced with *Chloris gayana* (Rhodes grass) or improved *Bracharia* spp. (Brachiaria hybrid) taking 15% of the feed basket and low-quality feed in the dry season replaced with hay from Rhodes grass and from improved Brachiaria taking 20% of feed basket each.
- In the high-rainfall zone, the share of *Pennisetum purpureum* (Napier grass) in the feed basket is reduced from 60% to 40%, no roadside grass is used anymore and *Pennisetum clandestinum* (Kikuyu grass) that is cultivated on farm or bought takes 50% of the feed basket. The remaining 10% are crop residues.

These feeding interventions only apply to the feed baskets of improved breed cattle. Investments into higher quality feed for local cows is unlikely as they are mainly kept for producing milk for domestic consumption and local markets when there is surplus. No feed intervention is assumed for the commercial systems in both countries. If crop residues are part of the feed basket we assume a main product removal fraction of 0.3 and a crop residue removal from field fraction of 0.7.

2.2 Milk yield and production in baseline and with interventions

We use milk yields per reproductive female as specified in the Dairy Development Roadmaps developed for the Livestock Masterplans (LMP) (Michael et al., 2018; Shapiro et al., 2017). According to the LMP, milk production in Tanzania is expected to increase from 2,159 million litres in the base year 2016/17 to 3,816 million litres in 2021/22, an increase of about 77% over five years. Productivity per dairy cow is expected to increase by 31% in the traditional and improved family dairy subsystem in the Central zone, by 53-59% in the improved family subsystem in the Highlands and Coastal & Lake zone and by 26% in commercial specialized dairy. The national average annualized milk productivity of a cow is expected to increase from 179 litres in 2016/17 to 254 litres in 2021/22 – and increase of 42% over five years (Table 1).

Table 1 Milk production in Tanzania: National total and per cow milk production in base year 2016/17 and 2021/22.

	National total (000' litre)			Annual per reproductive female (litre)		
	2016/17	2021/22	% change	2016/17	2021/22	% change
Central	848,140	1,046,010	23			
Traditional and improved family				165	216	31
Coastal & Lake	751,923	1,321,474	76			
Improved family				157	240	53
Highlands	344,186	740,219	115			
Improved family				215	343	59
Commercial	214,885	709,011	230	1,757	2,207	26
Total / Average	**2,159,134**	**3,816,714**	**77**	**179**	**254**	**42**

* Source: LMP, Tables 3, 4, 8, 10

Milk production in Rwanda is expected to increase from 757 million litres in the base year 2016/17 to 1,230 million litres in 2021/22 in the LMP, an increase of about 65% over five years. Productivity per dairy cow is expected to increase by 6% for cows of local breed, by 19% for crossbred cows and by up to 109% in commercial dairy systems. The national average annualized milk productivity of a cow is expected to increase from 1,269 litres in 2016/17 to 1,960 litres in 2021/22 – an increase of 54% over five years (Table 2).

Table 2 Milk production in Rwanda: National total and per cow milk production in base year 2016/17 and 2021/22.

	National total (000' litre)			**Annual per reproductive female (litre)**		
	2016/17	2021/22	% change	2016/17	2021/22	% change
Low rainfall						
Local breed	24,888	21185	-14.9	216	228	6
Crossbred	227,488	392152	72.4	1,323	1,572	19
Medium rainfall						
Local breed	28,183	23874	-15.3	216	228	6
Crossbred	242,264	416312	71.6	1,418	1,684	19
High rainfall						
Local breed	17,643	14930	-15.4	216	228	6
Crossbred	183,774	316438	72.2	1,512	1,796	19
Commercial						
Grazing (Gishwati)	15,721	31202	98	1,890	3,954	109
Non-grazing	6,267	14042	124	3,360	5,991	78
Total / Average	**746,228**	**1,230,135**	**65**	**1,269**	**1,960**	**54**

* Source: LMP, Table 6 - 7. In contrast to this table, the LMP narrative mentions an average annual milk production per reproductive female of 909 litres and 1,281 litres in 2016 and 2021, respectively. The change is 41% in the LMP narrative compared to 54% here.

2.3 Environmental impacts of feed production and livestock management

CLEANED is used as an ex-ante model to calculate dry matter requirements for livestock, water and land requirements to produce feed for local and improved cattle and methane emissions from enteric fermentation and manure management (Mukiri et al., 2019). Feed baskets specifying percentages of feed items fed and annual milk production as specified in the LMPs are input data into CLEANED. The feed parameters used here are listed in Appendix A

Methane emissions from enteric fermentation, from manure management and water and land used for feed production are calculated for all animal species on a farm and we consider dairy cows, adult males, steers/heifers and calves as four different animal species present at a farm.

Emissions from enteric fermentation are calculated as per IPCC Tier 2 method, Eq 87 and 88 in the CLEANED guide:

$$CH4_{enteric} = \sum_g EF_g * N_g$$

$CH4_{enteric}$ is the methane emission from enteric fermentation in kg CH_4 / yr, N_g is the number of head of livestock species for a livestock category and EF_g is the emission factor defined for an individual of an animal category in kg CH_4 / head / yr which is calculated as:

$$EF_g = \frac{GE_g \; x \; 365 \; x \; \frac{Ym_g}{100}}{55.65}$$

Y_m is the percentage of gross energy (GE) in feed converted to methane. We assume 6.5% for dairy cattle irrespective of the breed (CLEANED Excel sheet 'GHG Parameters'). GE is the daily gross energy intake required to satisfy both the energy and protein requirements of an animal in MJ/head/day as calculated from dry matter intake * 18.5 (CLEANED technical guide Eq. 31).

The emission factors in the baseline calculated per Tier 2 method are 108 kg CH4 per herd and 57 kg CH4 per herd for local breeds in Tanzania and Rwanda, respectively and 123 kg CH4 per herd and 122 kg CH4 per herd for improved breeds in Tanzania and Rwanda, respectively (Table 3). A herd consists of 2 to 3 individual animals, the cow and 1 to 2 followers, adult males, steers/heifers and/or calves. For comparison, the IPCC Tier 1 emission factors for enteric fermentation of a dairy cow is 46 for improved breed cows and 32 for local breed cows in both countries. A herd consisting of one cow, one adult male and one steer or heifer would have a Tier 1 emission factor of 119 for improved breeds and 105 for local breeds in both countries. The Tier 2 emission factors are higher than Tier 1 emissions factors, except for local breeds in Rwanda.

Table 3 Emission factors for enteric fermentation calculated from daily gross energy intake.

Emission factor (kg CH4 per herd)	**Local breed herd**	**Improved breed herd**
Tanzania		
Central	115	134
Coastal & Lake	95	136
Highlands	115	112
Commercial	-	109
National average	**108**	**123**
Rwanda		
Low rainfall	60	111
Medium rainfall	66	139
High rainfall	45	131
Commercial grazing (Gishwati)	-	128
Commercial non-grazing	-	100
National average	**57**	**122**

Methane emissions from manure management are calculated as per IPCC Tier 2 method, Eq 90-91 in the CLEANED user guide and as the sum of the methane emissions from manure from each animal species on the farm. Crossbreed cows are assumed to be in the stable all day with manure collected from the stable and all used as fertilizer for crops. Local breed cows are assumed to spent 40% of their time grazing and 60% in the shed with manure collected only in the shed.

The amount of water used for feed production is calculated as per Eq 80-85 in the CLEANED user guide from land requirements for a specific feed item and a crop- or grass-specific crop coefficient.

3 Results and discussion

3.1 Baseline dry matter intake

Average dry matter requirements per herd of local breed in Tanzania and Rwanda are 13.8 kg DM per day and 7.2 kg DM per day in the baseline, respectively. Dry matter requirements per dairy cow of improved breed in Tanzania and Rwanda are 15.6 kg DM per day and 15.4 kg DM per day in the baseline (Table 4, Figure 3). In a scenario with feed interventions and increased milk yields, dry matter requirement of a local breed herd increases to 13.9 kg DM per day and 8.2 kg DM per day in Tanzania and Rwanda, respectively. Dry matter requirement of an improved breed herd increases to 18.7 kg DM in Tanzania and 17 kg DM in Rwanda (Figure 3). However, as milk yields in the feed intervention scenario increases more than dry matter requirement, efficiency overall increases. For an improved breed herd, only 3.7 kg DM instead of 4.8 kg DM is required to produce one kg of Fat-Protein Corrected Milk (FPCM) in Tanzania. In Rwanda, only 2.6 kg DM instead of 3.3 kg DM of feed are required to produce one kg of Fat-Protein Corrected Milk (FPCM).

Table 4 Dry matter requirements for a given milk yield per herd in different dairy systems.

Dry matter DM£ (kg/day)	**Local breed herd**	**Improved breed herd**
Tanzania		
Central	14.5	17.0
Coastal & Lake	12.0	17.3
Highlands	14.6	14.3
Commercial	-	13.8
National average	**13.7**	**15.6**
Rwanda		
Low rainfall	7.6	14.1
Medium rainfall	8.3	17.6
High rainfall	5.7	16.6
Commercial grazing (Gishwati)	-	16.2
Commercial non-grazing	-	12.7
National average	**7.2**	**15.4**
£ Calculated with CLEANED: Total dry matter required divided by 365 days.		

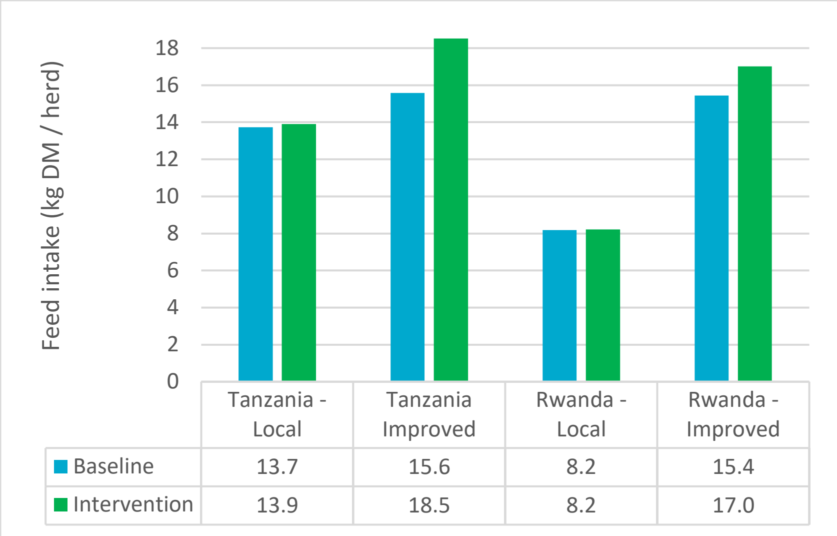

Figure 3 Dry matter requirement for a local breed herd and an improved breed herd per day.

As a rule of thumb, the dry matter intake in the baseline and in the feed intervention scenario calculated with CLEANED should not exceed the dry matter intake equivalent to 2-3% percent of an animal's bodyweight. The maximum dry matter intake for a herd assumed in Tanzania and Rwanda are:

- 27.0 kg DM/day for a herd of improved breed cow, adult male and steer or heifer. This is the sum of maximum dry matter intake of 12 kg DM for a cow, 7 kg DM for an adult male and 8 kg DM for a steer or heifer.
- 19.3 kg DM/day for a herd of local breed cow, adult male and steer or heifer. This is the sum of a maximum dry matter intake of 7 kg DM for a cow, 7 kg DM for an adult male and 5.3 kg for a steer or heifer.

3.2 Farm level environmental impact assessment

Emission intensity (kg CO2-eq per kg FPCM) for methane emissions from enteric fermentation in the baseline is between 1.5 and 14.7 in Tanzania and 0.7 and 5.5 in Rwanda, depending on the livestock production system. Emission intensity for methane emissions from manure management in the baseline is between 0.1 and 0.4 in Tanzania and 0.04 and 0.3 in Rwanda. Both emission intensities decrease with the feed intervention (Figure 4, Figure 5).

The amount of land and water needed to produce one unit of milk decreases with feed intervention (for improved breeds) or where milk yields increase only (for local breeds) (Figure 6, Figure 7). Land and water requirements in Tanzania for improved breeds are 0.6 ha per t FPCM and 0.5 l water per kg FPCM, respectively and decrease with the feed intervention. Land and water requirements in Rwanda for improved breeds are 0.4 ha per t FPCM and 0.4 l water per kg FPCM, respectively and decrease with the feed intervention.

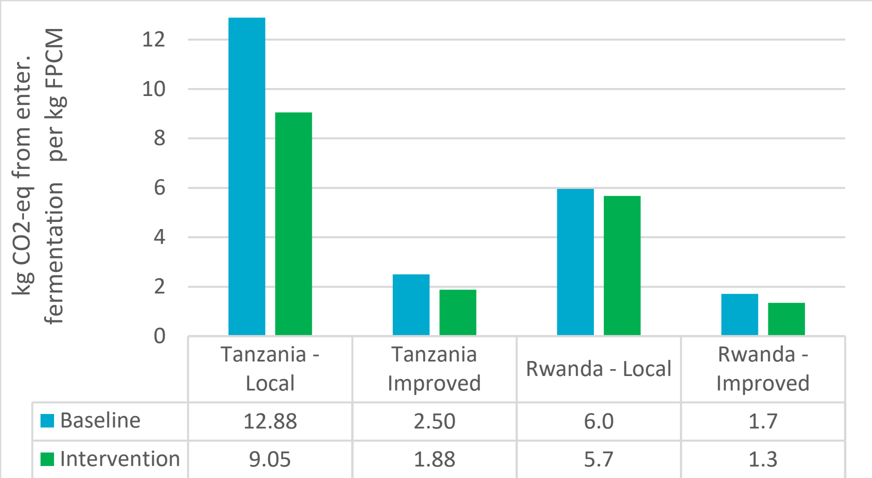

Figure 4 Emission intensity for methane emissions from enteric fermentation. FPCM is Fat-Protein Corrected Milk measured in kg. Milk production is unadjusted for losses along the value chain. One kg of methane (CH_4) is assumed to be 24 kg of carbon dioxide equivalent (CO_2-eq).

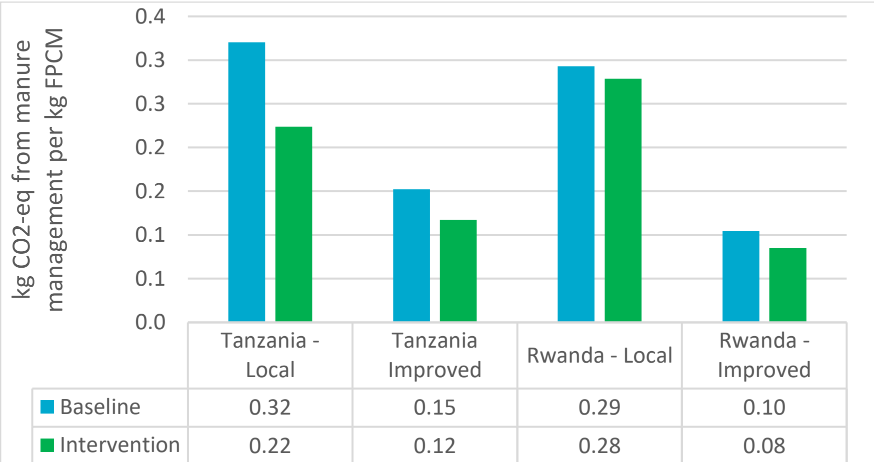

Figure 5 Emission intensity for methane emissions from manure management. FPCM is Fat-Protein Corrected Milk measured in kg. Milk production is unadjusted for losses along the value chain. One kg of methane (CH_4) is assumed to be 24 kg of carbon dioxide equivalent (CO_2-eq).

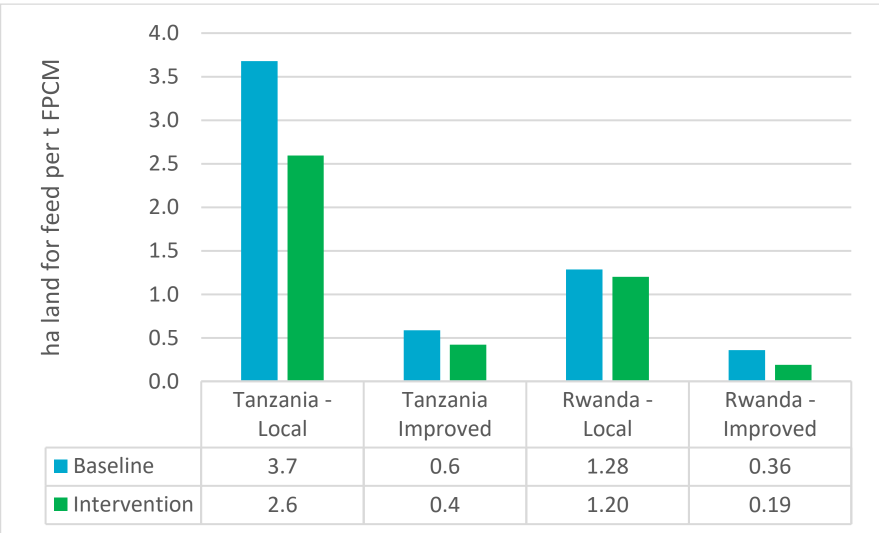

Figure 6 Land requirements for feed to produce one tonne of milk. FPCM is Fat-Protein Corrected Milk measured in kg. Milk production is unadjusted for losses along the value chain.

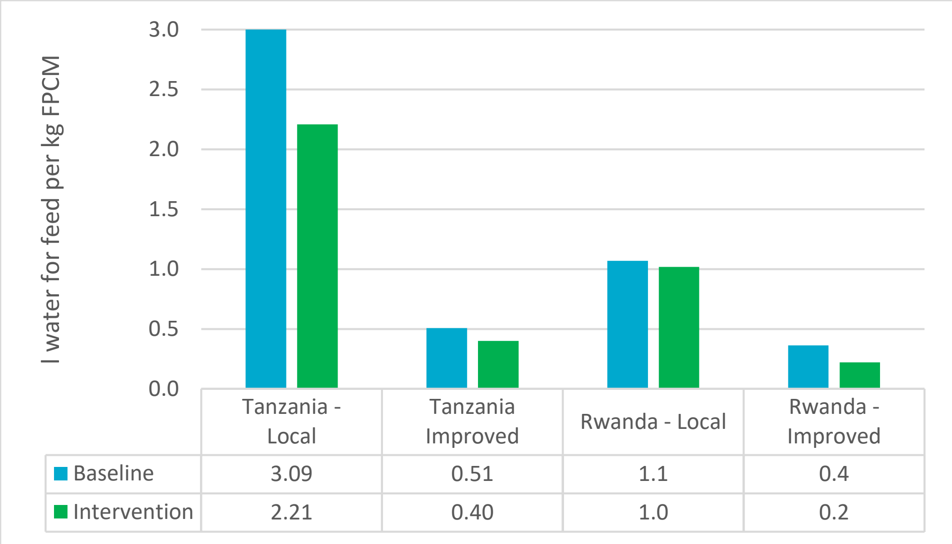

Figure 7 Water requirements for feed to produce one kg of milk. FPCM is Fat-Protein Corrected Milk measured in kg. Milk production is unadjusted for losses along the value chain.

3.3 From farm to national-level milk production and environmental impact assessment

Farm level biophysical impacts are upscaled to national scale impacts for the dairy system considering not only reproductive females but the whole cattle population by multiplying farm scale impacts with the number of herds in both countries. This method can only result in an approximation of national environmental impacts of changing feeding systems as there are considerable differences between local feeding systems in the same production zone, both in quantity and quality. The number of individuals per herd is estimated from the national cattle population statistics and is assumed to be 3.3 and 1.8 for the local breed herds in Tanzania and Rwanda, respectively and 2.5 and 2.3 for the improved breed herds in Tanzania and Rwanda, respectively. As in the LMPs it is assumed that the number of dairy cows between 2016/17 and 2021/22 increases by 10% in Tanzania and by 7% in Rwanda we assume the same increase for the rest of the cattle population (Figure 8).

The national milk production from local and improved cows is projected to increase by 80% (1,733 million litres) to 3,892 million litres in Tanzania and by 65% (484 million litres) to 1,230 million litres in Rwanda within five years from the baseline 2016/16 (Figure 8). Rwanda has implemented the One Cup of Milk per Child program in 2010 which aims at supplying school aged children with half a litre of milk twice a week. If the program is rolled out throughout the country this requires approximately 224 million litres of milk currently and with projected population growth to 2022 an additional 23 million litres of milk is required to supply the additional 451,000 school age children. The World Population Prospects 2019 data by the United Nations for Rwanda is 4,769,000 children of age 5-19 in 2022, compared to 4,318,000 children in 2017. Another 30-60 million litres milk could be produced for consumption by the rest of the population projected to grow by 2022 including children under five years of age assuming a weekly consumption of half a litre to a litre. The surplus of 401-431 litres of milk can be used for other dairy products or exported.

The increase in the cattle population are projected to lead to an increase the methane emissions from enteric fermentation and manure management by 11% to 4.6 MtCO2-eq in Tanzania and by 30% to 0.24 MtCO2-eq in Rwanda. For Tanzania this increase in methane emissions represents a very small fraction of the pledged reduction in greenhouse gas (GHG) emissions overall as part of the countries intended nationally determined contribution (INCDs) to limiting global average temperature increase to below two degree Celsius so should not influence that economy wide goal a lot. Tanzania's goal is to reduce greenhouse gas emissions economy wide between 10-20% by 2030 relative to the BAU scenario of 138 – 153 MtCO2-eq (see UNFCCC website on INDCs). Rwanda's goal is to reduce GHG emission from enteric fermentation by increasing fodder supply from Napier grass and Desmodium legume which increases efficiency in dairy production (see UNFCCC website on INDCs). Our results indicate that this goal cannot be achieved if at the same time milk production are increasing by 65% as the increase in overall cattle population needed to produce this additional milk leads to a gross increase in emissions from enteric fermentation.

The land required to produce feed for the cattle population is projected to increase by 12% to 33.3 million ha land in Tanzania and to decrease by 13% to 667,460 ha land in Rwanda. The decrease in land required in Rwanda is mostly driven by strong declines in land requirements in the medium and high rainfall zone where in the feed intervention scenario crop residues are replaced by higher quality feed with lower dry matter intake requirements for the animals. The amount of water required to produce feed is projected to increase by 9% to 28.2 billion litres in Tanzania and by 3% to 690 million litres in Rwanda (Figure 9).

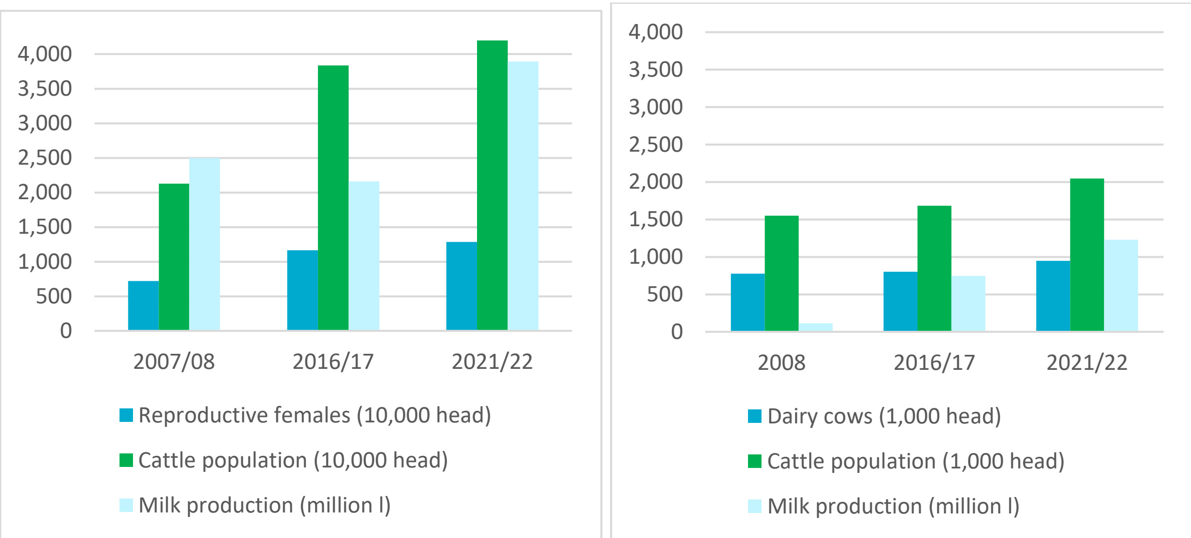

Figure 8 Number of reproductive females, total cattle population and national milk production in Tanzania (left) and Rwanda (right). Data for 2016/17 and 2021/22 is from the Livestock Masterplans or calculated with data provided in the masterplans. Data for 2008 is from the National Sample Census of Agriculture (Volume III: Livestock Sector, National Bureau of Statistics and the Office of the Chief Government Statistician, Tanzania) and the National Agricultural Survey 2008 (NAS 2008, National Institute of Statistics of Rwanda).

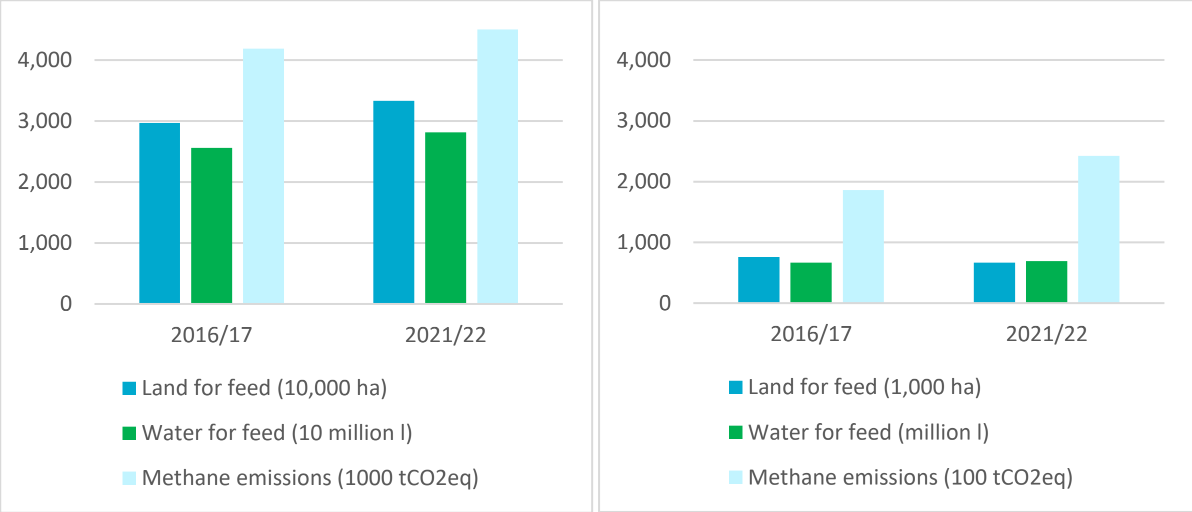

Figure 9 Land and water for feed production for cattle herds and methane emissions from enteric fermentation and manure management in Tanzania (left) and Rwanda (right).

Appendix A CLEANED crop and feed parameters

Table A 1 Nutritional value of feed items used in CLEANED.

Feed item	**DM content (%)**	**ME content (MJ/kg DM)**	**CP content (% DM)**
Cereal grains and by-products			
Banana (Musa acuminate) – crop residue (peels)	9.0	8.6	9.5
Groundnut (Arachis hypogaea) – crop residue	89.5	7.9	6.3
Maize (Zea mays) - bran	88.7	11.0	11.9
Maize (Zea mays) – stover (grazing) *	29.6	8.4	6.8
Maize (Zea mays) - green fodder	82.0	10.2	8.9
Rice (Oryza sativa) – bran with germs *	90.0	15.8	14.2
Rice (Oryza sativa) - straw *	91.9	5.8	4.2
Sugarcane (Saccarum officinarum) - molasses	74.3	10.9	5.8
Grass forages			
Kikuyu grass (Pennisetum clandestinum) (forage) *	20.1	9.7	15.1
Kikuyu grass (Pennisetum clandestinum) (hay) *	90.0	8.0	11.0
Brachiaria hybrid (forage)	26.0	7.3	7.3
Bread grass (Brachiaria brizantha) – hay *	84.0	6.6	5.2
Jaragua grass (Hyparrhenia rufa) – forage	26.0	6.1	5.3
Napier grass (Pennisetum purpureum) - forage	15.0	9.9	11.0
Naturally occurring pasture – grazing (as B. brizantha, fresh) *	29.6	8.1	10.4
Naturally occurring pasture – green fodder *	28.0	8.1	10.4
Rhodes grass (Chloris gayana) – hay *	86.4	8.1	10.1
Rhodes grass (Chloris gayana) - forage	28.1	7.5	14.1
Forage trees and legume forage			
Greenleaf desmodium (Desmodium intortum) *	24.2	8.4	15.5
Lablab (Lablab purpureus) - forage	18.3	11.4	22.9
Leucaena (Leucaena leucocephala) - forage	26.2	9.5	19.9
White clover (Trifolium repens) – forage *	16.8	11.1	24.9
Concentrates			
Concentrate (commercial) – Tanzania: maize bran, sunflower seed cake, common salt and minerals mixture *	93.5	9.4	21.1
Concentrate (commercial) – Rwanda: maize distillery grain *	89.0	14.2	29.5
* Some or all three parameters changed from standard CLEANED parameter to Feedipedia.org parameter or feed item parameters added from Feedipedia.org. Naturally occurring pasture – grazing and green fodder are parameterized as Brachiaria brizantha with its CP content being very close to results from lab analysis of Tanzanian mixed natural grasses (10.0, pers. comm. Beatus Nzogela).			

- Kc coefficients for Rhodes grass (*Chloris gayana*) and Kikuyu grass (*Pennisetum clandestinum*) as for Brachiaria: Initial 0.6, Mid-season 1.1 and Late 1.05.

- Dry matter yield for Rhodes grass and Kikuyu grass set to 13 t/ha and 19 t/ha, respectively. Dry matter yield for White clover was set to 3.72 t/ha (Yamoah & Mayfield, Herbaceous Legumes as Nutrient Sources and Cover Crops in the Rwandan Highlands, Biological Agriculture & Horticulture, 1990). Dry matter yield for Greenleaf desmodium and Potato was set to 12 t/ha and 10 t/ha, respectively.

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