Assessing the environmental impacts of intervention packages in dairy systems in Tanzania

CLEANED baseline and scenario assessment report

Maziwa Zaidi

More Milk in Tanzania

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Walter Mangesho
Jessica Mukiri
Emmanuel Mwema
Godfrey Ngoteya
Amos Omore
Birthe Paul
An Notenbaert

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About the authors

Walter Mangesho, Research Consultant Alliance of Bioversity International CIAT, Senior Research Officer II, Tanzania Livestock Research Institute (TALIRI), Tanzania.

Jessica Mukiri, Senior Research Associate, Tropical Forages Program, Alliance of Bioversity International and CIAT, Kenya.

Emmanuel Mwema, Research Consultant, Tropical Forages Program, Alliance of Bioversity International and CIAT, Kenya.

Godfrey Ngoteya, Research Coordinator, International Livestock Research Institute, Tanzania.

Amos Omore, Country Representative and Research Coordinator, International Livestock Research Institute, Tanzania.

Birthe Paul, Scientist, Tropical Forages Program, Alliance of Bioversity International and CIAT, Kenya.

An Notenbaert, Africa Team lead, Tropical Forages Program, Alliance of Bioversity International and CIAT, Kenya.

Cover photo by Paul Karaimu/ILRI, 2014.

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Acronyms and Abbreviations

AI	Artificial Insemination
CIAT	International Center for Tropical Agriculture
CLEANED	Comprehensive Livestock Environmental Assessment for improved Nutrition, a secured Environment and sustainable Development along livestock value chains
CO2eq	Carbon dioxide equivalent
CP	Crude protein
DM	Dry matter
ECF	East Coast Fever
FAO	Food and Agriculture Organization
FPCM	Fat- and protein-corrected milk
GDP	Gross Domestic Product
GHG	Greenhouse Gas
IFAD	International Food and Agriculture Development
ILRI	International Livestock Research Institute
LWG	Live Weight Gain
ME	Metabolizable energy
N	Nitrogen
TDV	Tanzania Development Vision
TLMP	Tanzania Livestock Master Plan
TLMI	Tanzania Livestock Modernization Initiative
URT	United Republic of Tanzania

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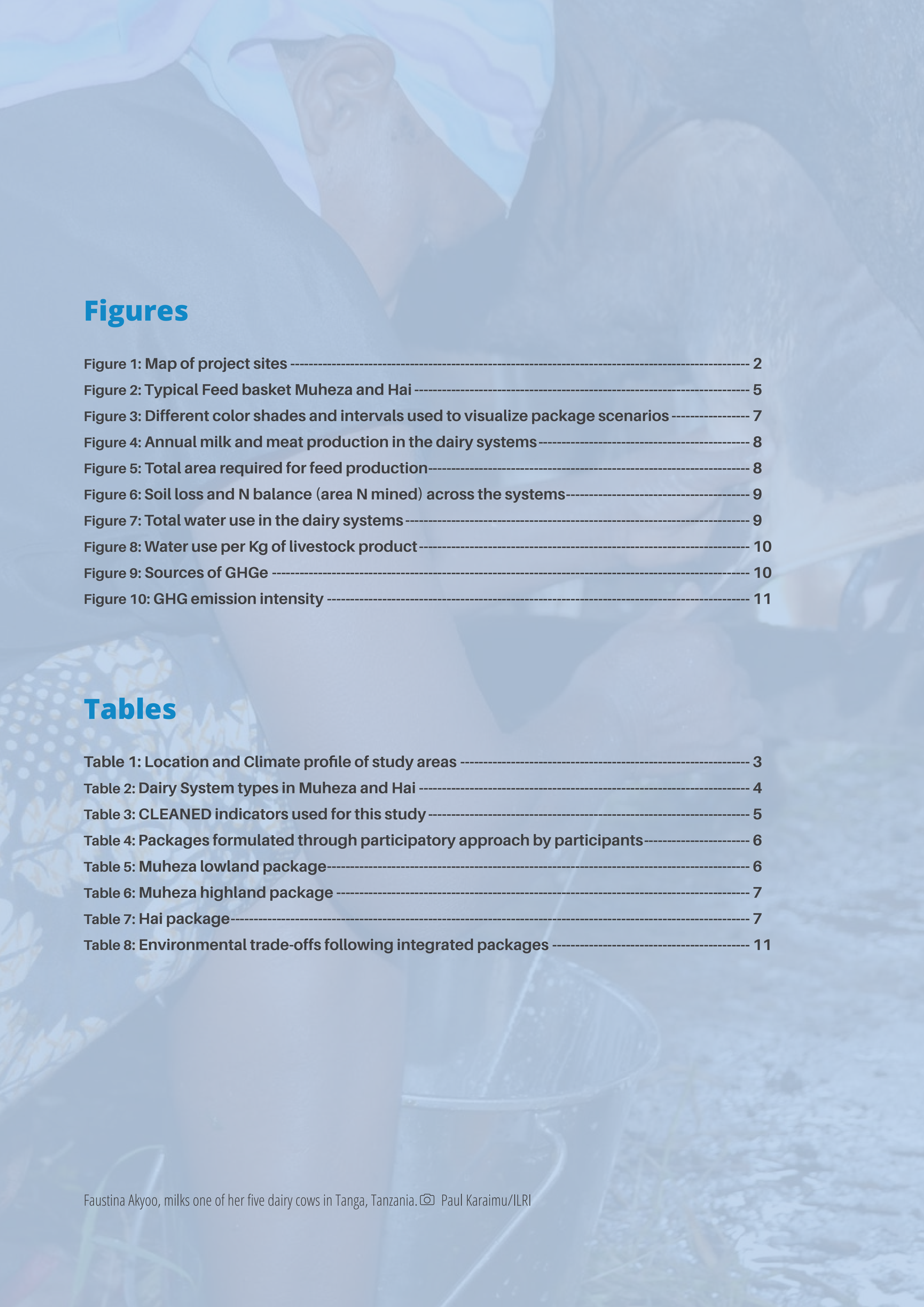
Dairy cow in Tanga, Tanzania. 📷 Paul Karaimu/ILRI



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Faustina Akyoo, milks one of her five dairy cows in Tanga, Tanzania. Paul Karaimu/ILRI

Livestock farmers in the district of Lushoto, in the Tanga region of Tanzania, are finding ways of boosting their production and lowering their environmental impact by planting improved forages. GeorginaSmith/2016CIAT

1. Introduction

The Tanzania dairy value chain is recognized as a promising pathway for achieving food security, improving livelihoods and enhancing overall economic growth (Katjiuongua and Nelgen, 2014). Livestock production is important in Tanzania contributing to about 30% of agricultural Gross Domestic Product (GDP) and 7% of country's total GDP (United Republic of Tanzania (URT), 2018). About 70% of the Tanzanian population is engaged in farming including livestock production with 50% of all households keeping livestock; 62% and 23% in rural and urban households respectively (Ministry of Livestock and Fisheries Department,2015).

Smallholder farmers are the major dairy producers in Tanzania. These are predominantly found in heterogeneous mixed crop-livestock farming systems and pastoral systems (Thornton & Herrero, 2014). Tanzania is a net importer of liquid and powder milk to meet the countries demand (Baregu, 2017). This offers an opportunity of building the dairy value chain and providing jobs and income in Tanzania. However, a number of challenges face the production of dairy systems. These include low genetic potential, animal health, poor market linkages (Maleko, et al., 2018a; Maleko, et al., 2018b)

To address these challenges the CGIAR Research Program on Livestock (Livestock CRP) has been implementing the Maziwa Zaidi project since 2012, with the overall vision of achieving inclusive and sustainable development of the smallholder dairy value chain (Kawuma et al., 2017). This is in line with the Tanzania Development Vision (TDV) (URT, 1999). Now, in its second phase, the overall objective of the project is to pilot uptake of dairy technology packages through institutional approaches that involve inclusive agribusiness models for improved livelihoods of smallholders and environmental sustainability in Tanzania.

The per capita milk consumption is expected to double from 50 to 100 kg/annum by year 2030 (URT, 2017). The production of milk is dependent on the availability of natural resources. However, livestock farming is associated with land degradation, air and water pollution, greenhouse gas emissions and the decline in biodiversity (Ramankutty et al., 2018; Rojas-Downing et al., 2017, Steinfeld, 2006). It is thus important to identify the trade-offs associated with dairy intensification.

Environmental assessments on dairy production have been carried out in the Southern Highlands and Tanga regions of Tanzania (Mwema et al., 2021; Notenbaert et al., 2020). These assessments captured the potential environmental impacts of dairy production in mixed crop-livestock and agro-pastoral production systems. However, there is limited data on the environmental impacts of dairy systems in Muheza and Hai districts.In order to design sustainable livestock systems in these sites, it is important to evaluate the potential trade-offs critical for decision-making. For this reason, CLEANED (Comprehensive Livestock Environmental Assessment for improved Nutrition, a secured Environment and sustainable Development along livestock value chains) a minimum data, ex-ante tool was used to calculate environmental footprints (Mukiri et al 2019). CLEANED assessments were carried out to assess the current environment impacts and trade-offs following introduction of integrated Maziwa Zaidi II packages in the intensive dairy production systems of Hai and Muheza districts in Tanzania.

This study aims to answer the following research questions:

1. What are the land, soil, water and greenhouse gas emissions (GHGe) footprints of the intensive dairy production systems in Muheza and Hai?
2. What are the environmental trade-offs of intensifying dairy production systems in Muheza and Hai with integrated Maziwa Zaidi II program packages?

2. Material and Methods

2.1 Description of the study area

The study was undertaken within the Livestock CRP Maziwa Zaidi II program led by Alliance of Bioversity International and International Center for Tropical Agriculture and International Livestock Research Institute (ILRI), together with their partners in intervention sites (Figure 1). The assessment was conducted between the period of October 2020 and June 2021.

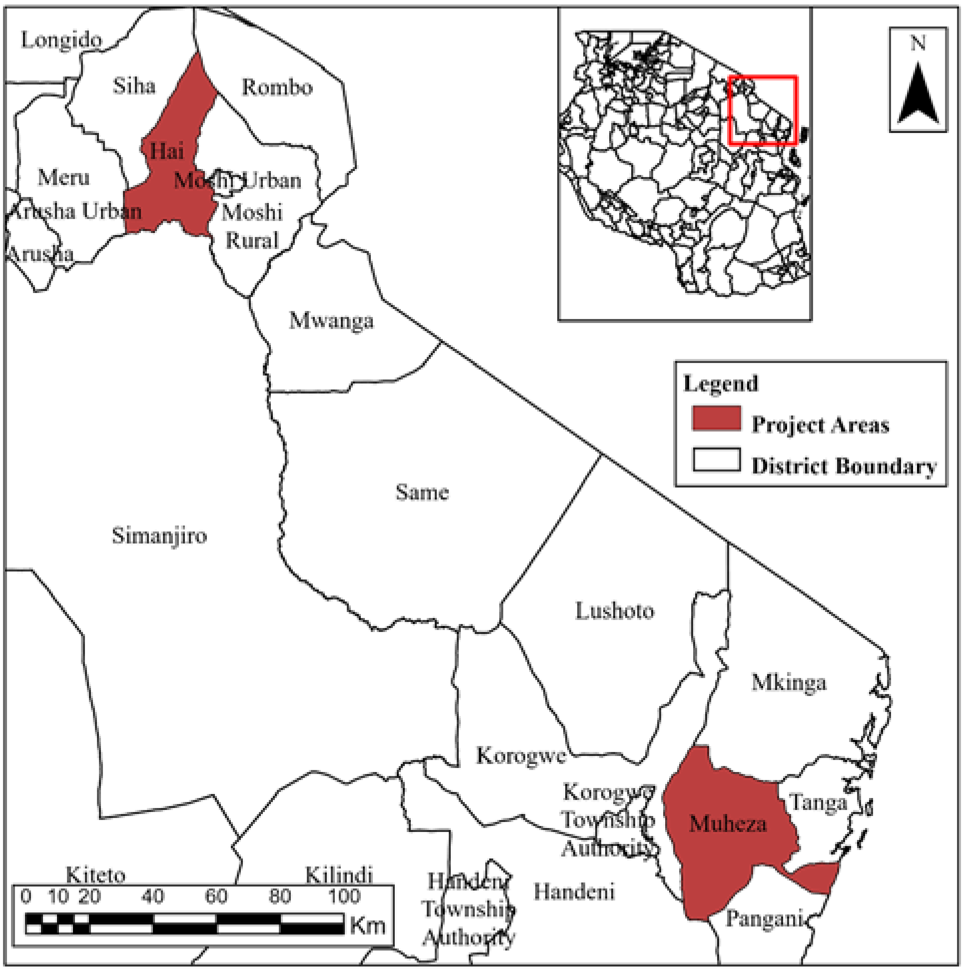

Figure 1: Map of project sites

Physical, and socio-economic attributes of the study area

Muheza is one of the eight administrative districts in Tanga Region located in north eastern Tanzania. It falls between longitude 38.78333 and latitude -4.83333 (Muheza District Profile, 2014). The district borders Tanga City on the Eastern side and Mkinga on the Northern side. It also borders Pangani District in the South and Korogwe District to the West. The district covers a total area of 1,498 square kilometers. According 2012 population and housing census general report, the district has a population of 204,461 and population density of people per square kilometer. The study site was in Muheza lowland and highland with average annual precipitation 474 and up to 1400 mm, respectively. The average annual temperature is 25.28 and 20.6 for lowland and highland, respectively (Muheza District Profile, 2014). Agriculture is the engine of Muheza's economy and livelihood, employing almost 75% of the district population (Muheza District Profile, 2014). The district has about 167,800 hectares of arable land of which 117,500 hectares or 70% has been cultivated (Muheza District Profile, 2014). The fertile soils and rainfall allow a variety of crops to be grown. Bananas, paddy, cassava and maize are the main food crops but are also sold. The major cash crops include sisal, tea, rubber, cashew nuts, coconuts, oranges and spices especially black pepper and cinnamon.

Hai District is one of the seven administrative districts of Kilimanjaro Region of Tanzania. It falls between longitude 37.20137 and latitude -3.29164 (Hai District Profile, 2020). It is bordered to the South and West by Arusha Region, to the West by Siha District, and to the East by Moshi Urban District, Moshi Rural District and

Rombo District. The district covers a total area of 1011 square kilometers. According 2012 National population and housing census general report, the district has a population of 210,533 and population density of 130 people per square kilometer. The district receives an average annual rainfall ranging from 500 mm in the lower zone to 1750 mm in the upper zone with an average annual temperature of 23°C (Hai District Profile, 2020). About 95% of people in this district depend on agriculture for their livelihood and the main crops produced include coffee, maize, beans, bananas, sunflower and paddy (Hai District Profile, 2020).

Table 1: Location and Climate profile of study areas

Site	Longitude	Latitude	Mean Annual Rainfall (mm)	Mean Annual Temperature (˚C)	Land area (sq. km)	Reference
Muheza highland, Tanga	38.6234	-5.0851	474	20.6	1,974	Muheza District Profile, 2014
Muheza lowland, Tanga	38.78333	-4.83333	1,100 to 1,400	25.28		
Hai, Kilimanjaro	37.20137	-3.29164	521 ± 188	23.3 ± 0.66	902	Hai District Profile, 2020

2.2 Dairy production system types in Tanzania

Livestock production systems can be classified using a number of criteria. According to FAO (2002), a farming system is defined as a group of farms with a similar structure, such that individual farms are likely to share similar production functions. Classifying livestock production systems like that gives opportunity to study, classify and group production systems into challenge and opportunity zones and to simplify planning of development interventions (URT, 2017).

Distributing milk at a dairy farm in Tanga, Tanzania. Muthoni Njiru/ILRI

In Tanzania, the production systems of livestock management are simply classified as extensive, semi-intensive and intensive. Extensive livestock production is mainly practiced in non-cultivated land where animals can graze freely. It is exercised in large farm size with low production per animal or per unit of land; huge numbers of cattle are kept with comparatively low labor intensity (URT, 2017). On the other hand, the semi-intensive system is characterized by allowing cattle access to pasture for the provision of forage during certain times of the day. The cattle are exposed to any combination of both extensive and intensive husbandry methods, either simultaneously or varied according to changes in climatic condition or physiological state of the cattle (OIE, 2012). Fewer numbers of cattle are kept in this system than in the extensive system but more than in the intensive system. The intensive management system of cattle involves housing of animals and feeding them in the stables with concentrated feedstuffs. It is mainly practiced in areas with shortage of land such as highland areas where most of the available land is used for crop cultivation. It is a labor-intensive system and generally fewer numbers of cattle are kept than in extensive or semi-intensive.

In this assessment, we looked at intensive systems as these were being targeted within the Maziwa Zaidi II program. These dairy systems were representative of an intensive dairy system in each location. They were characterized by the management, breed type, average annual milk production per cow, herd composition, feeding system type, and animal diet.

Table 2: Dairy System types in Muheza and Hai

Site	Livestock systems	Season	Season Months	Management system	Breed type	Average. milk production (kg)/cow/ year	Type and No. of animals	Feeding system	Type of feed (%)
Muheza - Highland	Intensive	Long rains	April to June	Zero grazing	Cross breed	3600	Cows: 3 Heifers:2 Calves: 2	Cut & Carry	Improved Forages (47) Concentrates (1) Crop residues (2) Natural Pastures (50)
		Short rains	July, Oct to Dec						Improved Forages (24) Concentrates (1) Crop residues (5) Natural Pastures (70)
		Dry Season	Jan to March, Aug & Sep						Improved Forages (5) Concentrates (2) Crop residues (4) Natural Pastures (89)
Muheza - low land	Intensive	Long rains	April to June	Zero grazing	Cross breed	2100	Cows: 3 Heifers: 2 Calves: 2	Cut & Carry	Improved Forages (4) Concentrates (1) Crop residues (10) Natural Pastures (85)
		Short rains	July, Oct to Dec						Improved Forages (4) Concentrates (1) Crop residues (13) Natural Pastures (82)
		Dry Season	Jan to March, Aug & Sep						Improved Forages (1) Concentrates (2) Crop residues (13) Natural Pastures (84)
Hai	Intensive	Long rains	March to July	Zero grazing	Pure Breed	3000	Cows: 2 Heifers:1 Calves: 1	Cut & Carry	Improved Forages (15) Concentrates (5) Crop residues (30) Natural Pastures (50)
		Short rains	Mid Oct to Dec						Improved Forages (15) Concentrates (10) Crop residues (45) Natural Pastures (30)
		Dry Season	Sep to Mid Oct and Jan to Feb						Improved Forages (15) Concentrates (10) Crop residues (45) Natural Pastures (30)

2.3 Data analysis and modelling

CLEANED approach

The CLEANED tool was used to assess the potential environmental footprints associated with intensive dairy farming systems in Muheza and Hai. CLEANED is a rapid ex-ante environmental impact assessment tool that allows the users to explore multiple impacts of developing livestock value chains in straight forward ways. It models the potential impacts of intensifying livestock along numerous pathways based on six indicators: land requirements, productivity, economics, soil impacts, water impacts, and greenhouse gas emissions. The CLEANED tool is a minimum data entry tool; it consists of inputs, results, parameters, and calculations (Mukiri et al., 2019). Table 3 gives a summary of indicators quantifiedin this study.

Table 3: CLEANED indicators used for this study

Indicator	*Explanation*
Land requirements	Estimates the total land required to grow the feed items prerequisite for the animals present on the livestock enterprise.
Soil impacts	Calculated by N flows, entering and leaving the livestock enterprise.
Water impacts	Estimates the amount of water used for feed production. It is presented by the actual crop evapotranspiration.
GHG impacts	It is calculated from different sources of emission using the Intercontinental Panel on Climate Change tier two methodologies.

CLEANED inputs and parameterization

The key input and parameter data needed in CLEANED include:

- Agro-ecological data – rainfall, season days, soil N, Soil C, Evo transpiration
- Livestock data – herd numbers, species, breed types, weights
- Livestock diet – feed type consumed; portion of feed consumed
- Feed- Crop management – yields, inputs, harvest management

This data was collected from primary and secondary sources. Primary sources included key experts working within the Maziwa Zaidi project sites i.e., vet, farmers and researchers. Secondary sources included literature sources such as Feedipidea, Maziwa Zaidi repository, USDA nutritional database, AO repositories, ISRIC, Tropical forages facts sheet and CGIAR publications. Annex 1 gives a breakdown of the data used and their sources. Figure 2 shows the result of using both literature and experts to construct the typical feed basket for animals across the different seasons.

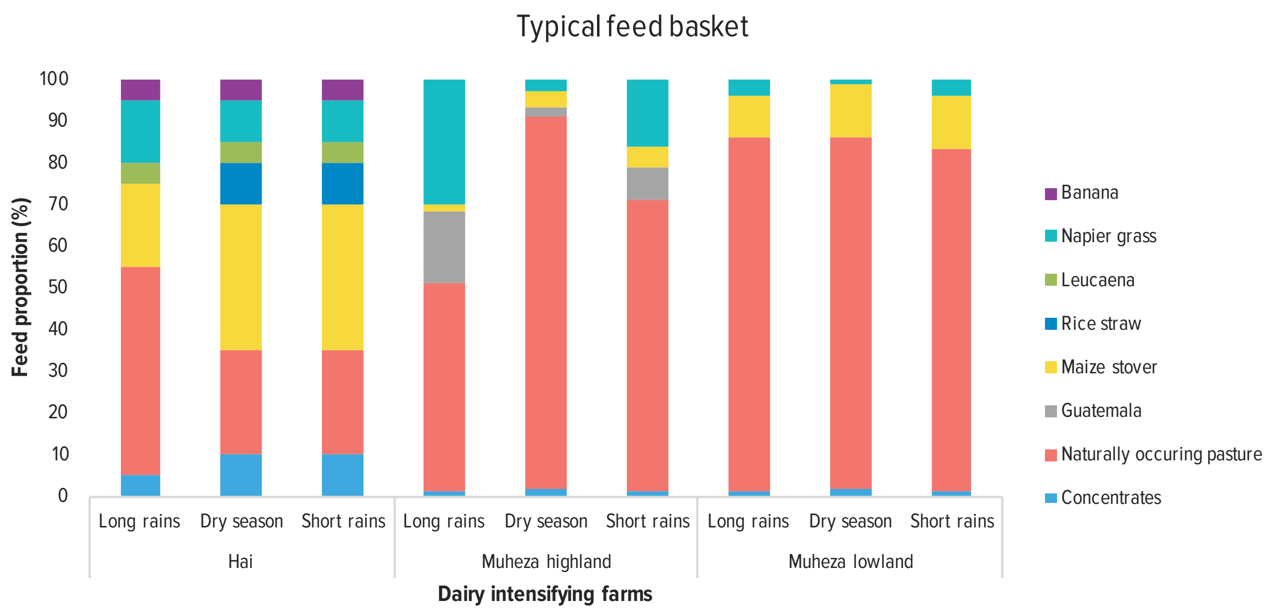

Figure 2: Typical Feed basket Muheza and Hai

Baseline calculation and validation

Baseline environmental footprints for the typical intensive dairy systems in Muheza lowland, Muheza highland and Hai were calculated. It was then followed by a hybrid stakeholder workshop that was conducted to validate the baseline data. The workshop involved 20 participants from various disciplines – livestock scientist, livestock practitioners, researchers and environmentalists (Mangesho et al., 2021). Preliminary models result on CLEANED were shared and discussed by participants. Key issues discussed were the representation oftypes (Production/Animal Numbers) and evaluation of the percentage of each type found in each location. All the input and parameter data were validated during the workshop. The participants scrutinized the input and parameter data used for modelling. The participants' main recommendations were to adjust the feed basket by using improved forages, the Brachiaria grass; improve genetics through effective use of artificial insemination (AI) service and improve herd health by vaccinating cattle against East Coast Fever (ECF) disease. The model was later adjusted based on participants' reactions to input data.There was also assessment ofthe relevance of CLEANED results and identification ofkey decision makers/experts. Participants were involved in developing future scenarios for model implementation that reflected best-bet integrated intervention packages per system i.e., identification of livestock production challenges that were prominent in the different locations and combination of interventions that would make sense for the different types.

Maziwa Zaidi intervention package scenarios

During the validation workshop, using the Maziwa Zaidi project interventions, packages/scenarios were mapped out with emphasis on their usefulness and applicability for farmers and entrepreneurs (Mangesho et al., 2021). Participants formulated the intervention package seen in Table 4.

Table 4: Packages formulated through participatory approach by participants

	Intensive package
Herd health	East Coast Fever (ECF) Vaccine
Feeds and Forages	Brachiaria
Genetics	Artificial Insemination (AI)

The improved intervention package was implemented in CLEANED with the assumption that there would be an overall improvement in productivity as a result of:

- Improved genetics
- Improved feeding
- Improved animal health.

Table five to seven gives a breakdown of the assumptions.

Table 5: Muheza lowland package

Input/ Parameter	*Baseline Value*			*New Value*			*Number Difference*			*% Difference*		
Herd composition (nr) Cow	3			3			0			0%		
Herd composition (nr) Heifer	2			1			-1			-50%		
Herd composition (nr) Calves	2			1			-1			-50%		
Average annual milk (kg)	2100			2730			630			30%		
Average annual growth per animal (kg)	120			130			10			8%		
Average Body weight (kg) - Cow	345			350			5			1%		
Average Body weight (kg)- Heifers	254			270			16			6%		
Average Body weight (kg) - Calves	110			120			10			9%		
Parturition interval (years)	1.2			1.1			-0.1			-8%		
Feed basket/ Diet - decrease of natural pasture (3 seasons)	85	84	82	70	65	60	-15	-19	-22	-18%	-23%	-27%
Feed basket/ Diet - increase of Brachiaria grass (3 seasons)	0	0	0	15	19	22	15	19	22	18%	23%	27%
Manure application tonne/ha	10			18			8			80%		

Table 6: Muheza highland package

Input/ Parameter	*Baseline Value*			*New Value*			*Number Difference*			*% Difference*		
Herd composition (nr) Cow	3			4			1			33%		
Herd composition (nr) Heifer	2			1			-1			-50%		
Herd composition (nr) Calves	2			1			-1			-50%		
Average annual milk (kg)	3600			4320			720			20%		
Average annual growth per animal (kg)	130			140			10			8%		
Average Body weight (kg) - Cow	430			460			5			1%		
Average Body weight (kg)- Heifers	280			320			16			6%		
Average Body weight (kg) - Calves	110			120			10			9%		
Parturition interval (years)	1.2			1.1			-0.1			-8%		
Feed basket/ Diet - decrease of natural pasture (3 seasons)	60	89	70	35	64	50	-25	-25	-20	-42%	-28%	-29%
Feed basket/ Diet - increase of Brachiaria grass (3 seasons)	0	0	0	15	25	20	15	25	20	25%	28%	29%
Manure application tonne/ha	10			18			8			80%		

Table 7: Hai package

Input/ Parameter	*Baseline Value*			*New Value*			*Number Difference*			*% Difference*		
Herd composition (nr) Cow	2			3			1			50%		
Herd composition (nr) Heifer	1			1			0			0%		
Herd composition (nr) Calves	1			1			0			0%		
Average annual milk (kg)	3000			3750			750			25%		
Average annual growth per animal (kg)	120			130			10			8%		
Average Body weight (kg) - Cow	340			360			20			6%		
Average Body weight (kg)- Heifers	249			260			11			4%		
Average Body weight (kg) - Calves	110			120			10			9%		
Parturition interval (years)	1.4			1.2			-0.2			-14.3%		
Feed basket/ Diet - decrease of natural pasture (3 seasons)	50	40	45	30	10	25	-20	-30	-20	-40%	-75%	-44%
Feed basket/ Diet - increase of Brachiaria grass (3 seasons)	0	0	0	20	15	10	20	15	10	40%	38%	22%
Manure application tonne/ha	10			18			8			80%		

Figure 3 shows a legend used to visualize results of intervention packages. Scenarios that resulted in a positive environmental change were represented using +signs. These represent efficiency gains as a result of improved feeding, better animal health and genetics. Scenarios worsening the current environmental situation were represented using –signs; usually to depict undesirable path with integrated packages.

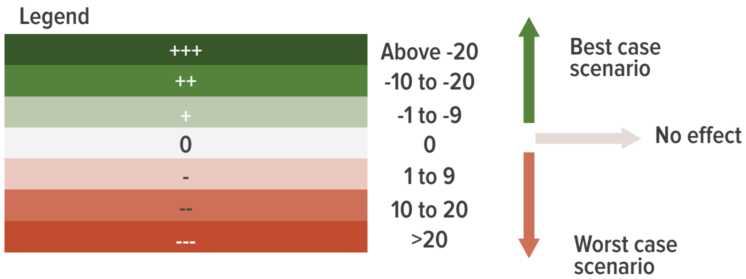

Figure 3: Different color shades and intervals used to visualize package scenarios

3. Results

3.1 Baseline outputs

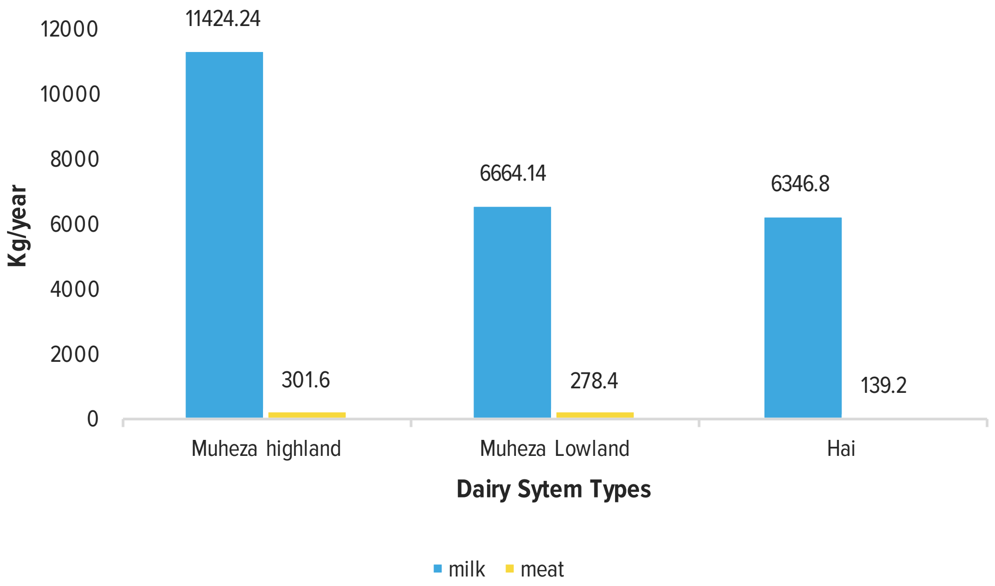

Figure 4: Annual milk and meat production in the dairy systems

» Out of the three systems assessed, Muheza highland produces more milk and meat.

» Hai system is also productive despite having low TLU

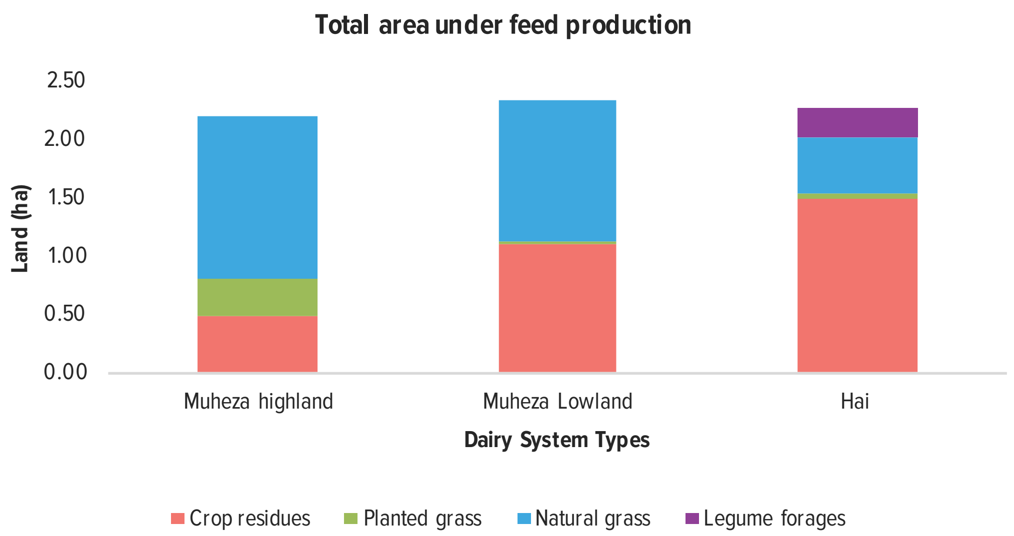

Figure 5: Total area required for feed production

» Less usage of planted grass in Hai than Muheza

» Higher dependence of crop residues in Hai than in Muheza

» High land footprint despite low TLU for Hai intensive system, but also high milk production

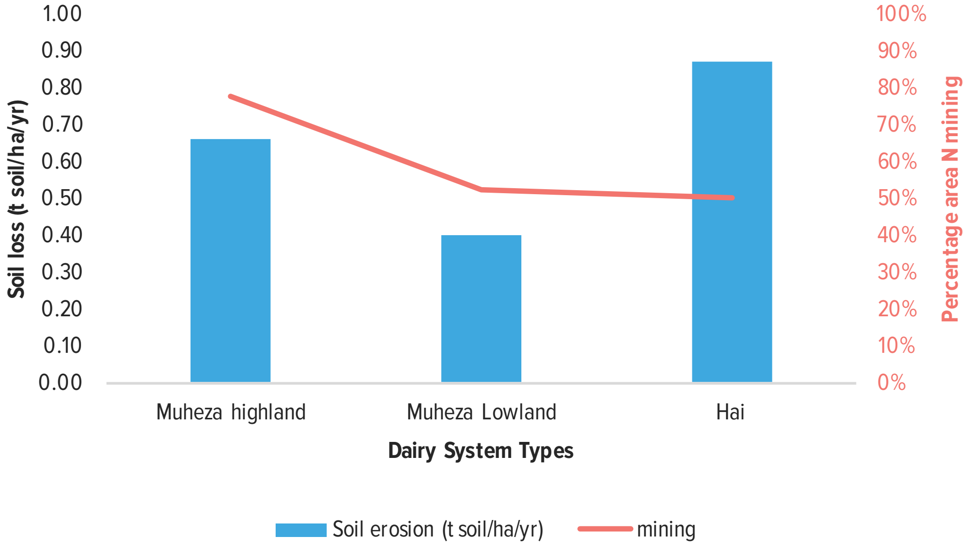

Figure 6: Soil loss and N balance (area N mined) across the systems

- Minimum N addition to the soil coupled with high crop cultivation leads to high Nitrogen (N) mining in Muheza
- High level of soil erosion in Muheza highland and Hai due to topographical nature of the area and high crop cultivation activities with less soil conservation practices

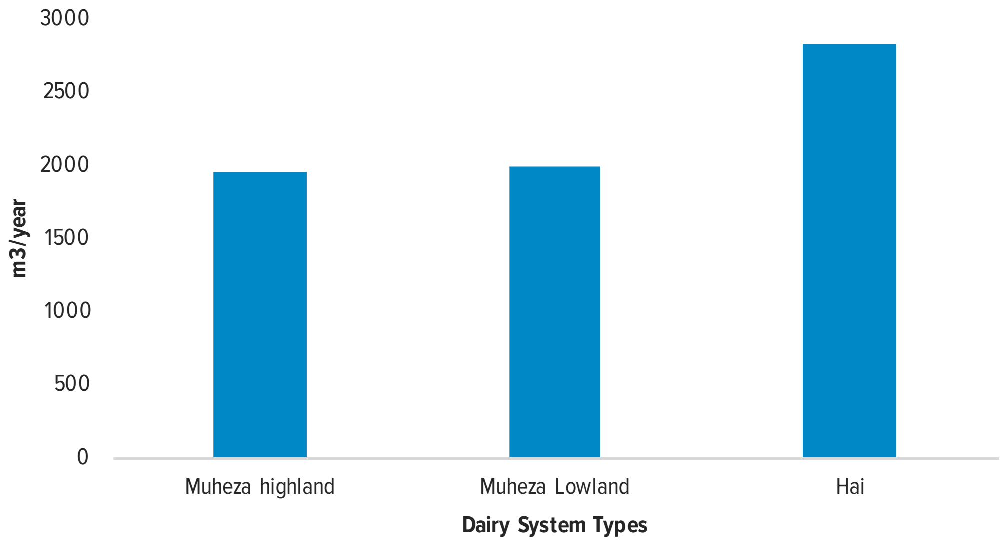

Figure 7: Total water use in the dairy systems

- Feeding of crop residues explains high water use in Hai
- Increase in production of high-quality forage would reduce relative water resource use and improve efficiency of intensive dairy production system

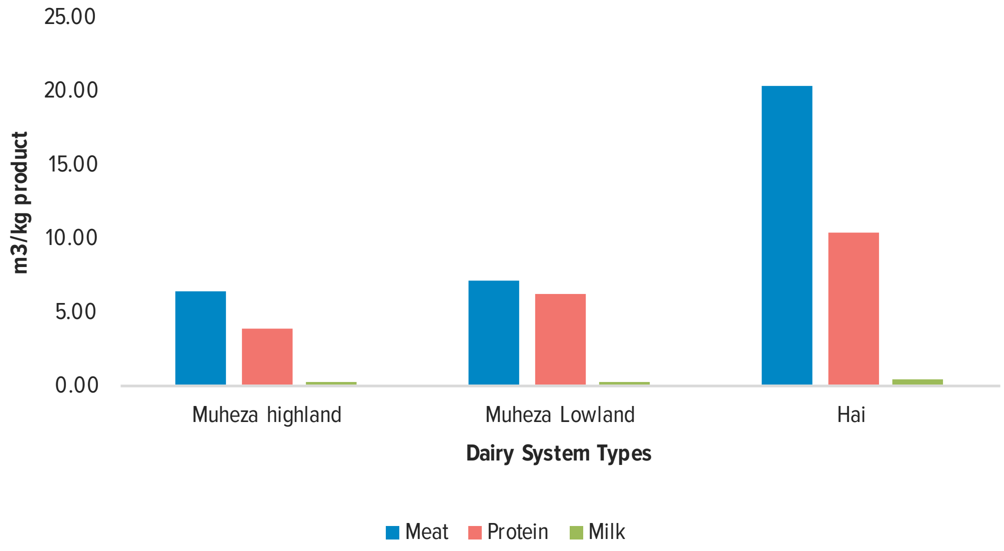

Figure 8: Water use per Kg of livestock product

- More water required to produce a liter of milk, meat and protein in Hai
- Out of the three systems in this study, Muheza highland is the most water efficient dairy system

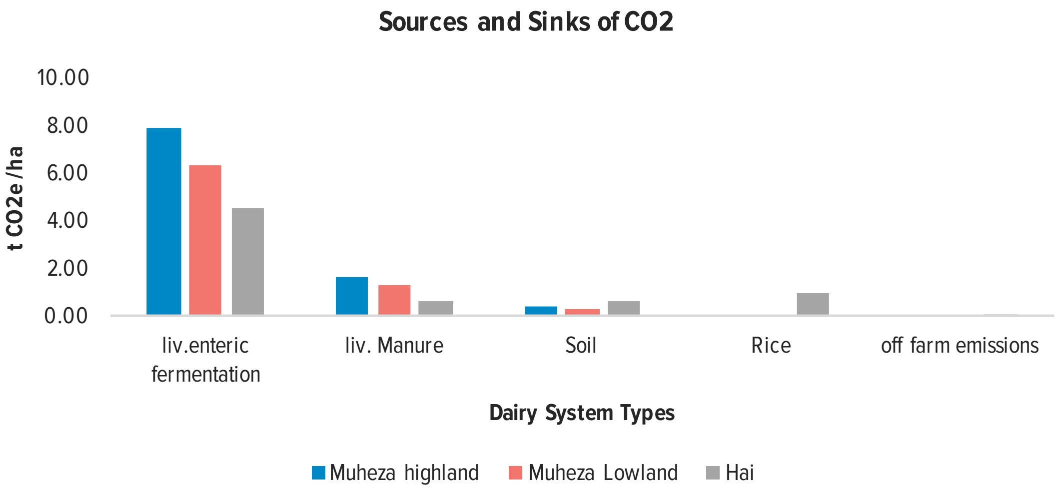

Figure 9: Sources of GHGe

- High milk production correlates positively with enteric fermentation especially when low quality feeds are used
- Poor manure management also increases emissions
- In Hai, there are notable emissions from rice farming
- Production and use of improved forages and proper manure management is highly recommended

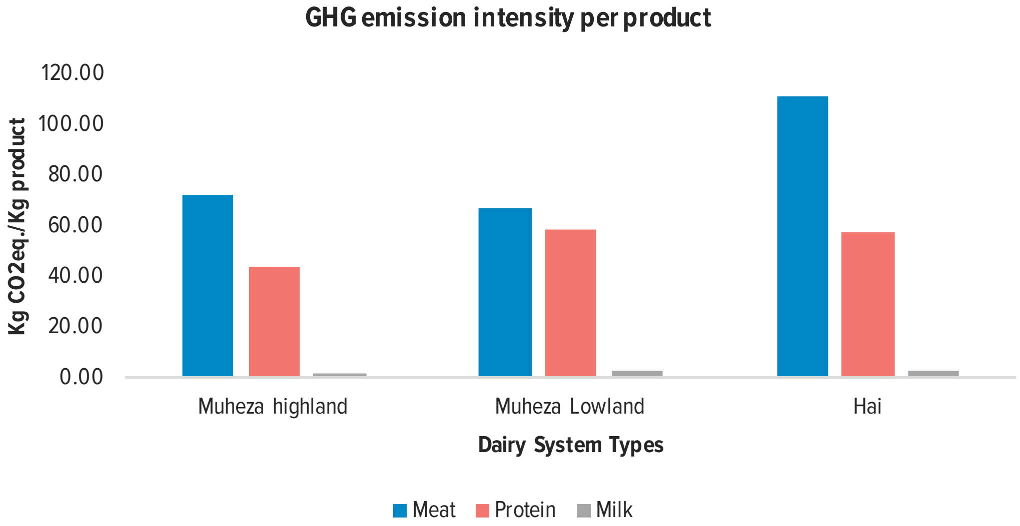

Figure 10: GHG emission intensity

- The Muheza highland systems show the lowest GHG emissions per kg of milk, while the Muheza lowland systems show the lowest GHG emission per kg of meat
- The Muheza highland systems exhibit the lowest GHG emissions per kg of protein from livestock products
- Hai systems show the highest GHG intensity per kg of meat, but due to the lower GHG emission per liter of milk, they still rank second when considering the GHG emissions per kg of protein from livestock products

3.2 Trade-offs in environmental impacts following implementation of Maziwa Zaidi package

Table 8: Environmental trade-offs following integrated packages

Farms	***Land requirements***		***Soil impacts***			***Water impacts***			***GHG emissions***		
	ha/yr	ha/MT FPCM	% Soil mining	Erosion (t soil/ ha/yr)	Erosion (kg soil/ kg FPCM)	m3/ year	m3/kg FPCM	m3/kg protein	t CO2 eq. / year	kg CO2eq/ kg FPCM	kg CO2eq/ kg protein
Intensive Dairy Muheza Highland	--	+++	+++	++	+++	+++	+++	++	---	+++	++
Intensive Dairy Muheza Lowland	+	+++	++		+++	+	+++	++	+	+++	++
Intensive Dairy Hai	---	+++	+++	+	+++	---	+++	+++	---	++	++

- More land required in Muheza highland and Hai but less in Muheza lowland, driven by high yielding of Brachiaria per unit hectare and reduced herd composition compared to baseline
- Overall improved efficiency in land (ha/MT FPCM), N balances, erosion (t soil/ha/yr; kg soil/kg milk), water requirements (m3/kg product), GHGe (kg co2e/kg product)
- Potential reduction in total GHG emissions in Muheza lowland driven by improved feed efficiency and proper manure management.
- More absolute emissions with increase in land requirements in Muheza highland and Hai.

4. Discussion

Baseline results depict high land requirements across the dairy systems due to a high reliance of natural pastures (45%) and crop residues (45%). Only a small fraction (5%) of land was under planted grass while the rest had legume forages. The feed basket is dictated by feed availability in different seasons. Crop residues are more available during the dry season when harvesting is just completed. Despite Hai having a low number of Tropical Livestock Units (TLU), it required more feed area. This is driven by higher feed requirements because of the higher productivity of the cows in combination with the production of maize stover and natural grass that have low yields per hectare.

Hai system had a minimum extend of N mining of 17% compared to 38% and 66% of Muheza lowland and Muheza highland respectively. This was mainly driven by higher rate of manure recycling for crop growth in Hai than in Muheza. In Muheza systems, farmers reported minimum N additions from manure collected to replenish soils despite continuous cultivation practices in the region. Most soil is lost in Muheza highland and Hai due to topographical nature of the area and intensive cultivation activities along the slopes. High precipitations (above 1000 mm/yr) on poorly managed grassland often result in increased soil erosion.

Muheza highland is the most water efficient system. More water is required to produce a kilogram of meat, protein and milk in Hai compared to Muheza lowland and Muheza highland (Figure 8). This is attributed to high crop cultivation in Hai that require much water as part of their growth requirements.

High milk production correlates positively with enteric fermentation especially when low quality feeds are used (Figure 9). Low quality feeds take more time to be digested by animals and this creates more room for methane emissions. Poor manure management also increases emissions as result of increased volatilization activity in the soil. Hai system has notable emissions from rice farming and this is due to longer flooding period that create ideal conditions for methane emitting bacteria.

With regard to environmental trade-offs of Maziwa Zaidi integrated packages (Table 8), improved animal health, genetics and forage, are likely to result in increased land requirements in Muheza highland and Hai. This is also the case with the intervention packages as modeled by Notenbaert et al. (2020) who reports increased land requirement for feed production with increased milk productivity in Tanga region. However, in Muheza lowland the use of Brachiaria with improved animal health and genetics proved to be more synergetic as productivity increased with less land required to produce animal feeds (Table 8). A reduction in land through intensification depicted that land in Muheza lowland can be preserved or used for other activities. This promotes environmental conservation efforts as described by Steinfeld et al. 2006 and Bosire et al. 2016.

Improving feed basket with 10 - 30% Brachiaria hybrid and reducing intake of natural pasture together with other interventions resulted into increased milk production per unit hectare by an average of 37% in all the systems (Annex 2).

After 80% manure application (Table 7), the replenishment of nitrogen into the soil has improved significantly leading to an average reduction of up to 34% in percentage area N mined in all systems (Table 8). Introduction of Brachiaria improved the cover factor within the systems resulting into total reduction in soil lost due to erosion activities. There is also a reduction in soil lost when producing a liter of milk compared to the baseline.

Total water use is likely to increase across the systems. This is ascribed to the higher amounts of feed that need to be grown. However, the water use efficiency improves, i.e. relatively less water is required to produce a liter of milk or kg of protein (Table 8). This can be attributed to presence of Brachiaria in the feed basket and the associated improvement of feed efficiency.

Absolute GHG emission are likely to increase in all sites except in Muheza lowland where they are projected to be reduced by 7% (Table 8). A 50% decrease in number of heifers and calves in Muheza lowland (Table 5) together with improved feed basket resulted to an overall reduction in GHG emissions. In other sites, the number of dairy cattle was increasing as farmers desired to own improved cattle after a successful artificial insemination exercise. Increase in herd composition proliferated total GHG emissions as high milk production led to increased enteric fermentation. Increased dairy cattle correlates with manure production and livestock manure emissions especially when gross energy efficiency for animals remains unattained. However, GHG emission intensities across the systems are reducing. This implies an environmentally sustainable pathway for the dairy farmers. Use of Brachiaria grass is contributing to this reduction with an overall improved feed efficiency that makes animals to be more energy efficient.

With integrated packages, there is an overall environmental efficiency gains in land (ha/MT FPCM), N balances, erosion (t soil/ha/yr; kg soil/kg milk), water requirements (m3/kg product) and GHGe intensity (kg CO_2e/kg product) in all the systems.

Faustina Akyoo is a dairy farmer in Tanga, Tanzania. Her five dairy cows are an important livelihood asset for her family. Paul Karaimu/ILRI

5. Conclusion and recommendations

Land requirements will always increase within and across the systems if reliance of crop residues as a livestock feeding strategy continues. The only pathway to prevent further expansion of land into forest areas in quest for livestock feeding is to introduce a high biomass/nutrient yielding forage. This will result in reduced feed area per system and hence lowering the competition of land between food and feedcrops.

Enteric fermentation is a major source of GHG emissions across the sites. This emission can be reduced by improving the feed basket efficiency through the use of hybrid forages such as Brachiaria Mulato II. Proper manure management in all systems reduces manure emissions. Despite baseline results showing higher soil footprint in Muheza highland and Hai, integrated packages depict reduced soil erosion. Production and use of improved forages and proper manure management can act as a good climate change mitigation option in the study sites. It is also possible to minimize soil loss in highland areas such as those of Muheza highland and some parts of Hai by planting cover crops such as Brachiaria. Improving soil cover and continuous replenishment of soil with nutrients is key to achieving a positive impact on soil health in all systems.

High water footprint correlates with high usage of crop residues within the systems. Although water reduces at relative level (per unit of product), achieving quick gains will require further adjustment of the feed basket where crop residues intake is reduced or replaced with improved forages. Increasing production of high-quality forage would reduce relative water resource use and improve efficiency of the intensive dairy systems.

In general, the integrated intervention packages show synergies as there is an overall environmental efficiency gains per unit of output i.e., land (ha/MT FPCM), N balances, erosion (t soil/ha/yr; kg soil/kg milk), water requirements (m3/kg product) and GHGe intensity (kg CO2e/kg product) in all the systems.

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Annex 1: CLEANED INPUT data

Area parameters

Agro-ecological data	*Unit*	*Hai*	*Muheza*	*Sources*
Annual evapotranspiration	mm/yr	1666	1359	[1]
Aridity index (ETO)	mm/yr	6467	9810	[1]
Precipitation	mm/yr	1078	1119	[2]
Soil Organic Carbon	g/kg	17	30	[3]
Bulk density	Kg/m3	1315	1262	[3]
Soil clay content	%	44	41	[3]
Soil total Nitrogen	g/kg	1627	2069	[3]
Soil depth	cm	200	200	[3]
Soil type	World Reference Base	Haplic Acrisols	Haplic Ferralsols	[3]
Rainy season	number of months /year	3	6	[2]

Notes: 1. CGIAR-CSI, 2. World Clim, 3. Soilgrids.org

Livestock parameters

Dairy System Type	*Livestock category*	*Average Body weight (kg)*	*Average LWG per animal (kg)*	*Herd composition*	*Annual milk production per lactating cow (kg)*	*Calving interval (years)*	*Sources*
Hai	Cows – improved	380	0	2	3000	1.4	[123]
	Steers/heifers improved	290	120	1	-	-	[12]
	Calves improved	110	120	1	-	-	[12]
Muheza Highland	Cows – improved	430	0	3	3600	1.3	[124]
	Steers/heifers improved	280	130	2	-	1.2	[12]
	Calves improved	110	130	2	-	-	[12]
Muheza Lowland	Cows – improved	370	0	3	2100	1.3	[124]
	Steers/heifers improved	270	120	2	-	1.2	[12]
	Calves improved	110	120	2	-	-	[12]

Notes: 1.Field data. 2. Barnsley Highlands. 3. Swai et al., 2014. 4. Swai et al., 2007.

Crop parameters

Crop product	Main product Fresh Yield (t FW/ha)	Main product DM content fraction	Main product N content (kg N/kg DM)	Crop residue N content (kg N/kg DM)	C (crop cover) factor	Average Harvest index	Energy (kcal per FW 100g)	Water content (g per 100 g)	Crop coefficient (Kc) avg
Napier	105.00[1]	0.15[2]	0.018[4]	0.018[2]	0.010[3]	0.90[4,5]	-	-	0.92[8]
Guatemala	90.00[1]	0.22[2]	0.009[2]	0.009[2]	0.010[3]	0.90[1,5]	-	-	0.92[8]
Maize	4.33[1]	0.30[2]	0.013[2]	0.006[2]	0.100[3]	0.52[6]	365[7]	10.37[7]	0.65[8]
Natural occuring pasture-Hai	41.00[1]	0.30[2]	0.011[2]	-	0.050[3]	0.90[1,5]	-	-	0.60[8]
Natural occuring pasture-Muheza	45.00[1]	0.29[2]	0.010[2]	-	0.050[3]	0.90[1,5]	-	-	0.60[8]
Leucaena	8.00[1]	0.26[2]	0.04[2]	0.04[2]	0.05[3]	-	-	-	1.08[8]
Banana	10.00[1]	0.06[2]	0.02[2]	0.01[2]	0.05[3]	0.43	30[7]	74.00[7]	0.68[8]
Rice	1.50[9]	0.93[2]	0.007[2]	0.007[2]	0.150[3]	0.37[10]	360[7]	12.89[7]	1.00[8]

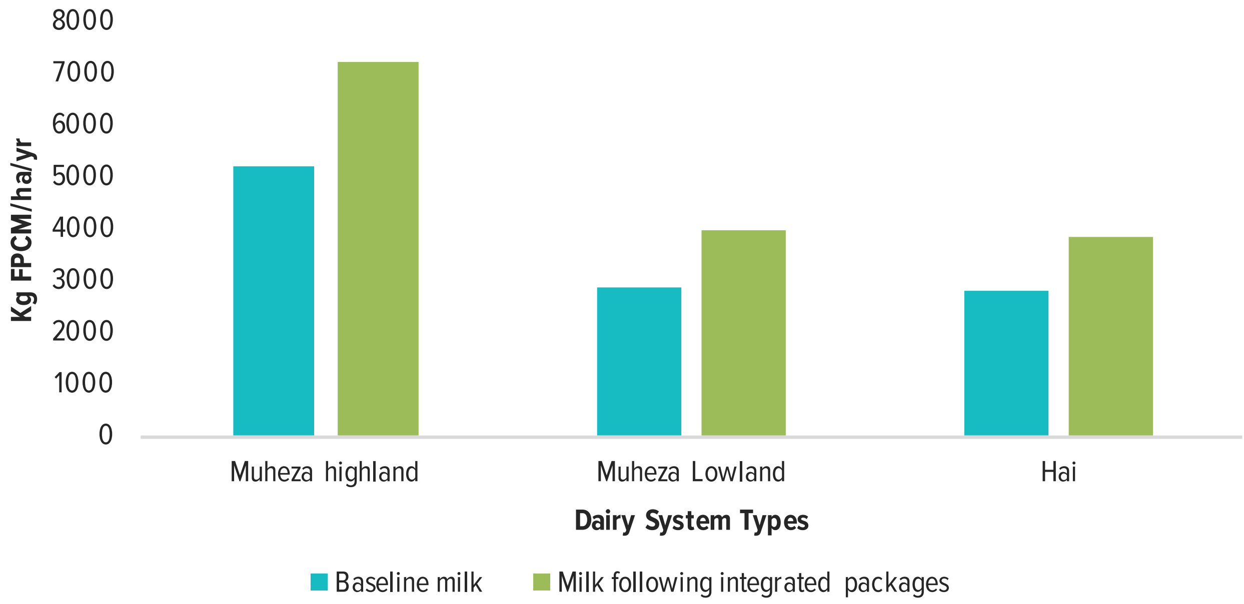
Notes:1. Expert data from Jessica Mukiri, Senior research associate, Alliance of Bioversity International and CIAT. 2. Feedipedia 2021. 3. Ahmed et al. 2014. 4.Osele et al. 2018.5. The Alliance of Bioversity International and CIAT & Australian Government 2021. 6. Australian Society of Plant Scientists et al. 2018. 7. USDA 2021. 8. FAO 1998b.9. SRI-Rice.10. Jianchang Yang and Jianhua Zhang 2010.

Feed parameters

Feed	DM content (%)	ME content (MJ/kg DM)	CP content (% DM)
Concentrate (commercial)	90.00[2]	12.10[2]	16.00[2]
Napier grass (*Pennisetum purpureum*) - forage	15.00[2]	9.88[2]	11.00[2]
Guatemala grass (*Tripsacum andersonii*) - forage	22.00[2]	8.20[2]	5.50[2]
Maize (Zea mays)-stover	87.00[2]	6.90[2]	3.90[2]
Naturally occuring pasture – Hai	31.90[1]	6.97[1]	4.83[1]
Naturally occuring pasture – Muheza	29.05[1]	6.55[1]	7.50[1]
Leucaena	29.90[2]	11.00[2]	23.30[2]
Musa spp.	5.70[2]	8.54[2]	10.50[2]
Rice straw	92.80[2]	5.80[2]	4.20[2]

Notes: 1. Expert data from Jessica Mukiri, Senior research associate, Alliance of Bioversity and CIAT. 2. Feedipedia 2021.

Annex 2: Total annual milk production



A farmer delivers milk at a collection centre in Tanga, Tanzania. Paul Karaimu/ILRI

Annex 3: Baseline and package results

Farms	Land requirements				Soil impacts						Water impacts						GHG emissions					
	Baseline		Package		Baseline			Package			Baseline			Package			Baseline			Package		
	ha/yr	ha/MT FPCM	ha/yr	ha/MT FPCM	% Soil mining	Erosion (t soil/ ha/yr)	Erosion (kg soil/ kg FPCM)	% Soil mining	Erosion (t soil/ ha/yr)	Erosion (kg soil/ kg FPCM)	m3/year	m3/kg FPCM	m3/kg protein	water (m3/ year)	m3/kg FPCM	m3/kg protein)	t CO2 eq. / year	kg CO2eq/ kg FPCM	kg CO2eq/ kg protein	t CO2 eq. / year	kg CO2eq/ kg FPCM	kg CO2eq/ kg protein
Intensive Dairy Muheza Highland	2.19	0.19	2.55	0.14	78	0.66	0.13	58	0.58	0.08	2476.65	0.17	3.89	1947.39	0.14	3.45	21.86	1.91	43.61	27.41	1.50	38.15
Intensive Dairy Muheza Lowland	2.32	0.35	2.19	0.25	52	0.40	0.14	43	0.40	0.10	1980.64	0.30	6.21	1942.01	0.22	5.40	18.62	2.79	58.36	17.32	2.00	48.16
Intensive Dairy Hai	2.27	0.36	3.10	0.26	50	0.87	0.31	20	0.80	0.21	2827.70	0.45	10.43	3900.83	0.33	8.13	15.43	2.43	56.92	23.30	1.96	48.60

Maziwa Zaidi

More Milk in Tanzania

Alliance

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Africa Hub

c/o icipe (International Centre of Insect Physiology and Ecology)
Duduville Campus Off Kasarani Road
P.O. Box 823-00621
Nairobi, Kenya

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