

A review of projections of demand and supply of livestock-derived foods and the implications for livestock sector management in LSIL focus countries

Mid-Project Research Report of the Feed the Future Innovation Lab for Livestock Systems (LSIL) Futures Foresight Component, Module I (Quantitative Scenario Modelling)

Working Paper No. 262

CGIAR Research Program on Climate Change,
Agriculture and Food Security (CCAFS)

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Nelly Njiru
Philip Thornton
Steven S. Staal



RESEARCH PROGRAM ON
**Climate Change,
Agriculture and
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Projections from the IMPACT model are not a prediction of what will occur in study countries but provide a framework for plausible futures based on information and model capabilities currently available. While IMPACT model results have historically been more closely linked to observations at global, multi-country region, and large-country levels, they should for this study, be appropriate for smaller-country applications. The opinions expressed are however fully those of the authors and do not necessarily reflect those of USAID, University of Florida, ILRI or IFPRI. The authors assume responsibility for all errors and omissions.

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Abstract

National planners and others in the international development community are looking to transform a rising demand for animal-source foods in many low- and middle-income countries into opportunities that benefit poor and vulnerable people. Scenario analysis and sectoral reviews aid the understanding of emerging opportunities and the potential of existing systems to harness them. An analysis was done of country-level results of a global model simulating the production and consumption to 2050 of livestock-derived foods under various scenarios of economic and climate change. The scenario results were assessed alongside historical data and relevant national policies of the livestock sectors of selected countries, to identify key entry points for further pro-poor livestock sector development. While increased focus on trade in livestock and livestock products seems rationale for some countries in the study, climate change and sustainability are given more prominence for others. The results provide context to planned stakeholder engagements on national programs and policies affecting livestock in the study countries.

Keywords

Scenarios; Livestock; Policies; Trade; Climate change; Sustainability.

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The report contributes to the CGIAR Research Program on Livestock.

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Introduction

With millions of poor people depending on livestock production for their livelihoods and incomes, and on farm and grazing animals for assets and insurance, the livestock sector offers much potential as a vehicle for poverty reduction in low income countries (Staal et al., 2009). Its roles in human nutrition and interrelationships with crop agriculture and the environment (see e.g., Herrero et al., 2013) further indicate that the sector needs to be considered among any options aimed at transforming present and future welfare outcomes in these countries. Up until the last decade however, many of the affected countries paid scant attention to the sector (FAO, 2010). Only more recently has there been increased partnership between international donor agencies, research for development institutions, and national governments and other interested entities, on issues related to smallholder livestock development in developing countries. The upgrading of livestock value chains is now better recognized as both viable and essential for pro-poor economic development (ILRI, 2019).

The challenges limiting competitiveness and growth of the livestock sectors of many developing countries tend to be multi-dimensional, complex and co-occurring, ranging from resource and technology constraints at the farm level (e.g., poor performing animal breeds, insufficient and or low quality feeds, and animal diseases), to failures at the level of markets and institutions (e.g., limitations in access to: credit and extension services, supply chains and infrastructure, and product value-addition) (FAO, 2010). Although the livestock sector is increasingly being recognized in some of the countries as providing pathways to reduced poverty and hunger, this attention to the sector is coming at a time when even more pressures are emerging for the global food and agriculture system. As complex as the local factors affecting livestock value chains and national livestock sectors already are, they must now be addressed within the context of a rapidly changing global and regional economies, e.g., as played out in urbanization, globalization and income growth; and in response to global climate change.

The Feed the Future Innovation Lab for Livestock Systems (LSIL) Future Systems Area of Inquiry (AOI) aims to facilitate different levels of future analysis depending on the current efforts and priorities within the focus countries. The strategy is to evaluate technologies and

guide policy efforts that can support the sustainable intensification of livestock systems, to transform the rapid increase in demand for animal-source foods into opportunities that benefit poor and vulnerable people in focal regions. The methods to be used include the following: (1) future scenario analysis and regional/national-scale modeling for global drivers, (2) value chain and trade network modeling for critical, internal production dynamics and (3) household scale modeling in selected areas for gender and nutritional vulnerability analysis. This analysis at different scales allows participatory and human capacity enhancing processes that set country-level interventions and development scenarios in their appropriate regional contexts.

This report is an initial review of historical data and plausible future projections of LSIL focus countries. It explores the influence of international climate and development drivers on national-level production and consumption of animal source-foods, and potential vulnerabilities. The report uses national statistics and outputs of a bioeconomic model of agricultural systems and markets to assess the importance of livestock in the LSIL focus countries and the potential for, and possible patterns of, future expansion and intervention in the livestock sector. The review covers six selected countries: Ethiopia, Rwanda, Burkina Faso, Niger, Cambodia and Nepal. Comparable livestock statistics are first presented for the six countries. This is followed by (six) brief country reviews that present model projections to 2030/50 from the global model IMPACT and then outline the structure and strategies for national management of the livestock sector in each country. Discussions on the IMPACT projections highlight key areas of focus for future livestock sector development. Suggestions are made on topics for follow-up analysis, including within the context of stakeholder engagements around national level policy.

Data

To assess the status of the livestock sector in the focus countries, we looked at relevant national statistics. These statistics are mainly published data from the World Bank and the FAO (World Bank, 2018; FAO, 2016). Data such as livestock populations, contribution of livestock to a country's national income, and proportions of households owning livestock are compared for the different countries in the section following. We next present in country overviews, model projections to 2030/50 simulated using the global integrated assessment model IMPACT (S. Robinson et al., 2015). The scenarios of global economic or climate change included in the analysis were originally developed in Sulser et al. (2014). Of different indicators available, we look at plausible future trends in the demand and supply of livestock-derived food (LDF) products, associated estimates of LDF imports and exports, and livestock feed demand. The projections provide quick indicators of key directions of change in the livestock sectors of the focus countries. The data analyzed are described following.

FAO national statistics

The set of focus countries is quite diverse in the sizes of their human population, ranging from 12 million in Rwanda to 105 million in Ethiopia. The countries are more similar in that they are all relatively low income (<1,200 USD per person per year) and have large rural populations (>70%). Livestock has an important role in the agricultural and wider economy of these countries, contributing at least 10% of all national income. Further, livestock keepers who earn below defined national poverty lines are 14% to 40% of the rural populations. Human population grows at annual rates of about 1.1% in Nepal and 3.8% in Niger¹. Economic growth rates have however been quite high over the last decade in these countries, ranging from 4.5% annually in Nepal to as much as 10.1% annually in Ethiopia (Table 1; Table 2).

Of the six focus countries, contribution of livestock to agricultural GDP and agriculture's share of national income are highest in Ethiopia, so that the contribution of livestock to the total economy is highest in Ethiopia, at around 15%. Livestock is also a big contributor to the overall economy in Niger (around 12% in 2014). While livestock's contribution to the overall

¹ Niger has one of the highest population growth rates in the world (United Nations, 2014).

economy is more modest in the other countries, the sector is a substantial part of the agricultural economy. Livestock accounted for at least 10% of the gross domestic product (GDP) of agriculture in all six countries in 2014. Data on the livestock sector's share of agricultural GDP showed a range from 10% in Rwanda to 35.6% in Ethiopia. Agriculture accounted for 14% (Nepal) to 43% (Ethiopia) of national GDP.

Stocks of cattle, sheep and goats, as well as poultry bird numbers are also highest in Ethiopia². Cattle numbers are particularly high, at 56.7 million heads in 2014, five times more than the number recorded for Niger which has the second highest cattle population. Pig numbers are highest in Burkina Faso at 2.3 million and are also high in Cambodia (2.3 million), Nepal (1.2 million) and Rwanda (1 million). There are less than 5 million poultry birds recorded for Rwanda but 18 million in Niger, 21 million in Cambodia and more than 30 million in each of Burkina Faso, Nepal and Ethiopia. Combined, sheep and goat population make up 3.2 million in Rwanda and more than 58 million heads in Ethiopia. No data was available on sheep and goat numbers in Cambodia.

Quantities of dairy and eggs produced are higher than meat produced in the focus countries, except in Cambodia where meat production surpasses that of dairy (Table 3). Per capita supply of meat, milk and eggs is lowest in Cambodia, at 18 kilograms (kg) per person per year. Supply is also low in Rwanda at 23 kg per person. It is moderate in Burkina Faso (41kg) and Ethiopia (50 kg), and relatively high in Nepal (64 kg) and Niger (77 kg). However, the percentage contribution of LDF to diets is highest in Cambodia, i.e., when LDF consumption is assessed alongside nutrient intake from all food groups. LDF contribute nearly 9% of the daily kilocalorie intake in Cambodia³. This measure is between 3% and less than 8% for the other five countries. LDF however are estimated to contribute more than 10% of diet proteins, in all the focus countries. An assessment of data on the prevalence of underweight among children aged under five showed that Rwanda had the lowest rate (with 10.5% prevalence) and Niger the highest (38% prevalence).

²Level estimates are presented, with no accounting for denominators such as income, land area or human population that could standardize country estimates of animal numbers.

³ See section describing IMPACT model data for why kilocalorie supply was used in the analysis.

Table 1. Selected macro-indicators of the focus countries

	Total human population (millions)	Rural population (% total)	Poor livestock keepers (% rural population) ¹	Annual GDP per capita (constant 2010 USD)	GDP growth (% annual, avg. 2008-2017)	Population growth (% annual, avg. 2008-2017)
Ethiopia	104.96	79.69	28.36	549.85	10.10	2.59
Rwanda	12.21	82.88	35.42	765.22	7.46	2.56
Burkina Faso	19.19	71.26	36.26	688.53	5.54	2.98
Niger	21.48	83.65	42.30	395.94	5.83	3.81
Cambodia	16.00	77.02	19.97	1,135.15	6.24	1.57
Nepal	29.30	80.66	13.77	728.40	4.50	1.11

Source: Except otherwise indicated, estimates are for 2017 and come from the World Bank Indicators (World Bank, 2018).

¹ Estimates of the % of rural people and of percent who keep livestock and live below nationally defined poverty lines are from T. P. Robinson et al. (2011).

Table 2. Contribution of livestock to national income (GDP) and stocks of live animals in the focus countries

COUNTRY	Contribution of livestock sector to agricultural GDP (%)	Agricultural GDP to national GDP (%)	Contribution of livestock sector to GDP (%)	Livestock population in heads				
				Cattle	Sheep	Goats	Pigs	Poultry birds ('000 heads)
Ethiopia	35.6	42.7	15.2	56,706,389	29,332,382	29,112,963	34,000	56,867
Rwanda	10.0	34.0	3.4	1,144,000	631,000	2,532,000	1,015,000	4,952
Burkina Faso	15.0	27.8	4.1	9,090,700	9,277,700	13,891,000	2,345,800	33,752
Niger	35.0	35.2	12.3	11,377,312	11,108,089	14,883,559	42,500	18,000
Cambodia	11.3	32.0	3.6	2,875,000	DNA ¹	DNA ¹	2,180,000	21,300
Nepal	24.0	35.0	8.4	7,243,916	789,216	10,177,531	1,190,138	48,469

Source: 2014 data retrieved from FAO (2016).

¹ DNA: Data not available.

Table 3. Selected measures of livestock production, food availability and nutrition in the focus countries

	Meat production, '000 MTs	Dairy and egg production, '000 MTs	Per capita supply of LDF (Kg/person/year)	LDF proportion of food supply in Kcal/person/day (%)	LDF proportion of protein supply in g/person/day (%)	Prevalence of underweight among children under age 5 (%) ¹
Ethiopia	694.00	4,037.33	49.92	5.93	12.52	29.20
Rwanda	90.33	222.00	22.98	3.44	10.99	10.50
Burkina Faso	240.67	415.67	41.87	6.20	15.14	23.23
Niger	289.00	1,015.00	76.89	7.98	18.15	37.90
Cambodia	203.00	45.00	18.21	8.79	29.37	26.45
Nepal	338.33	1,749.33	64.26	7.64	16.54	29.10

¹ Data on prevalence of underweight is a 3-year average using World Bank estimates for 2011-13 (World Bank, 2018), except for Rwanda and Cambodia for which 2010 and 2015 data were used/ These are the relevant years for which the data was available). The data on the other indicators are 3-year averages of published national statistics (FAO, 2016).

IMPACT model projections

Projections of demand and supply of LDF in 2030 and 2050 were assessed for the focus countries. These projections can help policy makers in visioning plausible ways in which the livestock sector could transition in their countries, and as such what will be needed in terms of resources, technologies, markets, institutions and policies. All projections used are from simulation runs of the IMPACT model, an integrated modeling system that links information from climate models, crop simulation models and water models to a core global, partial equilibrium, multimarket model focused on the agriculture sector (S. Robinson et al., 2015). IMPACT's multi-market model simulates the operations of global and national markets for more than 60 agricultural commodities, covering the bulk of food and cash crops traded globally. It solves for production, demand and prices that equate global supply and demand of these agricultural commodities. IMPACT's geographical scope covers 159 countries globally.

A core feature of IMPACT is its use in scenario analysis, where alternative futures of the global food and agricultural system, imposed by factors such as economic development and climate change, are tested for their impacts on development indicators of interest. For this report, we assessed results of IMPACT model scenarios earlier developed to capture key plausible changes in economic development and the management of climate change. These scenarios incorporate the Shared Socioeconomic Pathways (SSPs) and Representative Concentration Pathways (RCPs) jointly developed by research communities under the Intergovernmental Panel on Climate Change (IPCC) initiative (Riahi, 2014). The SSPs are a set of narratives that together describe the alternative demographic and economic developments determining energy, land use and related trajectories globally; while the RCPs are trajectories of greenhouse gas concentrations. They have been quantified using a range of earth system models, ESM (Riahi et al., 2017).

The scenarios included in this report integrate different SSPs and RCPs from the IPCC portfolio and have earlier been quantified for use in IMPACT (Sulser et al., 2014). Of 16 scenarios presented (Table 4), the moderate economic growth, no climate change scenario (See alphabet codes A and C in table) was selected as the baseline. All other scenarios are compared to the year 2010 and 2030/50 results for this scenario. Year 2050 results are assessed for the alternative scenarios. A single climate trend, i.e., RCP 6.0, was compared to the constant 2005 or 'no climate change' trend. According to Engström et al. (2016), RCP 6.0

is most compatible with the different SSPs. RCP 6.0 had earlier been simulated in IMPACT using four different ESM (S. Robinson et al., 2015). We include results from all four ESM here. The climate trend RCP 8.5, which is considered the harshest of future climates and used in many studies to depict upper boundaries on climate impacts, was not included. The combinations of economic growth assumption, model year, RCP simulation and ESM are represented using alphabet codes (Table 4, column 1). For convenience, these alphabets are referred in the results and discussions.

For the different scenarios, IMPACT generates country-level outcomes of food production, demand, and prices. We report these results as per-capita and aggregate supply of meat, milk and eggs, and production and net import quantities of the same. We also report on livestock feed demand linked to production. Although IMPACT generates secondary indicators of producer and consumer welfare, hunger, nutrition, land use and environmental impacts that are based on the primary results, we have not included those results in this initial assessment.

Table 4. Descriptions of IMPACT model scenarios included in the analysis

Alphabet code	Scenario Code	Pace of economic growth	Year(s)	RCP simulation	Earth System Model (ESM) used ¹
A	MiddleNoCC	Moderate	2010	None	none
B	FragmenNoCC	Slow	2030/50	None	none
C	MiddleNoCC	Moderate	2030/50	None	none
D	SustainNoCC	High	2030/50	None	none
E	FragmenGFDL_RCP_6.0	Slow	2030/50	6.0	GFDL
F	FragmenHGEM_RCP_6.0	Slow	2030/50	6.0	HADGEM
G	FragmenIPSL_RCP_6.0	Slow	2030/50	6.0	IPSL
H	FragmenMIRO_RCP_6.0	Slow	2030/50	6.0	MIROC
I	Middle GFDL_RCP_6.0	Moderate	2030/50	6.0	GFDL
J	Middle HGEM_RCP_6.0	Moderate	2030/50	6.0	HADGEM
K	Middle IPSL_RCP_6.0	Moderate	2030/50	6.0	IPSL
L	Middle MIRO_RCP_6.0	Moderate	2030/50	6.0	MIROC
M	SustainGFDL_RCP_6.0	High	2030/50	6.0	GFDL
N	SustainHGEM_RCP_6.0	High	2030/50	6.0	HADGEM
O	SustainIPSL_RCP_6.0	High	2030/50	6.0	IPSL
P	SustainMIRO_RCP_6.0	High	2030/50	6.0	MIROC

¹ GFDL or GFDL-ESM2M - National Oceanic and Atmospheric Administration's Geophysical Fluid Dynamic Laboratory (www.gfdl.noaa.gov/earth-system-model); HADGEM or HADGEM2-ES - the Hadley Centre's Global Environment Model, version 2 (www.metoffice.gov.uk/research/modelling-systems/unified-model/climatemodels/hadgem2); IPSL or IPSL-CM5A-

LR - the Institut Pierre Simon Laplace (<http://icmc.ipsl.fr/index.php/icmc-models/icmc-ipsl-cm5>); MIROC or MIROC-ESM - Model for Interdisciplinary Research on Climate, University of Tokyo, National Institute for Environmental Studies, and Japan Agency for Marine-Earth Science and Technology (www.geosci-model-devdiscuss.net/4/1063/2011/gmdd-4-1063-2011.pdf). All information on the ESMs has been obtained from (S. Robinson et al., 2015).

Per capita supply of LDF is reported in kilocalories rather than in, e.g., kilogram protein terms that will be more appropriate for assessing the nutrient contributions of animal-source foods. This is only as a matter of convenience. IMPACT reports food availability in kilogram quantity and kilocalorie terms to allow for easy comparison of the demand, production and/or availability of different commodities from different food groups, e.g., LDFs, cereals, fruits and vegetables, oils, and oilseeds. While food composition coefficients exist that can be used to calculate macro and micro nutrient equivalents of IMPACT outcomes when such comparisons are needed (e.g., (Enahoro et al., 2018), that is not the focus of this analysis.

We have used food supply as a proxy for average consumption and intake, using the three terms interchangeably. However, only food availability can be inferred from the aggregate data we have used (FAO national statistics and IMPACT measures). To report more accurately on food consumption or intake at individual level, household and other micro-level data will be needed.

Country reviews

The following (six) country reviews present assessments of future demand and supply of livestock-derived food products in the countries as projected by the IMPACT model. An attempt has been made to compare the same measures for all the countries. However, some variation exists in that livestock demand and production are evolving differently in the different countries, making it more efficient to highlight only the changes relevant to any one country. The IMPACT projections are followed by brief summaries of how the livestock sectors of the various countries are currently administered nationally and key policies guiding the sector. These should be useful for initiating conversations about how well current management structures or development strategies will serve anticipated transitions, or whether they need to change.

Ethiopia

Of the six countries in the study, Ethiopia had the second-lowest GDP per capita in 2017, higher only than Niger. However, Ethiopia has had a very high rate of economic growth, exceeding 10% annually over the last decade. The rural population is still quite large, at nearly 80% of the total population. An estimated 21 million of the country's (then 90 million) population in 2011 can be classified as livestock keepers living under the national poverty line (see Appendix Table 1). Livestock production is the main agricultural activity in Ethiopia, and livestock sales are the country's second largest export earner, after coffee. The livestock sector contributes 35.6% to agricultural GDP (see Table 1, Table 2). Ruminant animals are a very important component of the livestock sector in Ethiopia. According to the FAO statistics, there were around 57 million cattle and more than 58 million sheep and goats (collectively) in Ethiopia in 2014 (see Table 2). These represented 18% of the total cattle population and 8.2% of the sheep and goat population in Africa in 2014 (not shown in the tables). To put these numbers in context, Ethiopia's human population was 8.4% of Africa's population in 2014. These estimates highlight how important livestock sector intervention in Ethiopia could be to the region at large. Interventions that affect Ethiopia's ruminant meat or milk sector, and/or its human population, invariably affect a sizeable proportion of the continent.

There are four main production systems in the country: traditional pastoral/agro-pastoral, mixed crop-livestock, market oriented intensive specialized (commercial) and urban/peri-urban production systems⁴. Generally, there is limited supply of animal products in relation to the total population, with consumption of animal products lowest among the rural populace. Milk is however a major component of the diet in pastoral areas.

Livestock projections to 2030/50

In 2010, the supply of livestock derived foods in Ethiopia was around 76 kilocalories (kcal) on a per person per day basis (Table 5). The breakdown of this supply is 58% meat, 39% milk and 3% eggs. Further, beef supply made up 72% of the 44-kcal per capita supply of meat. Under the scenario of moderate economic growth and no climate change, i.e., the baseline scenario, LDF supply increases to 85 kcal in 2030 and 99 kcal in 2050. The share of meat in

⁴ T. P. Robinson et al., (2011) describes the functions and locations of global livestock production systems.

LDF supply increases slightly, from 58% in the base year to 60%/61% in 2030/50. However, the share of beef declines while the shares of other meat types, i.e., lamb, poultry and pork, increase in the simulation years (pork <1%). The supply of lamb increases the most (at 11%) in relative terms. Although quantity of milk supply increases, its share in per capita supply of LDF declines, from 39% in 2010, to 37% in 2030 and 35% in 2050.

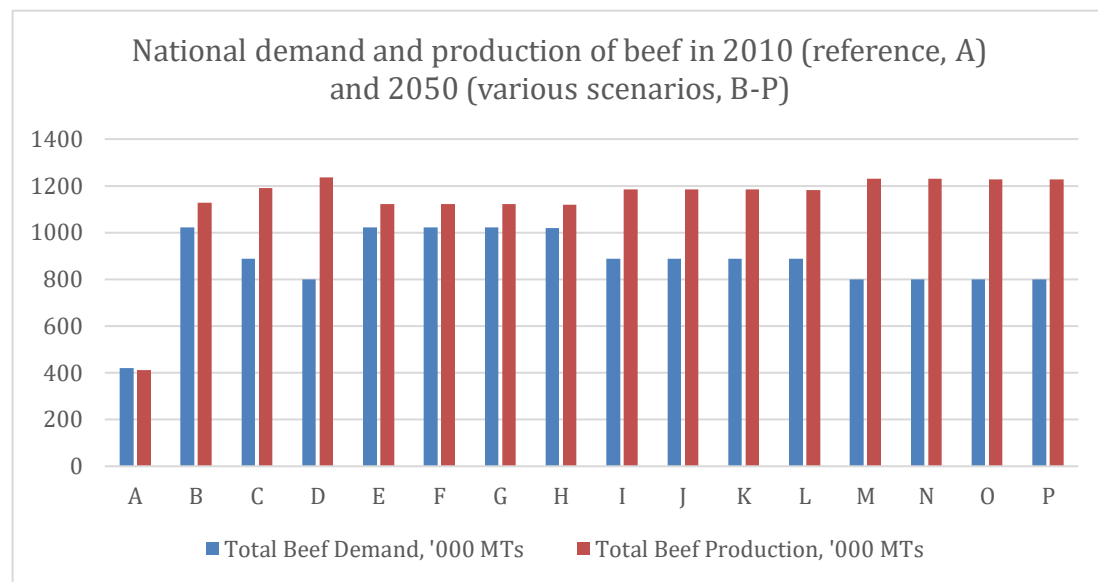
Table 5. Projections of the supply of different livestock-derived food (LDF) types in Ethiopia in 2010, 2030 and 2050*

	2010	2030	2050
	(kilocalories per person per day)		
Beef	31.51	33.95	34.65
Pork	0.14	0.23	0.39
Lamb	9.73	13.32	19.79
Poultry	2.41	3.57	5.54
Dairy	29.80	31.33	34.92
Eggs	2.12	2.89	4.19
All meats	43.80	51.07	60.37
All LDF	75.71	85.29	99.48

* IMPACT model results for moderate economic growth, no climate change (Middle No CC) scenario.

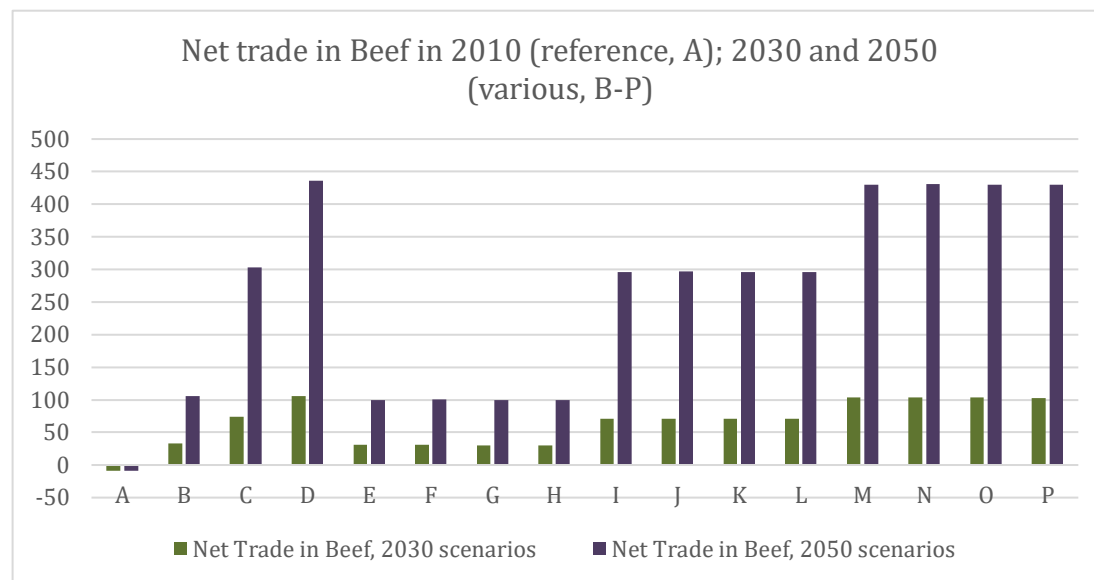
The IMPACT model projects an aggregate beef demand of 421,400 metric tons (MT) in Ethiopia in 2010. This is projected to increase to 678,500 MT in 2030 and 887,000 MT in 2050 under the baseline scenario, equivalent to an 11% increase (from 2010) in 2050. In comparison, beef production increases by 88% from 2010 to 2050 and is higher than beef demand in 2050. Figure 1 presents beef demand and production for a variety of economic growth and climate change scenarios in 2050. While national production of beef is about 98% of national demand in 2010, production surpasses demand (by 10% to 55%) in 2050 under the different scenarios of economic growth and climate change, indicating that the country could well hold a net producer position for a range of macroeconomic changes. The gaps between aggregate demand and production are smallest (of the scenarios assessed) when assuming slower global economic growth (see descriptions of Scenarios E, F, G, H in Table 4). It is important to note that while slow growth seem to suppress production, aggregate national demand for beef is increased.

Figure 1. Model projections of demand and production of beef in Ethiopia



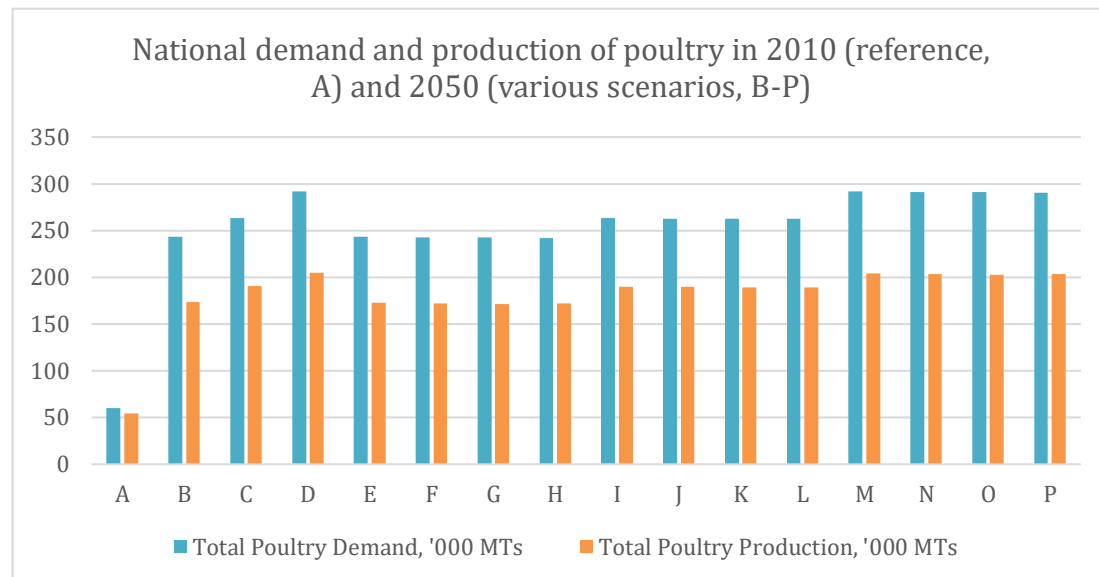
The model projections of net trade in beef are presented for 2010, 2030 and 2050 (Figure 2). Ethiopia is a net importer in 2010, by a small margin, and a net exporter in 2050 for under all scenarios tested. Net export quantities are generally higher for the high growth scenarios (i.e., M, N, O, P), lower for the slow growth scenarios (i.e., E, F, G, H) and in-between for the moderate growth ones (i.e., I, J, K, L). As a block, the no-climate change scenarios of 2050 (i.e., B, C, D), present the most variability in net trade outcomes.

Figure 2. Model projections of net trade of beef in Ethiopia



Poultry is another sub-sector that is projected to change quite substantially. Under the baseline scenario, poultry demand increases, by 121% in 2030 and 340% in 2050 relative to the base year estimates (Figure 3). Demand and production are highest when the global economy is fast growing (i.e., scenarios D, M, N, O, P), and lowest when it slows (i.e., scenarios A, E, F, G, H). Poultry production does not meet anticipated demand under any of the scenarios tested. However, import quantity relative to the demand does not vary by very much across the scenarios. Net poultry import quantity stands at between 28% and 30% of national demand under the different scenarios in 2050.

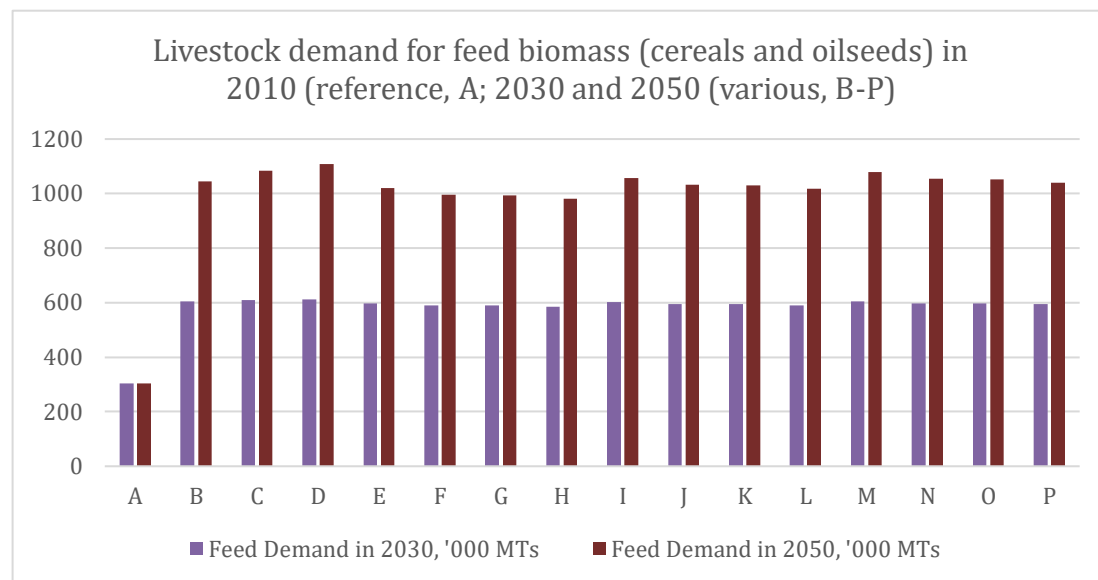
Figure 3. Model projections of demand and production of poultry in Ethiopia



Projected changes in the demand and production of beef, poultry, and other LDF lead to substantially higher demand for livestock feed biomass (Figure 4). Under the baseline, the combined demand for cereals and oilseeds used as livestock feeds increases from 304,300 MT in 2010 to 608,900 MT in 2030 and 1,085,100 MT in 2050 (i.e., 100% and 357% change in 2030 and 2050 respectively). These projections of feed demand quantities reflect impacts of both future economic and climatic change and are more variable in 2050 than in 2030.

⁵ Crop residues and other feed sources that may be widely used in Ethiopia are not included in the current analytical framework for IMPACT.

Figure 4. IMPACT projections of livestock feed demand in Ethiopia



National management of Ethiopia's livestock sector

The Ministry of Agriculture, Livestock and Development sector oversees livestock nationally in Ethiopia. In 2013, the government established a livestock and fisheries ministry which was recently merged with Ministry of Agriculture and Natural Resources, to form the Ministry of Agriculture, Livestock Resources Development. Ethiopia also has a ministry of Environment, Forest and Climate Change. Major national policies affecting the livestock sector are outlined below.

Agriculture and fisheries:

The Ministry of Agriculture (MoA) in Ethiopia was established in 1907, with the mandate to manage the agricultural and forestry sectors. Since 1991, the MoA has been leading the government policy of Agricultural Development Led Industrialization (ADLI) with the primary objective of accelerating national development and reducing poverty and food insecurity in rural areas.

Livestock:

Under MOA, Ethiopia is currently implementing a Livestock Master Plan (LMP) launched in July 2015 (Shapiro et al., 2015). The LMP is the government blueprint for planned transformation of the livestock sector. Its goals are to strengthen the livestock sector, enhance

nutrition and food security, improve resilience, and spur growth that will lift about 2.36 million households out of poverty by 2030. The LMP sets out targets for priority investments in options such as cross-bred dairy, meat and milk feedlot, and poultry development, that are expected to make big differences.

Environment:

One of the major policy documents guiding environmental management in Ethiopia is the Environmental Policy of the Federal Democratic Republic of Ethiopia that was approved by the Council of Ministers in April 1997. The general objective of this policy is to *‘improve and enhance the health and quality of life of all Ethiopians and to promote sustainable social and economic development through the sound management and use of natural, human-made and cultural resources and the environment to meet the needs of the present generation without compromising the ability of future generations to meet their own needs’*. Chapter three of the Policy document discusses the environmental impacts of Ethiopia’s livestock production systems.

Climate:

The Climate-Resilient Green Economy Strategy of Ethiopia was developed through an initiative led by the Prime Minister’s Office, the then Environmental Protection Authority, and the Ethiopian Development Research Institute. The Ministry of Environment, Forest and Climate Change is the lead organization for overseeing the implementation of this strategy. The objective of the strategy is to identify green economy opportunities that could help Ethiopia reach its ambitious growth targets (which are stipulated in the Growth and Transformation Plan) while keeping greenhouse gas emissions low. The strategy is currently being implemented and will require a boost in Ethiopia’s agricultural productivity, strengthening the industrial base and fostering export growth. The Ethiopian climate resilient green economy strategy (2011) has four initiatives for a climate resilient green economy (CRGE). One of these initiatives is to improve efficiency in the livestock value chain.

Ag-Biodiversity:

Ethiopia has a revised National Biodiversity Strategy and Action Plan 2014 which acknowledges the role of the country as a gateway to domestic animals transported from Asia to Africa. Majority of Ethiopia’s livestock are indigenous, with few exotic breeds imported in

recent years (last four decades). Indigenous breeds are considered threatened due to interbreeding or changes in production system, while the National Biodiversity Strategy highlights the lack of up-to-date breed level statistics. Formulated against the backdrop that biodiversity conservation will be a key condition for attaining overall socioeconomic development and sustainable environmental management, the National Policy on Biodiversity Conservation and Research issued in April 1998 provides a general framework towards effective conservation, rational development, and sustainable utilization of genetic resources. Ethiopia's indigenous genetic resources include a variety of animal and plant species, the most common of which are: Mammalian (cattle, sheep, goats, camels, donkeys, horses and mules), avian (poultry, ostrich and turkey) and honey bees. The country also has a broad range of pasture and forage resources.

Rwanda

Rwanda had the second-highest GDP per capita in 2017 of the focus countries, lower only than that of Cambodia (see Table 1). Economic growth has been quite fast in Rwanda over the last decade, averaging 7.46% annually between 2008 and 2017. The rural population is around 83% of the country's total population. Agriculture accounts for 34% of GDP, while livestock sector contributes 10% of agricultural GDP (Table 2). Livestock plays a critical role in socio-economic development agenda in Rwanda as a key pillar to economic growth and poverty reduction. T. P. Robinson et al. (2011) estimated that Rwanda's population of *poor livestock keepers*, i.e., those living below nationally-defined poverty lines and who owned livestock, was 3.09 million in 2011.

Livestock production in Rwanda follows three main production systems: extensive, semi-intensive and intensive zero-grazing systems with zero grazing being the most prevalent system. Cattle is the main livestock reared, with local breeds (like Ankole and their crosses) being dominant. Sahiwal and other sire lines are also reared. Goats, sheep, pigs, rabbits and poultry are also important in Rwanda. Ruminant livestock numbers are not very high in Rwanda, e.g., compared to other study countries such as Ethiopia, Niger and Burkina Faso. Poultry numbers are also relatively low. Rwanda however has a relatively large pig sector, of more than one million pigs.

Livestock projections to 2030/50

As in many countries starting from low initial levels, consumption of LDF is expected to increase substantially in Rwanda to 2050. The largest increase is expected in pork consumption. The supply of livestock derived foods in Rwanda was 58 kcal per person per day in 2010. Of this supply, 52% came from dairy, 46% from meat and 2% from eggs (Table 6). Further, beef made up 59% of the supply of meat at more than 16 kcal per person, while pork was 26%, poultry 11% and lamb 4%. Under the scenario of moderate economic growth, the share of dairy in LDF supply is 45% in 2030, which is 7% lower than observed in 2010; and 37% in 2050. This shows a decline in the relative importance of dairy, although total amounts increase. Meat supply per person increases from 27 Kcal/day in 2010 to 77 Kcal/day in 2050, (i.e., 192%). In addition, the share of meat in LDF supply increases from 46% to 61%. The main source of the increase is pork meat, for which supply per capita increases from 7 kcal in 2010 to 33 kcal in 2050 and share in meat supply increases from 26% to 43%. Although total supply of beef increases (as for all LDF products), its share decreases. The shares of lamb and poultry in meat supply are unchanged.

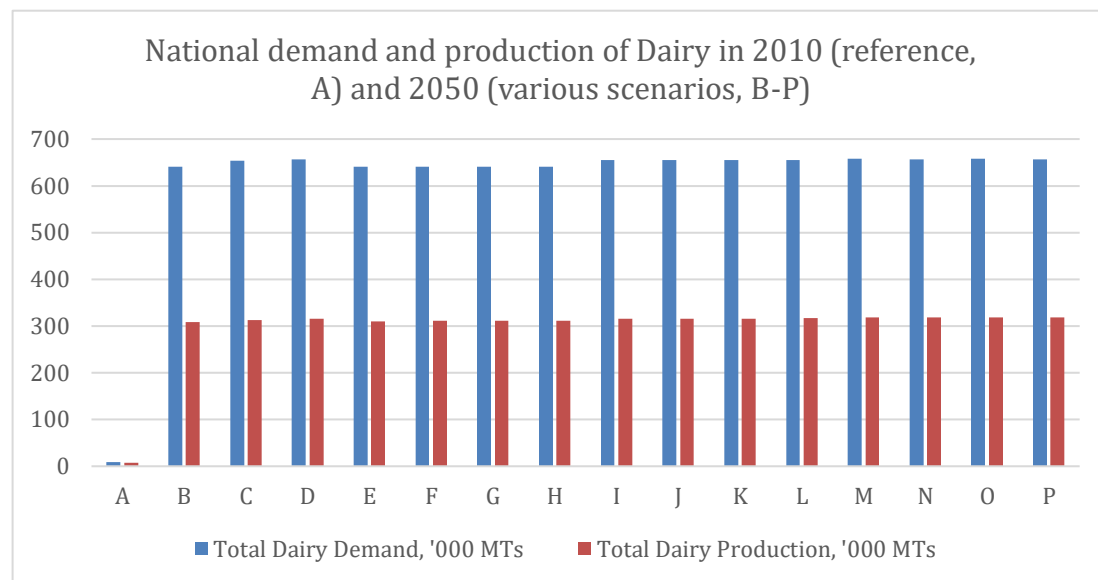
Table 6. Projections of demand for different LDF types in Rwanda in 2010, 2030 and 2050*

	2010	2030	2050
	(kilocalories per capita per day)		
Beef	15.54	22.73	32.53
Pork	6.95	15.51	33.13
Lamb	3.02	5.12	8.84
Poultry	1.02	1.77	2.99
Dairy	30.37	38.58	47.23
Eggs	1.00	1.46	2.15
Sum of Meat	26.53	45.13	77.49
Sum of all LDF	57.90	85.17	126.88

* IMPACT results for moderate economic growth, no climate change (Middle No CC) scenario.

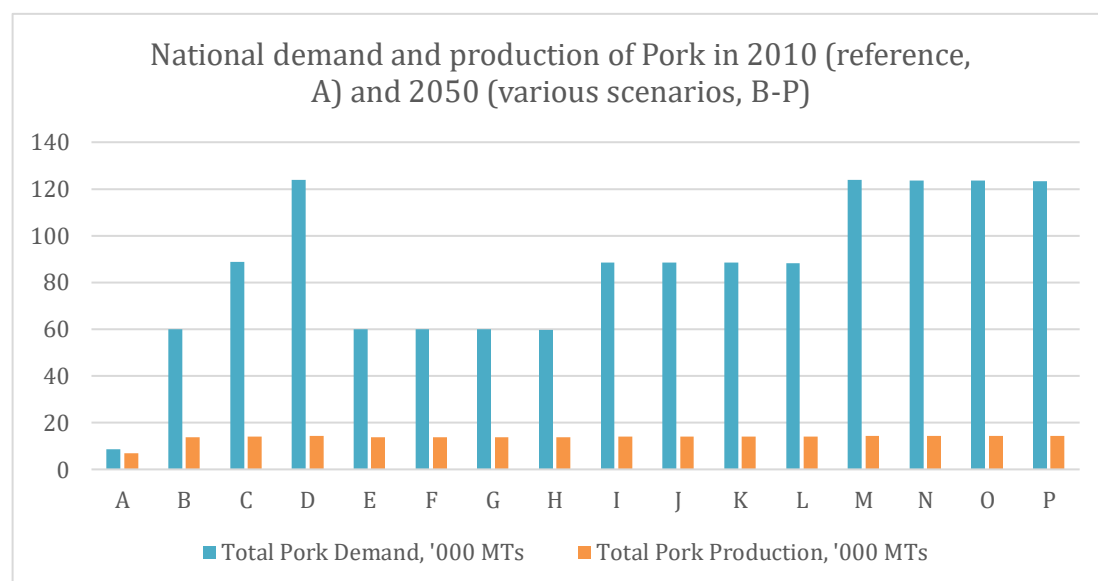
What the per capita supply estimates translate to in aggregate terms is 622,000 MT of dairy, 142,000 MT of beef, and 89,000 MT of pork supplied to households in Rwanda under the assumption of moderate economic growth in 2050. Household demand for lamb, poultry and eggs are 49,000 MT, 18,000 MT and 13,000 MT respectively. Figure 5 compares the demand and production of dairy in 2010 to a range of economic growth and climate change scenarios in 2050. Dairy demand is between 640,000 MT (scenario B) and 658,000 MT (scenario M), showing a trend of slightly higher demand when global economic growth is high and lower demand when economic growth slows. Substantial gaps are noted between country-level demand and production so that much of the demand for dairy in 2050 (i.e., half or more) is met through imports. However, the percentage of dairy demand coming from imports does not change significantly across the scenarios, at 51% to 52%. More variation is observed in the projections for pork (see Figure 6).

Figure 5. Model projections of dairy demand and production in Rwanda



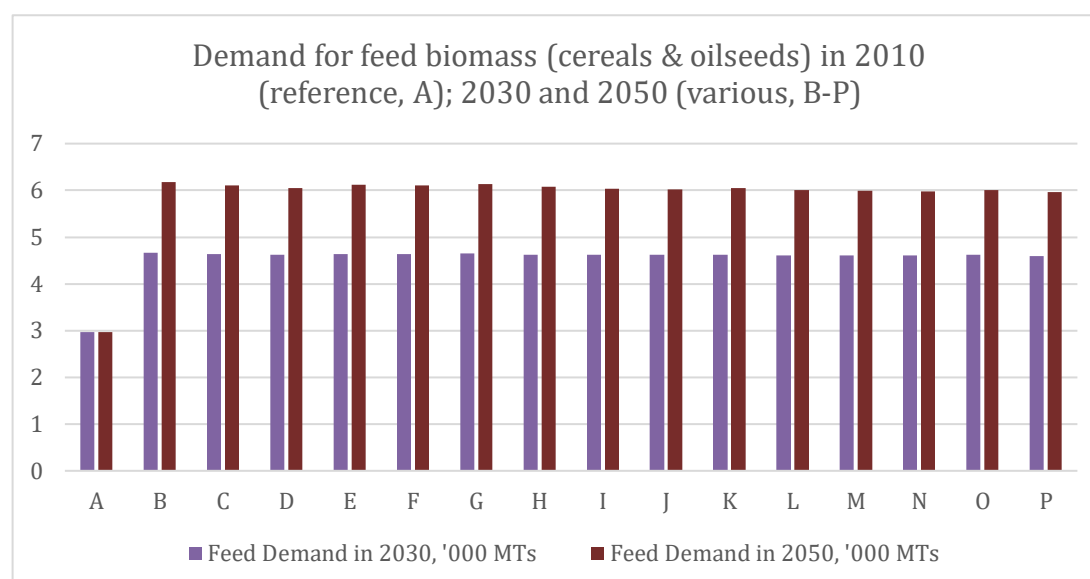
Aggregate demand for pork is highly variable across the alternative scenarios of 2050; while national production is consistent and relatively lower. As such, import quantity as a percentage of pork supply is high and variable, at 83% on average and ranging between 77% and 88%.

Figure 6. Model projections of pork demand and production in Rwanda



The model results show estimates of livestock feed demand in Rwanda are somewhat consistent under the different scenarios of global change (see Figure 7).

Figure 7. Model projections of livestock feed demand in Rwanda



Quantity of livestock feed demand is around 4,600 MT in 2030 and ranging between 5,950 MT and 6,180 MT in 2050. The future years' estimates thus represent growth from 2010 of around 55% in 2030 and between 101% and 109% in 2050.

National management of Rwanda's livestock sector

Rwanda has a ministry of Agriculture and Animal Resources (MINAGRI) with a mission to develop and manage suitable programs for transformation and modernization of agriculture and livestock in the country. The overall objective of the ministry is to ensure food security and contribute to the national economy. Rwanda put in place a National Agriculture policy in 2018 (NAP 2018) that replaced the preceding policy NAP 2004. NAP 2018 provides comprehensive strategic guidance to the agricultural sector, outlining policy actions that will create a competitive agriculture sector. The goals of the policy are: improved food and nutrition security, higher family incomes, and economic growth. This policy will be implemented under the fourth strategic plan for agriculture (PSTA4) (RoR, 2018).

The agricultural sector has a Strategic Plan for the Transformation of Agriculture in Rwanda Phase III (PSTA III), which aims to intensify and commercialize agriculture. Specific targets

under this Plan include the attainment of an annual agricultural growth of 8.5% and annual export growth rate of 28%. The Plan also highlights the aspiration to have 40% of agricultural land in Rwanda under modern agriculture in 2017/2018. Rwanda recently formulated its Vision 2050 and National Strategy for Transformation (NST) which stress the importance of agro-processing and technology-intensive agriculture with a commercial focus. This mandate falls under Pillar III: Transformation for Prosperity, of the NST. The NST1 seeks, under its economic transformation pillar, to increase crop and livestock quality, productivity, and production by modernizing agriculture and increasing resilience to climate change.

MINAGRI introduced a livestock master plan (LMP) in 2017 that was developed in collaboration with the International Livestock Research Institute (ILRI), with input from the Rwanda Agriculture Board (RAB) and universities and other research institutes in the Republic of Rwanda. The initial study to develop an evidence-based LMP using quantitative analysis of the sector was funded by the Food and Agriculture Organization (FAO) (Shapiro et al., 2017). Others include; Vision 2020, the economic Development and poverty reduction strategy 2008-2012, Agricultural development policy (PSTAIL) and several strategy papers. These direct the development of the economy, agriculture and livestock sectors. Rwanda also has a strategy and investment plan to strengthen animal genetic improvement (ROR, 2012).

Other policies that directly affect the livestock sector have been outlined below:

Climate and environment:

In 2010, the government of Rwanda commissioned the development of a National Climate Change and Low Carbon Development Strategy which aims to: develop a roadmap for future climate resilient and low carbon economic growth in Rwanda, build on existing climate change initiatives and opportunities that are currently being undertaken in relative isolation in Rwanda, provide a framework around which detailed sectoral studies and implementation plans can be built, develop local capacity in sourcing, applying for and obtaining international climate funding and contribute to the implementation of a Climate Centre in Rwanda to improve climate data and models for the region (SSEE & University of Oxford, 2011). The strategy was released in October 2011 (ROR, 2011). Rwanda also has a National strategy for green growth and climate change resilience. A draft National Environment and Climate Change Policy was released in June 2018 (ROR, 2018).

Burkina Faso

Livestock production is an important feature of the agricultural and rural landscape in Burkina Faso. It seems to also be relevant for household nutrition. The 2011 count by T. P. Robinson et al. (2011) estimated that 4.36 million poor people in the country depended on livestock for part of their livelihoods. A recent study that analyzed nationally-representative household data indicated that 80% of the households in Burkina Faso keep livestock, with ownership more prevalent amongst the poorest populations. Further, intake of livestock-derived foods was found to be more prevalent for children in poor households that kept cattle, goats, or chickens, compared to other poor households that did not keep farm animals (Enahoro, et al., 2018). Three production systems are commonly followed in the country. These are; pastoral, sedentary traditional (under village conditions) and sedentary improved (under modern conditions-peri-urban semi intensive and intensive) production systems. The common livestock species are: cattle, poultry, pig and dairy. Fish farming and bee keeping are also important. Ruminant meat dominates both the consumption and production of LDF in Burkina Faso.

Projections to 2030/2050

In 2010, the supply of livestock derived foods was 124 Kcal per person per day (Table 7). Meat (i.e., beef, lamb, pig and poultry) together made up 69% of this supply, milk 24% and eggs 7%. Beef accounted for nearly half (at 49%) of all LDF supply per capita. For the scenario of moderate economic growth, LDF (meat) supply increases to 194 (145) kcal in 2030 and 335 (264) Kcal in 2050. Under this scenario, the share of meat in LDF supply is 79% in 2050 and beef accounts for 57% of all meat supply. Sheep and goat meats' share of LDF supply declines from 18% in 2010 to 15% (12%) in 2030 (2050) although their quantities increase over the period. Poultry meat is 9% of supply in 2010 and 10% in 2030 and 2050.

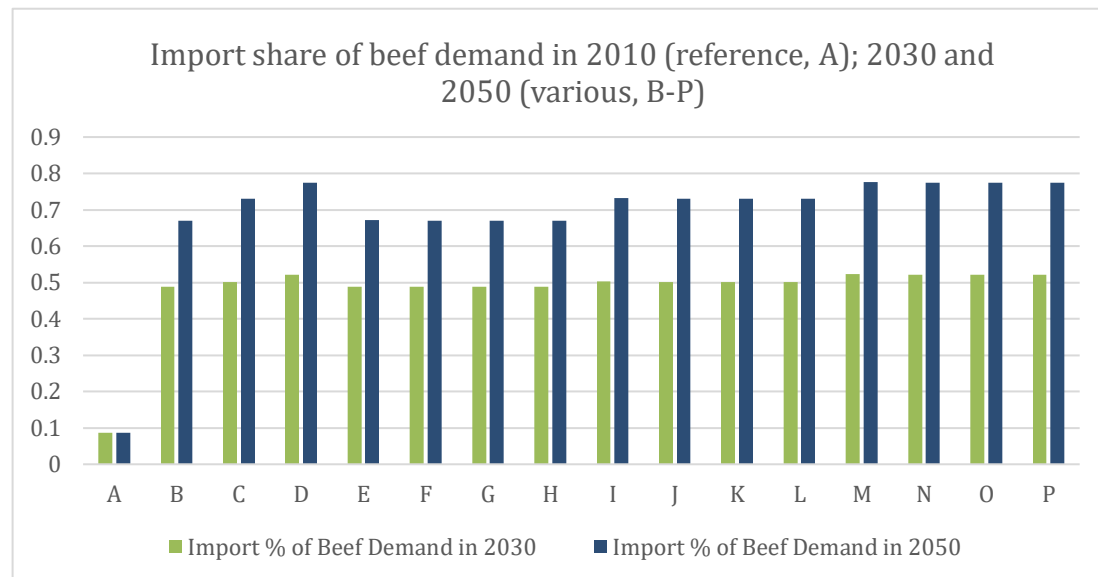
Table 7. Projections of demand for different LDF types in Burkina Faso in 2010, 2030 and 2050*

	2010	2030	2050
	Kilocalories per person per day		
Beef	41.87	76.71	150.38
Pork	21.03	32.75	54.15
Lamb	15.33	21.38	32.13
Poultry	7.55	13.88	27.16
Dairy	29.76	38.12	53.37
Eggs	8.32	11.59	17.53
All Meats	85.77	144.74	263.80
All LDF	123.86	194.42	334.70

* IMPACT model results for moderate economic growth, no climate change (Middle No CC) scenario.

Aggregate supply of beef is 402,000 metric tons annually in 2030 and 1.1 million metric tons in 2050 under the baseline scenario. For the same scenario, beef production in Burkina Faso is 201,000 MT in 2030 and 302,000 MT in 2050, suggesting imports are needed to meet around 50% and 70%, respectively, of beef demand in 2030 and in 2050. Figure 8 shows net trade in beef for the alternative scenarios of global economic growth and climate change. Imports make up about 9% of the aggregate demand for cattle meat by households in Burkina Faso in 2010. According to the model projections, this percentage is around 67% in 2050 under the slow economic growth scenarios (i.e., scenarios B, E, F, G, H), around 73% under moderate economic growth (i.e., C, I, J, K, L), and up to 77% under fast economic growth (i.e., D, M, N, O, P). For the range of scenarios however, beef demand under a specific economic growth scenario assuming no climate change may be higher or lower than the equivalent climate change scenario, depending on which ESM has been used; while production figures are all higher for the no-climate change options (i.e., compared to their equivalent climate change simulations).

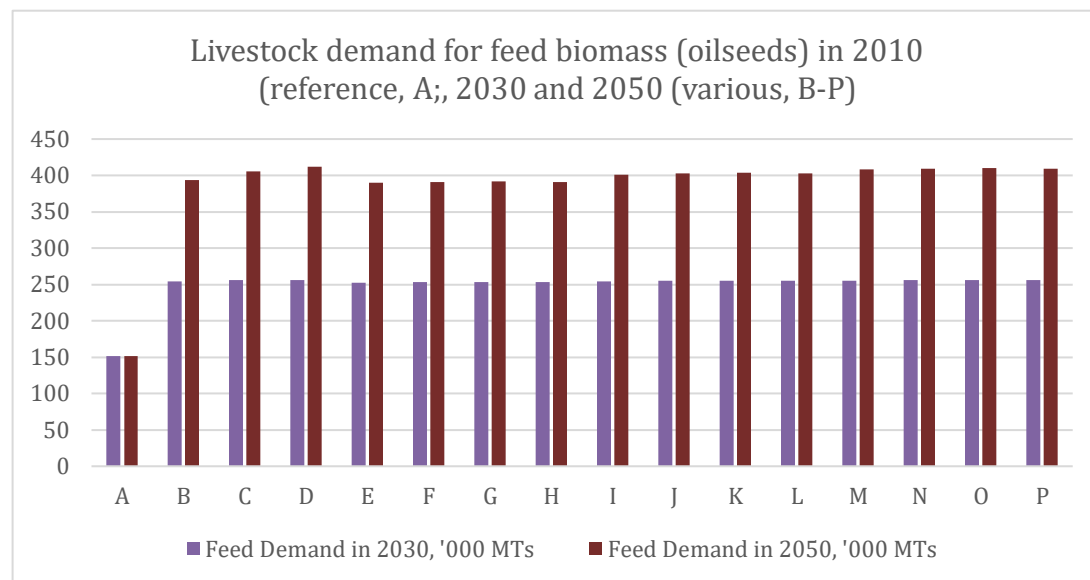
Figure 8. Model projections of import share of beef demand in Burkina Faso



Imports of dairy, chicken meat and eggs compared to their demand, are lower, ranging between 29% and 34% for dairy, 35% to 38% for poultry meat, and 51% to 53% for eggs. Meanwhile, Burkina Faso is projected to be a net exporter of both pork and lamb, (net-) exporting between 25% and 28% percent of pig meat demand, and 14% to 18% of the quantity of households' small ruminant meat supply in 2050 (not included in figures). The demand for livestock feeds associated with the future supply quantities is presented in Figure 9. The demand in Burkina Faso of internationally traded feed commodities, is composed of oilseeds mainly⁶.

⁶ Crop residues and other feed sources that may be widely used in Burkina Faso are not included in the current analytical framework for IMPACT.

Figure 9. Model projections of livestock feed demand in Burkina Faso



Total feed demand quantity increases by 69% from 2010 in 2030; and by 167% in 2050.

Demand in 2050 varies between 390,000 MT and (under slow growth) and 412,000 MT (under high growth). Generally, the no climate change scenarios of 2050 (i.e., B, C, D) lead to higher feed demand quantities (since production is higher) than equivalent economic growth scenarios that simulate in addition climate change.

National management of Burkina Faso's livestock sector

Burkina Faso has a ministry of animal resources and Fisheries (MRAH) which is responsible for the livestock sector. The ministry provides training and extension services for livestock producers, supports production of fodder and promotes feed processing industries, processing of livestock products, quality improvement and identification of markets. In 1999, the government adopted a Sustainable Growth Strategy for Agriculture and a Strategic Operating Plan which aims at: (i) increasing agricultural production by 5 to 10 percent per year over the next ten years (horizon 2010); (ii) contributing to growth of at least 3% per year in farmers' and livestock breeders' incomes, so as to reduce the incidence of poverty in rural areas; (iii) improving the availability and accessibility of an adequate and balanced diet, which includes increasing consumption of animal proteins; (iv) supporting capacity building of local actors; (v) reducing the role of the government in the agricultural sector and promoting the

development of rural markets; (vi) generalizing and strengthening sustainable natural resource management by rural communities; (vi) promoting policies targeted to women.

Policies and plans of direct relevance to the livestock sector are outlined below.

Livestock:

Three key policy and strategy orientations have guided the livestock sector in recent years: (i) The National Policy for Sustainable Livestock Development (PNDEL, 2010-2025) that sets the framework and blueprint for livestock development; (ii) the Action Plan and Investment Program for the Livestock Sector (PAPISE, 2010-2015) developed within the framework of the Livestock, Poverty and Growth (IEPC) initiative under the Alive initiative; and (iii) the National Plan for Adaptation to Climate Change in the Livestock Sector (PNDEL, 2013) which objective is to enhance livestock's contribution to national economic growth, food and nutrition security and subsequently improve the livelihood of the majority that depend on livestock. In October 2000 the government adopted the *Plan d'actions et programme d'investissement du secteur de l'élevage* (PAPISE), which is designed to: (i) optimize the production and productivity of the country's natural resources; (ii) create conditions for the private sector and livestock breeders' organizations to take the lead in the development of the sector; (iii) refocus the role of the State in the context of the decentralization process. Specific objectives relate to animal productivity, productivity of pastoral zones, and to the institutional framework.

There is also the 2010-2015 National Sustainable Development Policy for Livestock which aims to increase the contribution of the livestock sector to economic growth and nutritional security. This policy is implemented by Action Plan and Investment Programme for the Livestock Sector and this follows earlier policy frameworks on livestock. It includes 12 priority programmes that reflect policy priorities. These include: strengthening vocational training, building capacity of advisory and professional organizations, securing livestock production areas, improving pastoral water management, improving feed security, boosting the genetic potential of local breeds, and controlling animal diseases, among others (OECD 2013).

Climate:

Burkina Faso has a national climate change adaptation plan (NAP) dated 2015 which intends to manage economic and social development more efficiently by implementing planning mechanisms and measures taking account of resilience and adaptation to climate change between now and 2050". The objectives of NAP are to (i) reduce vulnerability to the impact of climate change by developing adaptation and resilience capabilities; (ii) facilitate the integration of climate change adaptation into new or existing policies, programmes or activities and in specific development planning processes and strategies in pertinent sectors and at various levels in a coherent manner.

Natural resources:

Burkina Faso has had several policies, action plans and programs for land and natural resource management (GoBF, 2007). Some of these include:

- Country Partnership Programme on Sustainable Land Management of 2006. This was approved by GEF as a pilot partnership programme for implementation of OP 15 on Sustainable Land Management.
- The National Action Programme to Combat Desertification (1999) an implementation of the UN Convention to Combat Desertification. It identifies sustainable natural resource management as priority framework for GoBF actions.
- National Environmental Action Plan (1991/1994) an outgrowth of UN Conference on Environment and Development and Agenda 21: defines national environmental policy and includes programme on land management.
- Rural Development Strategy (2004), which is consistent with the Poverty Reduction Strategy of the GoBF. It provides objectives for the rural sector through 2015 and identifies sustainable natural resource management among strategic axes.
- Action Plan for Integrated Management of Water Resources (2003), this is based on the Water Management Law of 2001: reorients water management from sectoral to integrated (watershed) approach, establishes institutions/capacity for watershed management.
- National Biodiversity Strategy and Action Plan (2000) implementation of the UN Convention on Biological Diversity: promotes conservation and sustainable use of biodiversity, including ecosystems and habitats, wetlands and dry zones.

- National Strategy on Climate Change (2001) implementation of the UN Framework Convention on Climate Change: promotes reduction of greenhouse gas emissions through sustainable management of natural resources.
- Environment Initiative of NEPAD (2003) An outgrowth of New Partnership for Africa's Development: provides a coherent action plan and strategies to address the region's environmental challenges, including land degradation.
- Millennium Development Goals (2000) Commitment to human development by the international community: includes the goal of ensuring environmental sustainability and reversing the loss of environmental resources.

Niger

Livestock is the second most important export item in Niger after uranium. In addition, Niger has the highest herd population in the Sahel region, with an estimated 11.4 million heads of cattle by 2014. The main animal breeds kept in Niger are: Cattle, goats, sheep, camels and horses. There are about 5 cattle breeds and many crosses hence many variants. Six production systems are common: the agro-pastoral system, semi-modern dairy farms/ semi-intensive farms, re-organized traditional system (where cattle raising is abandoned for camels and goats), enhanced traditional system (i.e., livestock keepers maintain specific bovine breeds and mobility), small producers (large number of farmers using livestock as "live bank" and large land owners (owned by large traders as safety assets for trade activities (FEWS NET, 2017).

Meat consumption in rural areas is generally very low, as ruminant livestock raised in these areas are often bought and sold, but rarely eaten. Chicken meat consumption is also low in rural areas. Consumption of meat from local sheep is higher than the consumption of goat or cattle meat, and ruminant meat consumption is higher than that of poultry.

Livestock projections to 2030/2050

In 2010, the total supply of LDF in Niger was 192 kcal per person per day. Dairy accounted for 92 kcal, or 48% of the supply while meat was 99 kcal (52%) and eggs 1.3 Kcal (less than 1%). Beef had the highest share (70%) of meat supply followed by lamb (26%). Poultry meat and pork were low at 3% and 1% share, respectively, of livestock meat supply. Under the

scenario of moderate economic growth, total supply of LDF increases to 268 kcal in 2030 and to 442 kcal in 2050. By 2050, the share of dairy is down to 35% while the share of meat now accounts for 64% of all LDF supply. Beef supply is 77% of all meat supply in 2050.

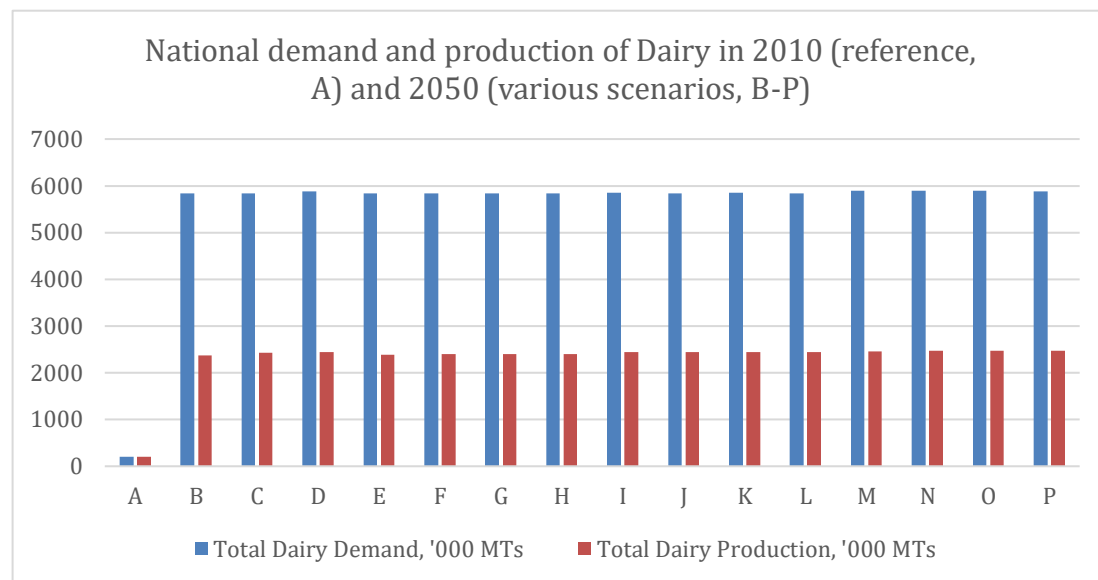
Table 8. Projections of demand for different LDF types in Niger in 2010, 2030 and 2050*

	2010	2030	2050
	kilocalories per capita per day (% of total supply)		
Beef	69.57	114.63	219.81
Pork	1.14	1.93	3.88
Lamb	25.30	33.15	49.32
Poultry	3.13	5.46	11.24
Dairy	91.66	111.82	155.69
Eggs	1.31	1.73	2.59
All meat	99.13	155.17	284.25
All LDFs	192.10	268.72	442.54

* IMPACT model results for moderate economic growth, no climate change (Middle No CC) scenario.

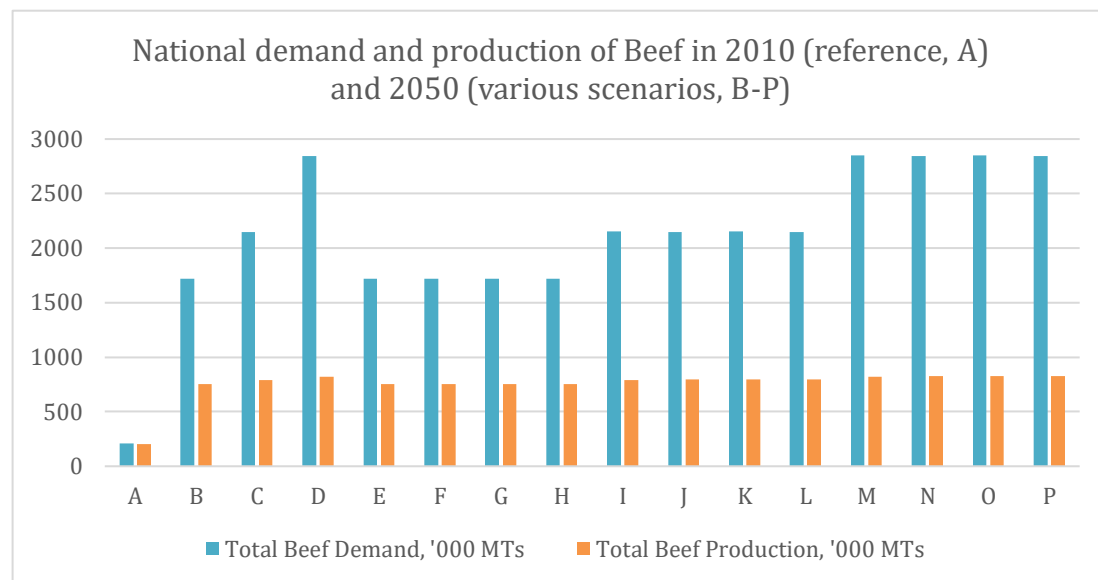
The per capita estimates add up in aggregate to 5,460,000 MT of dairy supplied, 2,149,000 MT of beef and 611,000 MT of lamb in 2050. Estimates for poultry, eggs and pork are much lower, at 165,300 MT, 39,500 MT and 20,000 MT, respectively). Figure 10 compares demand and production of dairy in 2010 to measures of the same indicators in 2050 for the different economic growth and climate change scenarios. Figure 11 provides similar data for beef.

Figure 10. Model projections of dairy demand and production in Niger



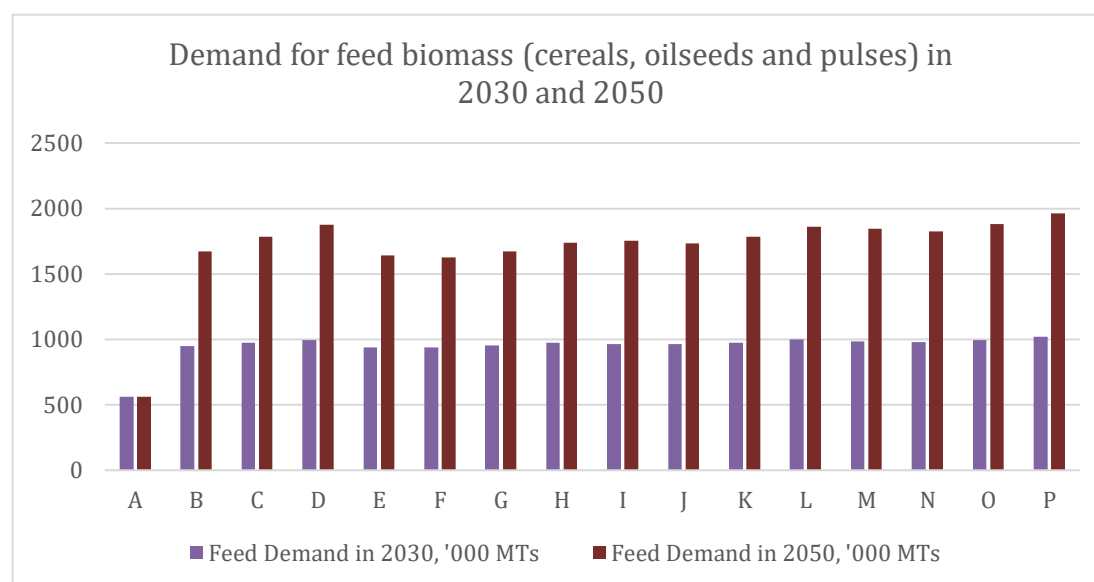
Dairy demand is relatively stable under the different scenarios, at around $\pm 0.5\%$ of the average demand of 5,856,000 MT. The demand for beef on the other hand is highly variable, ranging around $\pm 25\%$ of the average quantity of 2,238,000 MT. The slow economic growth scenarios (i.e., B, E, F, G) lead to lower demand (than the moderate growth scenarios) while the fast growth scenarios (D, M, N, O, P) lead to higher demand. Production estimates do not vary by much but are lower than the estimates of demand throughout. Production is in addition lower under climate change compared to the no climate change scenarios.

Figure 11. Model projections of beef demand and production in Niger



Given the dynamics of demand and production, dairy import quantity is 58% to 60% of the demand for dairy; while beef imports relative to demand is around 56% under low growth, 63% under moderate growth, and 71% under high economic growth. The projected trends for livestock feed demand are shown in Figure 12.

Figure 12. Model projections of livestock feed demand in Niger



Under the moderate growth no climate change scenario, feed demand is projected to increase by 217% (73%) from 2010 to 2050 (2030). Feed demand quantities are highest for the high economic growth scenarios (i.e., C, M, N, O, P), corresponding with the higher country demand and production of LDF observed for these scenarios. Climate change does not lead to consistently higher or lower demand. Instead, feed demand is higher under some ESM climate trends (IPSL, MIRO) than is observed in the no climate change case, and lower under others (HGEM, GFDL)⁷. At more than 80% of the total feed biomass, cereals make up the bulk of livestock feeds from commodities that are internationally traded⁸ (not shown in figures).

National management of Niger's livestock sector

Niger has a state ministry of Livestock and Fisheries development mandated to provide public extension services to farmers. Its mandate is executed by environment, water and forest directorate and delivered through extension services. In 2010, Niger passed a sector-specific law on pastoralism that added onto the text of the Rural Code. The Rural Code (1993) contained several rules and regulations establishing standards that are thought to

⁷ See Table 4.

⁸ Crop residues and other feed sources that may be widely used in Niger are not included in the current analytical framework for IMPACT.

protect/safeguard and revitalize Nigerien pastoralism. The code also promotes preservation of areas where herders are entitled to collective use rights and stipulates that transhumant stockbreeders must be allowed access to watering points. However, these policies do not impose on pastoralists accountability for management of the environment.

Cambodia

Cambodia has the highest income (1,135 US dollars per person) of the six countries included in the analysis. Its agricultural sector contributes 32% to national income, while livestock contributes slightly more than a tenth of agricultural GDP (see Table 1). A high proportion of its population, i.e., 77%, live in rural areas, with around 20% of them, 2.3 million people according to T. P. Robinson et al. (2011), classified as poor livestock keepers.

Livestock projections to 2030/2050

In 2010, the supply of livestock derived foods was 147 kilocalories per person per day. The breakdown of this supply was 90% meat, 6% dairy and 4% eggs, highlighting the particularly important role of meat in animal protein consumption in Cambodia. Pork made up 72% of the supply of meat, beef 20% and poultry the remainder. Lamb did not feature to any recognizable degree in the supply of protein in diets. Under the scenario of moderate or business-as-usual economic growth, the share of meat in LDF supply is projected to decline by 2% (to 88%) in 2030 and to 86% in 2050, as egg consumption increases slightly, from 4% of animal protein in 2010 to 6% in 2030 and 9% in 2050. Further, the share of pork in meat supply is projected to decline from 2010 to 2050, making room for increased intake of beef and poultry. Lamb still is not included in the projections of animal source protein supply in Cambodia in 2050.

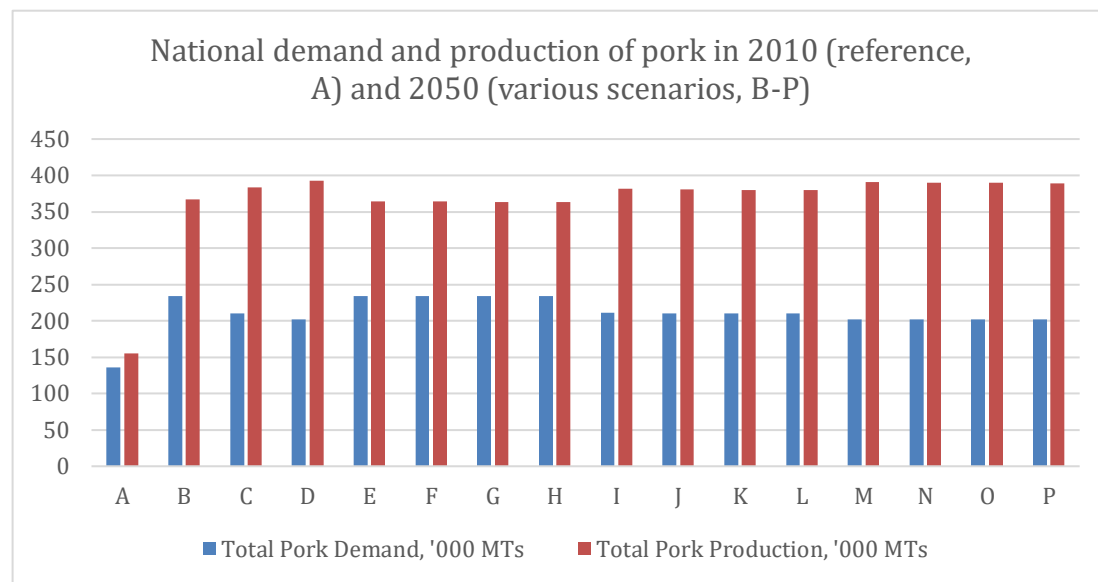
Table 10. Projections of the supply of different LDF types in Cambodia in 2010, 2030 and 2050*

	2010	2030	2050
	kilocalories per capita per day		
Beef	25.95	42.71	51.98
Pork	94.27	114.37	117.50
Lamb	0.01	0.01	0.02
Poultry	11.54	24.13	32.15
Dairy	9.43	12.26	13.43
Eggs	5.97	12.27	20.18
Sum of meats	131.77	181.22	201.64
Sum of all LDF	147.17	205.75	235.25

* IMPACT model results for moderate economic growth, no climate change (Middle No CC) scenario.

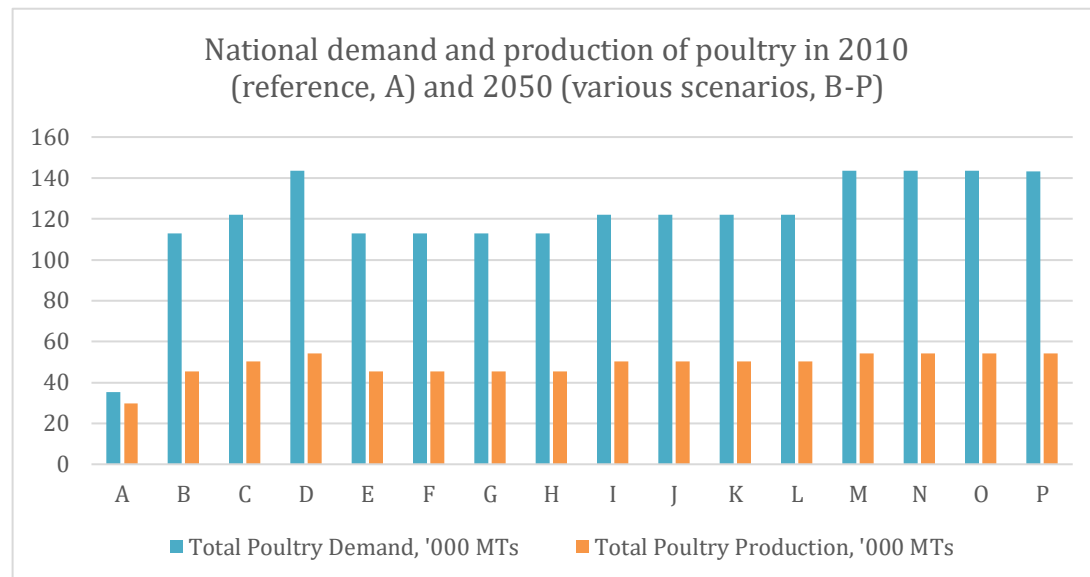
Aggregate pork demand increases from 136,000 MT in 2010 to 234,000 MT in 2050 (a 73% change) under the baseline scenario (Figure 16). Meanwhile, pork production increases by 136% over the same period, from a starting quantity of 155,000 MT. As such Cambodia's grows as a net exporter of pork over the simulation period. By 2050, Cambodia's pork export quantity is 40% of total production under the baseline scenario, up from 2% in 2010. Demand is highest (and production lowest) for year 2050 scenarios of slow global economic growth (i.e., B, E, F, G, H). As was observed for Ethiopia's beef sector, this result likely reflects the importance of global prices to national demand for a product for which the focus country is a net exporter. For the range of scenarios, export as a percentage of production is lowest under slow economic growth. Within each assumption on economic growth, the no-climate change scenario leads to higher production than the scenarios with climate trends included. However, the differences are small.

Figure 16. Model projections of pork demand and production in Cambodia



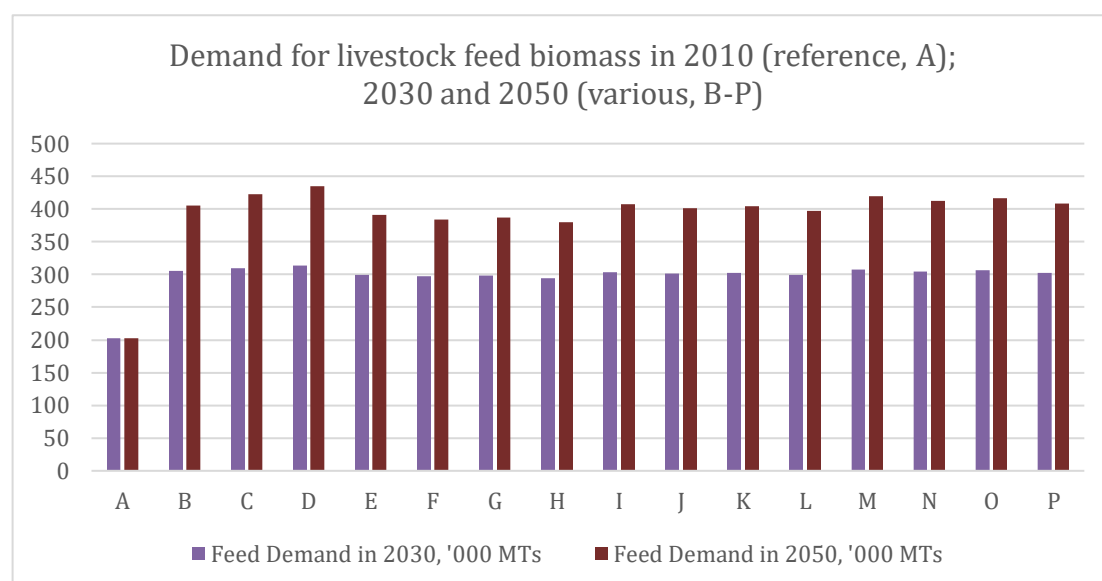
An analysis of poultry projections leads to markedly different results. Production is 29,000 MT in 2010, or 85% of the 35,000 MT of poultry demand under the baseline/moderate growth scenario (Figure 17). The production gap widens over the model's simulation years, so that poultry production is only 41% of the demand in 2050. Demand is lowest for the slow global growth scenarios and highest for the high growth scenarios. Production is slightly lower under climate change than in the no climate change case (i.e., for a given assumption of economic growth). Poultry imports relative to demand is 59% to 62% over the range of scenarios.

Figure 17. Model projections of poultry meat demand and production in Cambodia



Demand for livestock feeds increases by 51% in 2030 compared to 2010 demand, and by 100% in 2050, i.e., under the baseline assumption on economic and climate change (see Figure 18).

Figure 18. Model projections of demand for livestock feeds in Cambodia



Feed demand is made up of mostly cereals (around 57%) and oilseeds (~42%) with roots and tubers contributing <1% (not included in figures). The demand for livestock feeds is dampened in 2050 both when global economic growth is slower, and under climate change.

National management of Cambodia's livestock sector

The government of Cambodia includes a ministry of Agriculture, Forestry and Fisheries (MAFF). The roles, responsibilities and organization of MAFF were established by Sub-decree (no. 18, dated October 2nd, 1984) by the Council of Ministers and have been subsequently amended several times. The ministry is mandated to oversee agriculture in Cambodia. The Cambodia government has prioritized agriculture as a key sector for development since it first released its rectangular strategy. Version III of the strategy aims to push agricultural investment beyond strengthening rural incomes, into improved technology, research and development, crop diversification and promotion of commercial production and agro-industrialism (Royal government of Cambodia, 2013).

Government policies we identified that could be directly relevant to changes in the livestock sector are outlined below for the Agriculture, Livestock, Climate Change and Environment sectors/sub-sectors.

Agriculture:

Cambodia has an Agricultural Sector Strategic Development Plan (ASDP) 2014-2018 and the Rectangular strategy phase-III which considers agriculture as a priority sector by clearly identifying that the enhancement of agricultural productivity, diversification and commercialization, land reformation, the sustainable management of natural resources, notably forestry and fisheries resources, are the fundamental areas to accelerate the economic growth and poverty reduction of the Cambodian population. The ASDP 2014-2018 is considered an important milestone in determining MAFF's direction and actions for medium-term implementation to accelerate the agricultural sector development. This document has been identified and examined the prioritized areas of agricultural sector development which will represent the MAFF development goals, objectives, outcomes, outputs and activities to be implemented during a 5-year period, 2014-2018 (MAFF, 2015).

Livestock:

The Department of Animal Health and Production (DAHP), a section under the supervision of MAFF, is responsible for the management of livestock research and education in the country. The roles and responsibilities of the department include; drafting of livestock legislation, developing standards related to livestock production and health and monitoring risks relating to human health, animal health, production and welfare, and the environment. The Department of Agricultural Extension (DAE) holds the government mandate to develop agricultural and extension system that is appropriate to the needs of the country (Soeun, 2012). The functions of this department include assessment of farmers' constraints, needs and opportunities; training and retraining of farmers; and development of linkages with researchers, policy makers, NGOs, and farmer's organizations (Soeun, 2012)

Climate change:

In 2013, Cambodian government promulgated its climate change strategic plan 2014-2023 aimed at reducing (Randolph et al., 2007) climate change impacts on national development, and contributing, with the international community, to global efforts for mitigating GHG emissions under the UNFCCC (Royal Government of Cambodia, 2013). In addition, in 2016, the ministry of environment launched its 2014-2018 Climate Change Priorities Action Plan (CCPAP), to convert financial resources and key practices into focused action. CCPAP has a strong focus on climate-smart agriculture, which is to be incorporated at the sub-national and community level (Ministry of Environment Cambodia, 2016).

Environment:

In late 2017, Cambodia launched its new roadmap for sustainable development, the *National Environment Strategy and Action Plan (NESAP)*. The NESAP identifies priority policy tools and financing options for sustainable natural resource management and environmental protection. This will guide government ministries, private sector, civil society, and development organizations to mainstream environmental considerations into development policies, plans, and investments. The NESAP was developed under the guidance of an Inter-Ministerial Taskforce comprising senior officials from 15 ministries. Representatives from civil society as well as major development organizations including the World Bank, ADB, the European Union were involved via a series of national consultations.

Nepal

The rural population is 81% of the total population of Nepal, with around 13%, or 3.12 million, according to T. P. Robinson et al. (2011), being poor and owners of livestock. The livestock sector is an important component of agriculture, contributing 24% to agricultural GDP, while agriculture accounts for 35% of total national GDP. Nepal has extremely diverse animal genetic resources with about 17 different domestic animal species. The main animals reared are: cattle, buffalos, goats, sheep, pigs and poultry. Three production systems are dominant: the transhumance (animals moved between fixed points), the sedentary (animals make daily forays from the village to community grazing land) and stall-fed (common in peri-urban area where animals are fed with crop by-products, tree fodder, grasses and weeds) systems. Consumption of LDF per person is estimated at 14kg of meat, 48 units of eggs and 91 liters of milk per year. There is local deficit in the production of both meat and milk.

Livestock projections to 2030/50

In 2010, the supply of livestock derived foods added up to 130 kilocalories per day in per capita terms. The breakdown of this supply was 65% dairy, 32% meat and 3% eggs. Beef accounted for 65% of all meat supply. Under the scenario of moderate economic growth, the share of dairy in LDF supply is projected to decline to 58% in 2030 and slightly under half (48%) in 2050. Egg consumption remains relatively stable over time at 3% to 4% of all animal protein consumption while share of meat consumption in the average diet increases from 32% in 2010 to 48% in 2050. Although total intake is shown to increase for all meat types, all the share gain goes to beef. Share of beef in meat supply increases by 6% over time while pork and lamb intake decline in share by 3% and 4%, respectively from 2010 to 2050. The share of poultry is unchanged at 5%.

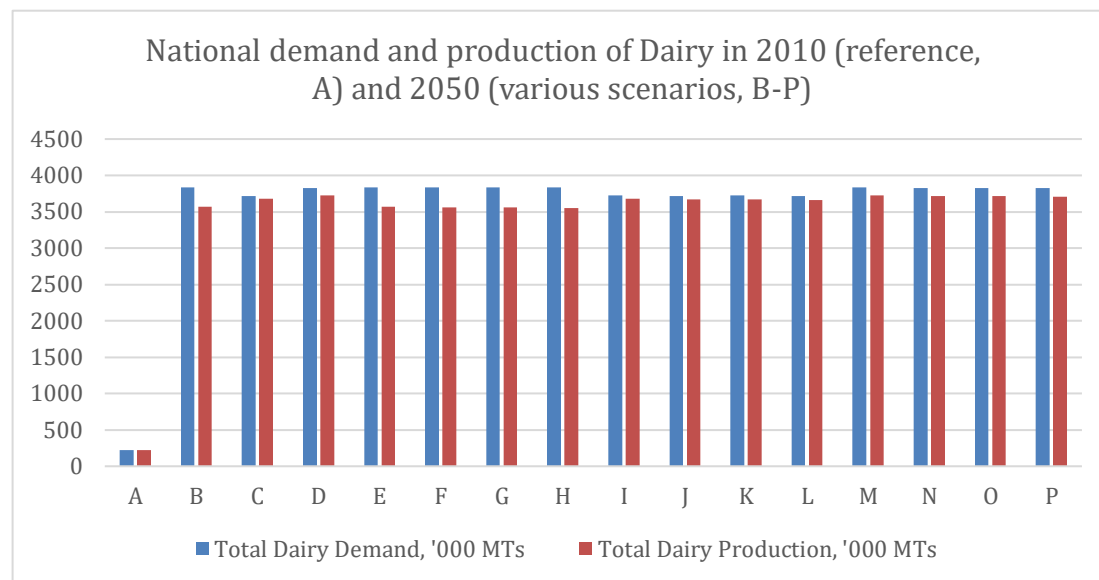
Table 9. Projections of demand for different LDF types in Nepal in 2010, 2030 and 2050*

	2010	2030	2050
	kilocalories per capita per day		
Beef	27.23	44.72	85.53
Pork	5.25	7.53	11.60
Lamb	7.32	10.03	16.57
Poultry	2.12	3.39	6.16
Dairy	83.98	97.72	121.65
Eggs	4.21	5.85	8.96
Sum of Meats	41.92	65.67	119.87
Sum of all LDFs	130.10	169.25	250.49

* IMPACT model results for moderate economic growth, no climate change (Middle No CC) scenario.

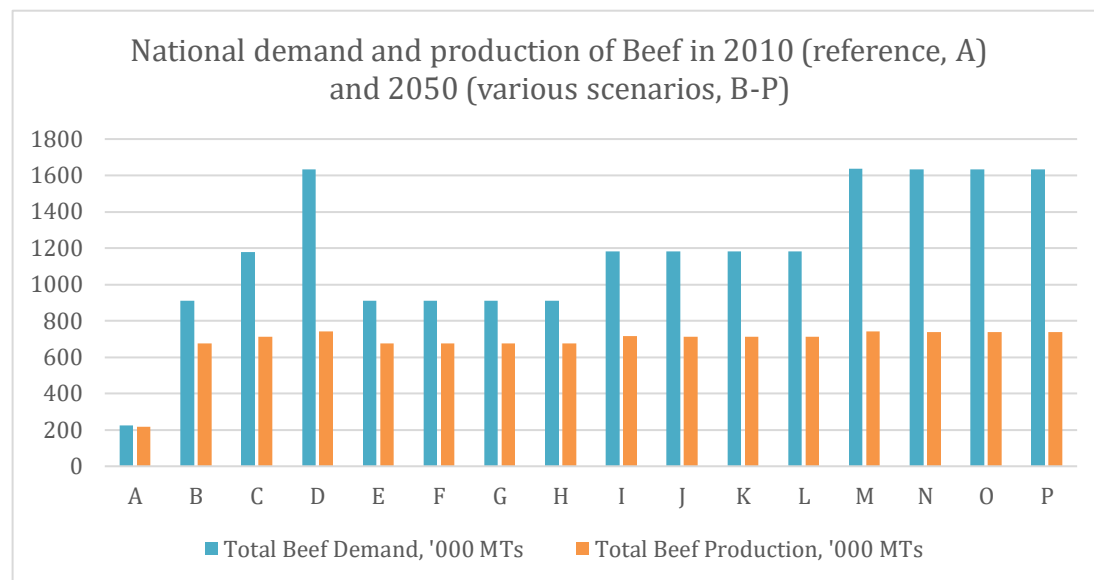
Following the baseline scenario specified for this study, IMPACT estimation of dairy demand in Nepal in 2010 is 224,000 MT while national production is 218,000 MT. As such, country production accounts for up to 97% of the country demand, and net imports for 3%. Figure 13 compares baseline dairy demand and production in 2010 to the same under a variety of economic growth and climate change scenarios in 2050. Dairy demand in 2050 is on average 15 times what it is in 2010. National production of dairy similarly grows rapidly but is not enough in 2050 to provide for all the additional demand. Net imports as percentage of demand is on average 1% for the moderate growth scenarios (i.e., C, I, J, K, L), 3% for the fast growth scenarios (D, M, N, O, P), and 7% for the slow economic growth scenarios (B, E,F,G,H), indicating slightly lower production with a slower global economy. Climate change does not seem to impact noticeable differences on dairy demand or production, and relative imports are consistent for the climate-affected and no-climate change trends. Figure 14 presents the data on beef demand and production.

Figure 13. Model projections of dairy demand and production in Nepal



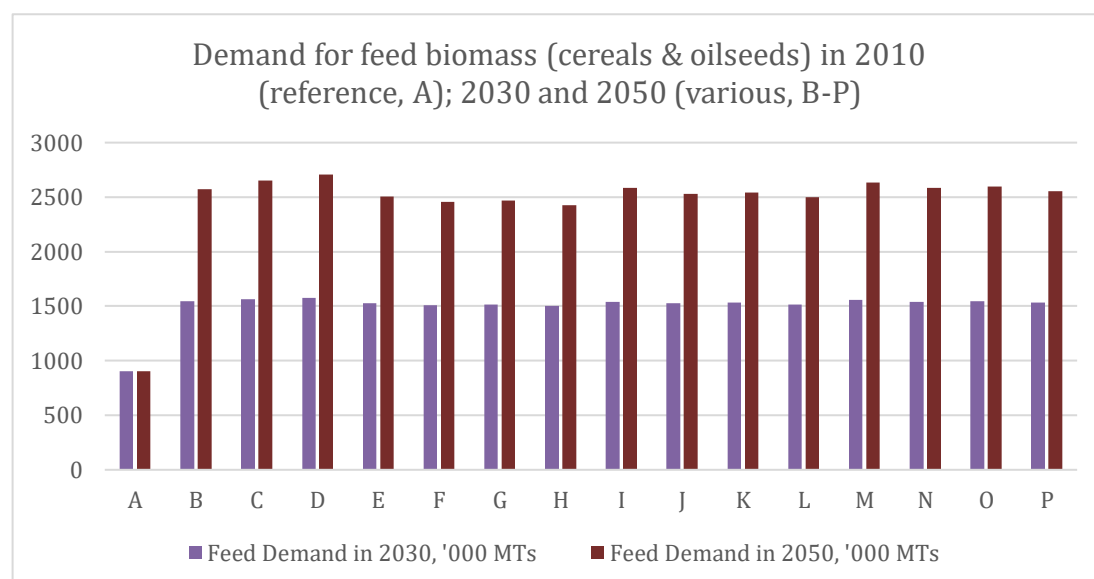
Beef demand in Nepal increases four-fold from 2010 to 2050 while production increases 2.3 times. Import as a percentage of the demand thus increases from 3% in 2010 to 40% in 2050 under the baseline scenario. There is substantial variation in production between the scenarios so that relative imports average 26% in the low growth case (i.e., B, E,F,G,H), 40% in the moderate growth case (i.e., C, I, J, K, L), and 55% in the high growth case (i.e., D, M, N, O, P). No substantial differences however arise from the climate trends.

Figure 14. Model projections of beef demand and production in Nepal



Demand for livestock feeds is 904,000 MT in 2010. It is 1,562,000 Mt in 2030 and 2,571,000 MT in 2050, representing 73% and 193% increases to 2030 and 2050, respectively, under the baseline assumption (Figure 15).

Figure 15. Model projections of feed demand in Nepal



Demand for livestock biomass varies somewhat under both economic change (i.e., faster economic growth leads to higher feed demand), and climate change (i.e., given the assumption on economic growth, feed demand is higher under the no-climate change assumptions).

In summary of the projections for Nepal, milk demand and production projections are noted to remain close, raising limited concerns related to the imports or exports of dairy. This is important as milk is currently the dominant type of LDF in the country. However, both poultry and beef consumption are projected to grow substantially, with no such anticipated growth in their production. The effects of climate change are most noticeable in the trends on livestock feed production and use.

National management of Nepal's livestock sector

Nepal has a Ministry of Livestock Development (MoLD) which was established in December 2015. The constitution of Nepal 2007 subsumes livestock development under agricultural development. Promotion of the Livestock Sub-Sector (LSS) is administered and facilitated by the Department of Livestock Services (DoLS) under the Ministry of Agricultural Development (MoAD) of the Government of Nepal (GoN) which assumes ultimate responsibility for all agricultural development in the country, including livestock development. However, LSS is interconnected to other development and infrastructure sectors that fall under different ministries and agencies.

Nepal has a livestock sector master plan dated 1993 which aimed at improving animal productivity, considered key to improving the welfare of the rural people. The need for a livestock master plan was realized during implementation of the Asian Development Bank-assisted livestock sector investment study in 1990/1980 (Asian Development Bank, 1993). In addition, there are national policies affecting the livestock sector within policies designed for the agricultural and other sectors. Three such policies are: The National Agricultural Policy 2004, Agro-Business Promotion Policy 2006, and Agricultural Sectoral Operating Policies (ASOPs) of the Approach Paper to Thirteenth Plan, 2012/13–2015/16 (GoN, 2017). The Agricultural Perspective Plan (APP), 1995-2015 identified livestock as one of the four priority outputs, and aimed to raise its share in the AGDP to 45 percent. This was to be achieved through raising the annual growth rate of the livestock sector to 6.1 percent, up from 2.9 percent earlier (Pradhanang et al., 2015).

Other livestock-related policies are: the Animal Feed Act, 1976; Animal Health and Livestock Services Act, 1999 and Animal Health Program Implementation Procedure, 2013; Animal Slaughterhouse and Meat Inspection Act, 1999; Labor Policy, 1999; Child Labor Act, 2000; Forestry Sector Policy, 2000 (Forest Policy, 2000) (*aims to base livestock quantities on the amount of fodder production and highland pasture so as to improve forest management and increase the production of fodder by community efforts*); National Micro-Finance Policy, 2005(*aims at alleviating poverty targeting agricultural and livestock sector*); Dairy Development Policy, 2007 (*envision investment in the income and employment generating and poverty-alleviating dairy business*); Agriculture Bio-diversity Policy, 2007; Trade Policy, 2009 (*lays emphasis on commercial livestock farming and the promotion and supply of improved breeds*); Climate Change Policy, 2011(*emphasize the need for sustainable management of forests, agro-forestry, pasture, rangeland, and soil conservation*); Breeding Policy, 2011; Birds Rearing Policy, 2011; Rangeland Policy, 2012; Livestock Insurance Policy and Agriculture and Livestock Insurance Regulation; and National Land Use Policy, 2012.

Highlights of the results

The discussion following covers the national statistics and IMPACT model projections analyzed.

National statistics

Data showing the livestock sector as an important contributor to the agricultural and/or total GDP is important to note. Where livestock is already a key economic activity, this could present levers to induce economic growth and transformation (FAO, 2010). In other cases, livestock as a substantial part of the rural economy, even when this is only a small part of the overall economy, could present a key opportunity to address food and nutrition insecurity, poverty, and/or inequality, and rural development (Staal et al., 2009; Randolph et al., 2007; Herrero et al., 2013). Further, the data on the role of livestock in the economy and that on animal stocks together suggest that investments in livestock development in the focus countries may be strategic even from regional perspectives. Livestock contributes 15% to

Ethiopia's economy, while the country accounts for 8% of the human population and up to 18% of cattle numbers in Africa.

High animal numbers, as observed in Ethiopia for example, could mean heightened needs to address feed availability, environmental impacts and the use of natural resources, as well as food safety, zoonotic diseases, and other issues that may be associated with livestock production. However, it is not necessarily the case that the countries with higher stocks face higher risks of these factors. Differences in economic development, human populations and their interactions with livestock, climate and environment, land areas (and stocking rates) as well as in the systems of livestock production and management of production externalities, all contribute to determining what direct outcomes and negative or positive externalities will be realized (ILRI, 2019).

An assessment of the data on LDF supply alongside data on the prevalence of underweight among children does not reveal any advantages to the countries with higher per capita supply of LDF in either level or relative terms (e.g., as % of total food supply). This will suggest that strategies to increase aggregate supplies of LDF will not necessarily lead to desired outcomes on household nutrition. Complexities related to incomes, prices and market access, amongst others, affect geographical and even intra-household distributions of food supply, such that substantial disparities can be observed in LDF consumption and nutrition outcomes at the household or individual level, even when aggregate supplies appear abundant. Lower-income countries that hope to see desired improvements in macro and micro-nutrient intakes and in the associated nutrition and health outcomes will typically be those that implement interventions that directly address these complexities (Headey et al., 2018). There will be the need to look at other data such as household surveys to better analyze the links between aggregate LDF supply, household consumption, and nutrition outcomes (Enahoro et al., 2018).

Livestock projections

IMPACT model simulations for Ethiopia showed a net producer position under the selected scenarios of macroeconomic change, consistent with the continued orientation of the country's livestock sector (e.g., as outlined in the livestock master plans) towards policies that assume increased net exports of beef or live beef cattle. On the other hand, the plausible positive effects of a slower global economy on beef demand and production within Ethiopia

are also important to note. These results reveal the important role of export markets in Ethiopia's beef sub-sector. As demand for beef exports from Ethiopia increases following rises in the global economy, higher prices tend to dampen local consumption. Attention may thus need to be paid to such effects with continued export orientation of the sub-sector. Issues related to local beef prices, LDF consumption, and health outcomes of nutritionally vulnerable groups such as the poor, women, and young children may need emphasizing (see e.g., Randolph et al., 2007). The analysis for Ethiopia raises issues related to the current capacity of local livestock production. Pressures will likely mount on livestock feeds and the management of natural resources needed for production (e.g. land, water). Ethiopia should benefit from investments in more effective feed storage and efficient feed marketing systems (Abegaz et al., 2007; Gebremedhin et al., 2009).

Country-level demand for LDF is projected to grow faster than production of the different LDF types in Rwanda. Pork demand is observed to be particularly high relative to its production, as well as highly variable under the different assumptions of global change. Although pork is not the most commonly consumed type of meat in the country currently, there is a growing appetite for pig meat in the country, making these results important. The government of Rwanda sees the pig sector as a key sub-sector for development investment, and increased pig production as strategic for improving livelihoods and incomes (Shapiro et al., 2017). Much of the new demand for livestock-derived foods in Rwanda is projected to come from imports, making it important that the country follow a food security strategy that is resilient (at least in the context of LDFs) to a wide range of changing conditions in the global food and agricultural system. Where LDFs will be produced locally, much attention will need be paid to feed resources and environmental and natural resource management issues related to their use. A high proportion of its population living in rural areas and a relatively high dependence of this population on livestock, make such attention necessary.

In Burkina Faso, beef is currently the most important LDF in quantity terms. Its demand is projected to grow quite fast, outpacing that of all other LDF except poultry. Poultry will however account still for only a tenth of meat intake (whereas beef is projected to count for nearly 60%) in 2050. Dairy and egg demand are also projected to decline in relative terms over the period. These results raise questions about the implications for nutrition, particularly of young children, who in some settings in Burkina Faso have been shown to have been better

provided with milk and eggs (Enahoro et al., 2018). The results may also be relevant for other aspects of malnutrition. If, for example, the increased aggregate supply of red meat ends up being all consumed by a small segment of the population, there could be heightened risks of diet-related non-communicable diseases for these new groups of heavy meat consumers (Walker et al., 2005). IMPACT projections for Burkina Faso also show discernible impacts of climate change on LDF production. Beef production is lower under climate change, leading to higher relative imports. Livestock feed demand is also lower. Overall, it appears very rapid changes in livestock demand and supply and their effects on the country's international trade in food commodities will require the most attention in Burkina Faso. Local management of livestock feed resource will also be important.

Demand for beef in Niger is projected to grow the fastest of all LDF types. Dairy demand declines in relative terms, while egg demand is minimal currently (1% of all LDF consumption) and projected to remain the same over the simulated period. These results raise similar issues for nutrition as have been noted above for Burkina Faso. Further, projections of beef and dairy production, already markedly lower than the demand estimates, and lowered further by climate change. The results highlight the need for policies that will ensure food security and nutrition are maintained under threats of shocks from both international food markets and a changing global climate.

The net producer position of Cambodia in pig meat production as at 2010 is further consolidated by 2050, according to the model projections. Export markets and global prices may play an important role in local farmer incomes and household nutrition, particularly if much of the new production occurs in small-scale/backyard production. However, there are an increasing number of commercially-run pig operations, with production moving from the rural areas to the peripheries of big cities where demand is growing (Huynh et al., 2007). Papers such as Gerber et al. (2005) highlighted the potential implications of such transitions for increased environmental pollution. Although pork consumption is expected to remain high in Cambodia, its relative importance is projected to decline, making way for increased beef and poultry consumption. Milk consumption also declines slightly on a relative basis, as egg intake is increased. Cambodia is the only one of the focus countries for which we see such an increase (5%) in the share of eggs in LDF consumption.

In Nepal, dairy remains the primary source of LDF in 2050, although its share in per capita consumption decreases, from 65% to less than half. A big shift is similarly observed in beef consumption, which goes up. This potential displacement of white meat for red meat in the diets of consumers could lead to interesting impacts and trade-offs in nutritional and environmental dimensions. Dairy imports increase slightly while beef imports increase by very much, with climate change potentially dampening the production of both products. These issues invite further assessments for their policy relevance.

The projections of LDF demand analyzed are thus interesting both in terms of the absolute increases in quantities of LDF that will need to be produced (or imported) but also in the context of impacts that their compositions will have on development outcomes in the different countries. An implication for policy will be that strategies useful for influencing public health or environmental outcomes in one or more countries may not work elsewhere. For example, a push to increase the share of white meat in diets, e.g., to manage risks of diet-related non-communicable diseases may be more consistent with policy in Ethiopia, where both poultry and pig meat shares are projected to increase but may be more challenging to implement, or unnecessary, in Niger or Nepal.

Implications for policy focus and future research

The results from the IMPACT model give some initial indications about areas in which policies that emanate from or affect the livestock sector in the study countries may need to evolve. In Ethiopia for example, the effects of higher local and global demand for ruminant animals and animal products, and of international trade in these commodities, need to be included in livestock, environment and land use policy design and implementation in the future. Concerns about food prices, poverty reduction, agricultural biodiversity and environmental sustainability, amongst others, will also keep LDF demand and trade central in livestock sector planning. A baseline assessment of Ethiopia, conducted as part of the larger body of work under the LSIL livestock foresight sub-program would indicate that while anticipated changes in the demand and production of LDF have been recognized and explicitly planned for within the livestock ministry (e.g., in the LMPs), the same may not hold

within land use or environmental management policies⁹. There did not seem to be a coordinated approach by the different ministries to managing the outcomes of livestock sector transitions. Policy frameworks such as the Climate-Resilient Green Economy Strategy present opportunities for such (i.e., livestock-climate-environment interactions and synergies) to be pursued.

Other LSIL countries could, possibly, similarly benefit from more integrated policies for the livestock sector. For example, livestock feed demand is projected to increase substantially for most of the countries, raising questions of whether the needed feed resources can be produced locally, how to raise the productivity of feed production, and where additional land is needed, what regulations or incentives to utilize in the management of currently cropped or newly converted land areas. These all have different potential implications for environmental impacts and agricultural biodiversity. When additional demand for LDF will be met with imports, issues arise around where the new sites of production will be, and what rules govern agricultural expansion and environmental impacts there (see e.g., Enahoro et al., 2019).

It is important to highlight that the model projections are not predictions for how the demand, trade and other measures of LDF will evolve, but plausible outcomes based on current data and knowledge about key interactions of the countries' livestock sectors. Country-level engagements could be used to improve the model's input data for the said countries, or to develop and quantify new scenarios for the countries, as has been done in previous interfaces between the IMPACT model and policy stakeholders (Vervoort et al., 2013). An equally important exercise in the context of the current research program would be to engage stakeholders using the existing results as the starting point of discussions on how LDF demand and supply could transition in the different countries, and the readiness of existing and planned policy or programs to accommodate these changes.

For future research, the quantitative foresight analysis could be extended to include both the primary results obtained from the IMPACT model (e.g., commodity demand, supply and trade

⁹ In a workshop held in Addis Ababa, Ethiopia in July 2018, the LSIL futures scenarios team worked with representatives of the government and Ethiopia's livestock sector, to assess the robustness of Ethiopia's livestock master plans against plausible scenarios of change in the East Africa region, i.e., the CCAFS East Africa scenarios as previously described in Vervoort et al. (2013).

quantities, commodity prices), and post-model calculations of food security, producer and consumer welfare, and various forms of resource use. If climate mitigation or adaptation is an important focus for policy makers, IMPACT assessments as presented in this report could be extended to include other climate trends, e.g., RCP 8.5 that represents the harshest of the IPCC climate worlds, as well as environmental impacts such as greenhouse gas emissions. These options may better elaborate the challenges around agricultural productivity and production that global climate change will present. Where there are well elaborated strategies for livestock sector development (e.g., the Livestock Master Plans in Ethiopia and Rwanda) these could be explicitly tested using *ex ante* impact analysis tools that account for climate change and other important long-run trends. Future research could delve deeper into analyses of the links of anticipated transitions in the livestock sector to outcomes such as competitiveness of local industries, employment, livelihoods and poverty, nutrition, or environmental impacts. Such analyses will use one or more of: (1) application of the IMPACT model framework to country-specific issues, (2) new/updated country-level livestock data, (3) integration of IMPACT with other tools better suited to national and sub-national modeling and *ex-ante* impact assessments, and (4) the use of different analytical tools and methods altogether.

Appendix

Appendix Table 1. Number of ‘poor livestock keepers’ in USAID LSIL countries

	Pastoral	Mixed crop-livestock	Other	All systems
Ethiopia	1,771,799	18,979,128	256,080	21,007,007
Rwanda	-	2,998,660	95,057	3,093,717
Burkina Faso	441,628	3,917,289	2,611	4,361,528
Niger	1,992,330	4,050,474	5,266	6,048,070
Cambodia	60,210	2,121,724	121,355	2,303,289
Nepal	83,805	2,129,442	906,625	3,119,872

Source: T. P. Robinson et al., 2011, using the World Bank nationally-defined poverty lines

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