Progress report on livestock master plan modelling innovations

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Contents

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Overview

The following report presents progress made to date on enhanced outputs and models used in the context of livestock master plans. This work was made possible through funds allocated by the CGIAR Research Program on Livestock (CRP Livestock). Where applicable, links to data and models used in the context of these reports are given. This information represents work in progress that will be continued in the context of the International Livestock Research Institute (ILRI), the International Center for Tropical Agriculture (CIAT) and the Commonwealth Scientific and Industrial Research Organization (CIRAD) work (with partners) in 2020 through the CRP Livestock and the Bill & Melinda Gates Foundation (BMGF)-funded project Policy Options for Livestock Investment, Capacity Improvement, and Equitable Solutions (POLICIES).

Contents

This report is organized in two parts.

Section 1: "A multi-market modelling approach for livestock sector investment and policy analysis" was compiled by Sirak Bahta, Dolapo Enahoro and Karl M Rich.

Section 2: "Attaching environmental calculations to the LSIPT LMP applications" was compiled by An Notenbaert, Katharina Waha, Jessica Mukiri and Birthe Paul.

Section 1

A multi-market modelling approach for livestock sector investment and policy analysis

By Sirak Bahta, Dolapo Enahoro and Karl M Rich

1 The LSIPT tool

Although livestock has great potential to contribute to economic growth and poverty reduction in developing countries, investments by national governments and international agencies have, historically, been limited. This could be partly ascribed to a lack of capacity and critical data. Additionally, sector stakeholders do not have adequate tools to measure and articulate the livestock sector's potential to reduce poverty and promote economic growth.

To address these issues, within the Partnership for Livestock Development, Poverty Alleviation and Sustainable Growth in Africa (ALive), which was established in 2004, the Livestock Sector Investment and Policy Toolkit (LSIPT) was developed, because it was recognized by livestock specialists from African governments and international agencies, that the livestock sector had not been receiving the appropriate level of support from policymakers and investors.

ALive brought together specialists from CIRAD, the International Institute for Environment and Development (IIED), the Food and Agriculture Organization of the United Nations (FAO), and the World Bank to develop a set of tools to help identify, collect and analyse livestock sector data, document the importance of the sector to households and national economies and, based on this analysis, present to decision makers strategic options for investment, which would provide high returns in terms of economic growth and reduction of poverty for livestock keepers, while identifying any trade-offs.

The LSIPT consists of a set of tools (mathematical models, format questionnaires and other aids) that have been field tested and reviewed—most notably in Zambia. It enables in-depth and systematic quantitative analysis of the major constraints facing the livestock sector, and the effects of proposed interventions on economic growth and poverty alleviation. To enable investment scenario analysis, LSIPT uses cost benefit analyses of proposed policy and technology investment options; providing guidance for prioritizing investments according to their potential impacts on private and social development goals. It also provides methods and tools for the analysis of critical processes to decision-making and policy design such as the diversity of livestock production systems, their links to households and their vulnerability, the different value chains and the contribution of livestock to poverty alleviation and to national gross domestic product (GDP). Possible investment scenarios or technical changes can be simulated in LSIPT, which can help decision makers in choosing the most appropriate investments and policy options.

Since 2012, parts of the toolkit have been used by ILRI to assist in the preparation of livestock master plans (LMPs) in Ethiopia (with the assistance of CIRAD and the financial support of the BMGF), Tanzania (BMGF), Rwanda, (with support of FAO), Uzbekistan (World Bank), and most recently in Bihar, India (BMGF).

The tool is structured in six modules. Each module is composed of submodules, activities, and steps. Specific tools are proposed to support the realization of each activity. Most of the data are connected at the different scales of analysis from the livestock system and household to the nation.

The first module or M 1—initial assessment—proposes an initial understanding of the importance of the livestock sector and the links between livestock and poverty. It conducts a rapid assessment of the potential advantages offered by the livestock sector in supporting the poor population of the country.

The second module M2—coalition of change—has been conceived to support the constitution and the mobilization of a national team, like a committee of experts representing various disciplines and institutions, and coalition of partners that oversees realizing the diagnosis of the livestock sector (Modules M3 and M4) and validation of results, respectively.

The modules M3 and M4, which deal with the micro-meso and national level, respectively, constitute the diagnostic section of the LSIPT and as such the core assessment of livestock's contribution to economic growth and poverty reduction.

The module M5—strategies and action plan—helps to develop strategic livestock sector development plans and detailed investment proposals. This module uses the results of the diagnosis realized in previous modules to elaborate a strategy and an action plan that can be incorporated in various strategy and investment programs (e.g. integrated rural development programs, pro-poor investment programs etc.).

Finally, module M6—learning-based monitoring and evaluation—proposes an up-to-date information system on the impact of the inclusion of the livestock sector in an action plan on equitable wealth creation and sustainable economic growth.

The six modules are completely connected to each other by links of (i) cause and effect (Module 1), (ii) links of aggregation (between modules 3 and 4), (iii) links of input-output tools (modules 3, 4 and 5), (iv) command links and networking (Module 2 with the other modules), and (v) link of control (Module 6 and modules 3, 4 and 5).

1.1 Limitations of LSIPT

Although the tool takes into consideration the biological herd dynamics as the basis for forecasting future production and economic contribution of the livestock sector, the whole analysis is based on a very rigid assumption that prices of inputs and outputs are fixed for the entire period of estimation.

The whole analytical process is cumbersome and consists of perpetual back and forth movements between modules, submodules, and activities (as some results from one tool can be validated once aggregated with other indicators in the next step at the macro level, for example, as well as a constant comparison with existing statistical figures in order to adapt or validate each step of the analysis.

The tool is limited in modelling the changes in and evolution of markets, trade and value chains as a result of proposed investment options, particularly in the design of livestock sector strategies that compute returns to a range of scenarios over a projected period of analysis.

Gender and environmental considerations are also not given sufficient emphasis due to the limited flexibility inherent in the LSIPT platform, nor are considerations of digital-readiness and financial inclusion that can mediate uptake taken into account. The entire LSIPT analysis is often made at national rather than regional levels.

1.2 Proposed update to the livestock sector investment and policy analysis

The proposed updates to the livestock sector investment and policy analysis have three major objectives. First, to improve consistency of the analyses with appropriate socio-economic theory and biophysical realities; second, to expand the capacities for quantifying multi-dimensional factors and impacts related to livestock sector development; and third, to improve the functionality of the analytical platform in terms of increased user-friendliness and the ability to exchange data with and use information from other models and tools relevant to ex ante impact assessments of livestock sector interventions. In practical terms, an upgrade to the livestock sector investment and policy analysis will be in form of a migration of the core analyses to a multi-market modelling framework with single and two-way linkages to modules emphasizing biophysical characterization, e.g. of herd dynamics and feed use and availability relevant to livestock, and key interactions of the sector with socio-economic welfare and impacts. Figure 1 summarizes the proposed platform for LSIPT analyses. The details are below.

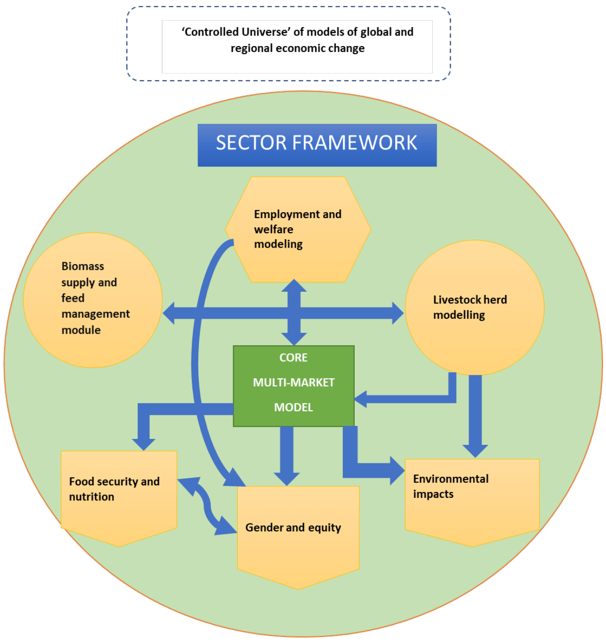
1.3 Model interoperability

An important objective and thus important feature of the improved livestock sector investment and policy analysis will be its amenability to using and subsequently feeding into the data and analyses of a larger community of models for understanding and simulating macro drivers of global and regional change. The models within this universe that are of immediate relevance to the livestock sector investment and policy analysis will include those that can simulate scenarios of global socio-economic change directly affecting LMP countries (e.g. Sherman et al. 2015), and models that can regionalize markets and trade, regulation, policy, and other macro interventions of importance to national livestock planning (Rich and Winter-Nelson 1997). A second tier of models with anticipated usefulness for the livestock sector investment and policy analysis will be models of global climate change as well as bioeconomic models of natural resources availability and management.

2 Core model development

Within the sphere of livestock sector investment and policy analysis updates, the development of a market model of the livestock sector will be the core model improvement being proposed. Rather than building an economic model from the start, this task will entail migrating the key structure of the herd dynamics and economic analysis in LSIPT to an already existing framework for quantitative modelling of livestock sector market interactions at the country-level.

Figure 1: Schematic of the proposed livestock sector investment and policy analysis framework



A primary focus of the model update is to allow for livestock sector fundamentals such as the herd sizes and input use to be driven by market forces; as well as allow markets, trade, and value chains to respond appropriately to investment-induced adjustments in the livestock sector. Key features of the core model will thus be the relationships between livestock input use and the choice of livestock production systems, household and value chain characteristics, the demand and supply and trade of livestock-derived food, and prices. The core of the framework will be a single-country, multi-(agricultural commodity) market, partial equilibrium/sectoral model, such as has been used to assess pig input and output markets in Vietnam (Minot et al. 2015). Links of the core model to other model components are illustrated in Figure 1 and described in the following.

2.1 Livestock herd modelling

Existing multi-market models typically define herd size exogenously and are informed by regional trends on animal stocks. Herd growth and composition can be endogenized to consider biophysical realities of animal life cycles, growth, fertility, morbidity and mortality rates, etc.

Herd growth can be further regulated by feed availability.

Herd modelling can also be used to provide possibility for scenario testing, of example that of genetic, feed and animal health improvements as well as other improvements in animal management.

Input: feed availability, user parameters on animal management.

Output: 'informed' herd growth rates and composition that can respond to resource management and to economics (investments, prices).

Links to: core model, feed module and environmental impacts.

2.2 Biomass and feed modelling

Existing models may not account for a vast proportion of the livestock feeds used in developing countries.

The feed basket can be expanded to better capture the options faced by a developing-country and smallholder livestock producers.

Feed modelling to provide management scenarios that can be tested outside of the core model when there are largely non-traded/non-tradeable inputs that produce tradeable outputs (explore if non-traded inputs can become traded input as value grows).

Input: land use, natural and managed biomass, land use management.

Output: feed compositions (type, quality) and quantities.

Links to: core, herd module and environmental impacts.

2.3 Environmental impacts

Many standard models now incorporate environmental impacts. A useful approach will be to identify (a) which ones are most relevant to livestock sector planning in the countries of interest and (b) are best addressed within the updated LSIPT framework.

Updated modelling could simulate environmental impacts on a larger scale, e.g. greenhouse gas emissions, or look at more localized issues such as land use change (and associated impacts on) water availability and quality, deforestation and or land degradation, among others.

Input: specifics to be decided (e.g. manure management, fertilizer input).

Output: impacts on air, land (including soil, vegetation), or water.

Links: core, herd and feed modules.

2.4 Food security and nutrition

Models such as the International Model for Policy Analysis of Agricultural Commodities and Trade (IMPACT) have used post-simulation models to estimate outcomes related to the supply, demand and trade of food commodities.

More recent studies have extended these types of analyses to assess the supply of specific, key nutrients (e.g. Dolapo et al. 2018); and the prevalence of diet-related non-communicable diseases (e.g. Marco 2016 etc.).

LSIPT modelling could adapt one or more of the existing approaches as needed.

Input: demand, supply, trade of different food types, household and country characteristics.

Output: food supply, nutrient availability, risks of diet-related non-communicable diseases in humans.

Links to: 'universe'/employment and welfare (informing household characteristics), core, gender.

2.5 Employment and welfare modelling

Sectoral models dive deep into a sector and are unable to account for impacts on the whole economy.

An emerging trend is to link sectoral model outputs to general equilibrium models, typically in a two-way feed, to inform the impacts of a sectoral driver or intervention on parameters of interest. This could be explored in the context of LSIPT.

Input: household and production system characteristics, country social-accounting matrices/other documentation of inter-sectoral linkages of an economy.

Output: informed socio-economic trends that can influence and respond to market changes and outcomes.

Links to: 'universe,' core, gender.

2.6 Gender and equity

Very few standard models have attempted to incorporate issues of gender into the analysis. LSIPT updates could explore this in a likely limited, but meaningful way.

Focus could be on defining what key characteristics of the livestock sector or outcomes of its interventions affect women differently from men. It could also explore how this can be captured in a simple, but reasonable way.

The impacts could be analysed in the contexts of food security and nutrition, employment and incomes.

Input: specifics to be decided.

Output: sex-disaggregated impacts of food security and nutrition, employment and incomes.

Links: 'universe,' core, food security.

Section 2

Attaching environmental calculations to the LSIPT LMP applications

By An Notenbaert, Katharina Waha, Jessica Mukiri and Birthe Paul

1. Introduction

Despite the multiple roles livestock play in smallholder livelihoods in low- and middle-income countries (LMICs) –including income, food, nutrition, asset provision, insurance, and nutrient cycling– livestock is also responsible for contributions to greenhouse gas (GHG) emissions, land use change, soil degradation, water use and loss of biodiversity. Following this rationale, the 'better incorporation of environmental impacts/consequences in the livestock sector development' was identified as a priority for future development of the Livestock Sector Investment and Policy Toolkit (LSIPT) toolbox during a technical workshop in December 2018. Recommendations of the workshop were to start off by developing a stand-alone environmental module that uses data from LSIPT to calculate GHG emissions and water use from livestock. Later activities would include the incorporation of a feed basket and development of scorecards to highlight the trade-offs that exist amongst different interventions. This report presents the progress towards that objective.

1.1 Proposed approach for the environmental impact assessments

In the first instance, focus will be on GHG emissions, and more specifically on a so-called Tier 1 approach. In a second step, a move towards Tier 2 calculations will be made and associated land requirements estimated too. Water requirements will be included in a second iteration.

The proposed steps for calculating Tier 1 and Tier 2 GHG emissions and associated land requirements for feed production are as follows:

1. Calculate Tier 1 GHG emissions for business as usual (BAU) as well as scenario (SCEN) (based on animal numbers from the LMP – BAU and 'with intervention').
2. Add Tier 2 GHG emissions and land requirements using the Comprehensive Livestock Environmental Assessment for improved Nutrition, a secured Environment and sustainable Development along livestock value chains (CLEANED) model.

The core of the CLEANED model is the feed baskets, which will need to be defined for every combination of LMP distinct production zone with cow breed. There are two strategies for developing feed baskets that are assumed to produce milk yields as stated in the LMP (in each subsystem; for BAU and with intervention):

i. Prescribing the share of each feed source as per expert consultation and triangulation with data in the LMP feed resources module and the Feed Assessment Tool (FEAST) assessments.

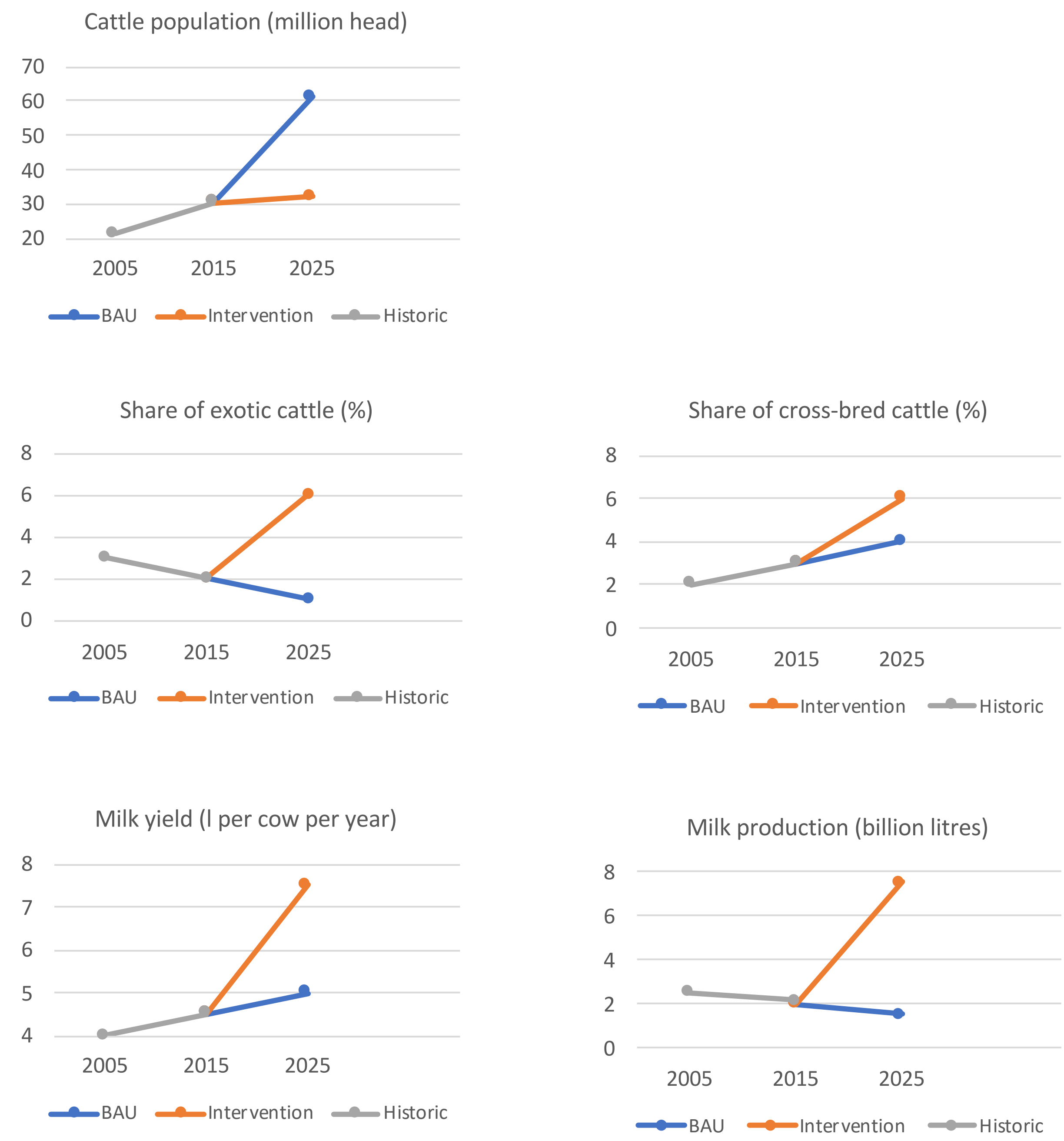
ii. Refine/calibrate these expert-opinion-based feed baskets, through running the RUMINANT model (Herrero et al. 2002) to figure out the feed requirements for the desired milk yield.

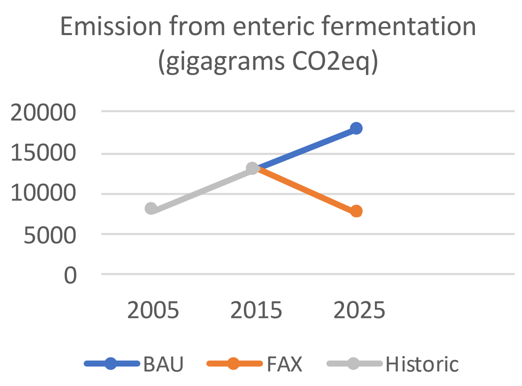
3. Extract animal numbers and productivities from the core model (different for BAU and SCEN).

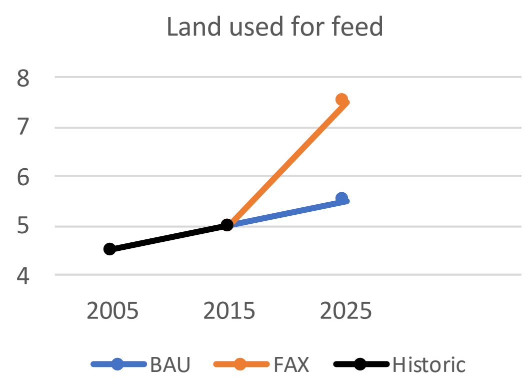
4. Collate secondary data/assumptions on manure management system, rice growing system and the length of the dry season.

It is expected that, with different interventions, the amount of land used for feed production and emissions from enteric fermentation in LMICs will increase but at lower rates than in BAU, as milk productivity will increase at higher than the historic rate.

Figure 2: Hypothetical results of scenario analysis for feed intensification.







Data for the years 2000 and 2005 are from the Tanzanian Annual Agricultural Sample Surveys 2007/08 and 2015/16, the World Bank's LSMS-ISA survey, the livestock master plan, FAOStat emissions database computed following Tier 1 IPCC guidelines and own calculations. Data for year 2025 is hypothetical.

2 Case study Rwanda and Tanzania

The proposed methodology is currently being tested in Rwanda and Tanzania.

Animal numbers

LMPs' results for changes in number of cross-breed cattle, milk production in improved family dairy systems and in daily milk production per reproductive female between 2016/17 and 2021/22.

Table 1: Tanzania

	National total ('000 litre)			Annual (litre)		
	Base year (2016/17)	2021/22	% change	Base year (2016/17)	2021/22	% change
Central	848,140	1,046,010	23	-	-	-
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	1,096,109	2,061,693	88	179	254	42

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

	National total (number of cross-breed cattle)		
	Base year (2016/17)	2021/22	% change
Central	-	-	-
Coastal & Lake	156,857	1,394,338	789
Highlands	375,337	930,286	148
Commercial			
Small	159,000	420,000	164
Medium	91,800	240,000	161
Total / Average	798,897	2,984,624	46%

Source: LMP, Table 2 and 16. Number of improved cattle in 2008 was 519,463. Improved cattle growth rate was 5.9% year between 2003–2008 (National Institute of Statistics of Rwanda 2008). The national surveys for Tanzania only report number of improved cattle and it was 275,770 in 2016.

Table 2: Rwanda

	National total ('000 litre)			Annual (litre)		
	Base year (2016/17)	2021/22	% change	Base year (2016/17)	2021/22	% change
Low rainfall						
Local breed	24,888	21,879	-14.9	216	228	6
Crossbred	227,488	351,152	72.4	1,323	1,572	19
Medium rainfall						
Local breed	28,183	23,874	-15.3	216	228	6
Cross-bred	242,264	416,312	71.6	1,418	1,684	19
High rainfall						
Local breed	17,643	14,930	-15.4	216	228	6
Cross-bred	183,774	316,438	72.2	1,512	1,796	19
Commercial						
Grazing (Gishwati)	15,721	31,202	98	1,890	3,954	109
Non-grazing	6,267	14,042	124	3,360	5,991	78
Total / average	746,589	1,230,135	65	909	1,281	41

* Average daily milk yield is changing from 0.8 to 0.84 for local breeds in all zones, from 7 to 14.6 in grazing, 12.4 to 16.3 in Non-grazing, 4.9-5.8 in Cross-bred-low rainfall, 5.25 to 6.2 in cross-bred-medium rainfall and 5.6 to 6.6 for crossbred-high rainfall. There's an overall increase in national average of 41% from 3.4 to 4.7. Calculated from assuming a lactation period of 270 days.

Source: LMP, Table 6 – 7. Milk production 2008/09 was 115,330,124l.

	National total (number of cross-breed cattle)		
	Base year (2016/17)	2021/22	% change
Low rainfall			
Cross-bred	292,822	430,252	47%
Medium rainfall			
Cross-bred	285,171	419,010	47%
High rainfall			
Cross-bred	203,932	299,643	47%
Commercial			
Grazing (Gishwati)	13,772	13,772	0
Non-grazing	3,199	3,809	19%
Total / average	798,897	1,166,487	46%

Source: LMP, Table 5. The number of hybrid/exotic cattle and local cattle in 2008/09 was 240,898 and 1,307,623 (National Institute of Statistics of Rwanda 2008).

2.1 Subsystem feed baskets (in BAU and under SCENARIOS)

We still have to define representative feed baskets for nine dairy systems in Rwanda and six dairy systems in Tanzania. Every combination of LMP-defined production zone with cow breed is possible.

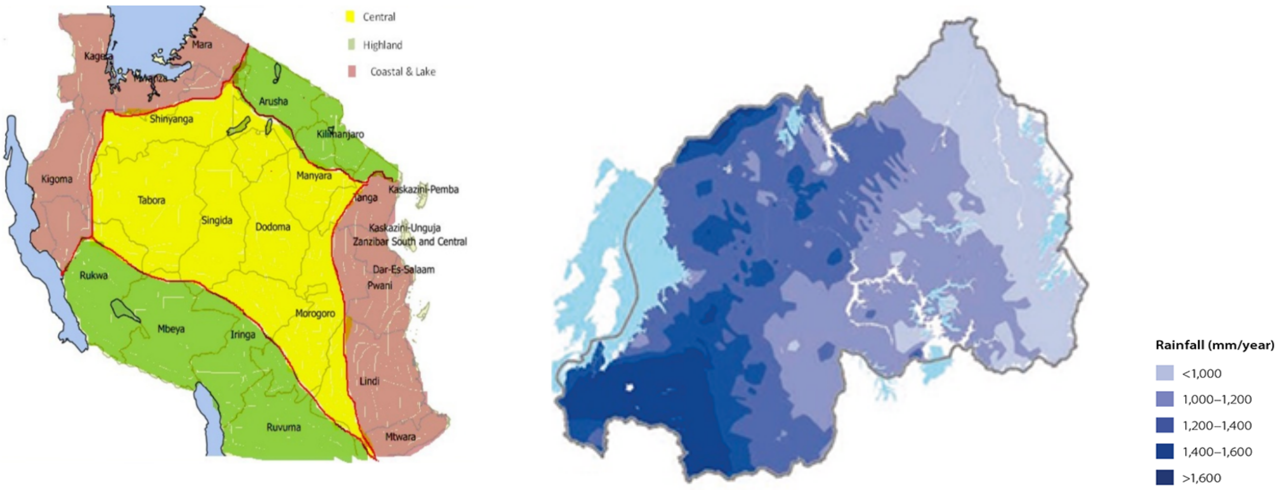
Table 3: Rwanda

Approx. share of cattle population	Exotic breed	Cross-breed	Indigenous breed
Rwanda low rainfall low altitude	10%	20%	40%
Rwanda medium rainfall medium altitude	80%	60%	20%
Rwanda high rainfall high altitude	10%	20%	40%

Table 4: Tanzania

Approx. share of cattle population	Improved breed	Indigenous breed
Tanzania Coastal & Lake	50%	25%
Tanzania Highlands	40%	25%
Tanzania Central	10%	50%

Figure 3: 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).



Feed baskets need to be prescribed in terms of percentages of different feed items (dry matter, metabolizable energy and protein .

The different strategies will be tested for the baseline feed baskets first. The application of this strategy for developing 'intervention feed baskets,' will depend on the time/effort needed for strategy 2, the availability of sufficient input data and our assessment of the feasibility of increased milk yields as stated in the LMPs.

2.2 Stand-alone calculations

Data from the LMP-LISPT runs will be extracted/transferred to an intermediate excel file, which will in turn be linked to the latest version of the CLEANED model (https://dataverse.harvard.edu/dataset.xhtml?persistentId=doi:10.7910/DVN/G0G8IY). This is work in progress.

The latest versions of all calculations/models can be found on https://github.com/annotie/Env_LISPT.

Expected results

1) GHG emissions – Tier 1 and Tier 2.

2) Land requirement for feed production.

3 Discussion of results

Results will be discussed in the context of overall milk production, environmental trade-offs and food security.

The milk yield targets set by the Climate Smart Dairy project, the Tanzania Livestock Master Plan and Rwanda Livestock Master Plan have increased by 25%, 26–42% and 65%, respectively. Tanzania and Rwanda have set GHG emission targets. These Intended Nationally Determined Contributions (INDCs) for GHGs reflect national goals to reduce emissions overall. For Tanzania that is a 10–20% reduction in GHG emissions by 2030 compared to the BAU scenario (138–153 MtCO2e gross emissions). For Rwanda the reduction target is not quantified.

For food security, we can calculate milk availability per capita per day in each scenario and compare to recommended quantities or World Health Organization (WHO) recommended protein intake for adults and children. This will be done in consideration of the population growth scenarios. The One Cup of Milk per Child program recommends 0.5l of milk twice a week, about 143 ml per day (Herforth et al. 2019). The recommended level of protein intake is ~ 0.8 grams of protein per day and kilogram of body weight for adults > 18 years and 0.84–1.31 grams of protein per day and kilogram of bodyweight for children < 18 years (WHO 2007, p. 243 Table 46 and p. 244 Table 47).

As the feed basket data is such a core issue, in terms of feasibility (land requirement) as well as GHG emissions and water footprint, we would recommend incorporating a feedback loop between the core model and the current stand-alone feed module. If this is not feasible, there will still be a need to collect feed basket data during the LSIPT data collection phase. Other extra data to be collected includes:

i. manure management systems

ii. fertilizer application to feed crops

iii. rice growing systems (if rice is part of the feed basket).

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