Program for climate-smart livestock systems

Country stocktake: Uganda

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Summary

This is one of a series of documents that summarises information relating to the livestock sector in the three Program for Climate-Smart Livestock Systems (PCSL) project countries (Ethiopia, Kenya and Uganda). Prevailing livestock systems and their baseline performance in Uganda are summarised first, followed by a summary of what is known about the impacts of climate change on livestock production and livestock systems. Section 4 briefly summarises some recent research on adaptation and mitigation options for livestock systems in Uganda. Section 5 considers some of the work that has been done to date on projections for the livestock sector to the middle of the century. Section 6 considers the national livestock and climate change policy environment. The paper concludes with a consideration of system intervention points and major gaps in knowledge, to help guide project activities in Uganda.

1. Introduction and background

The livestock sector is a major contributor to food security in sub-Saharan Africa (SSA), contributing a vital source of income to many rural poor people as well as providing critical nutritional benefits through animal source foods that are protein dense and that contain a wide array of micronutrients. Agricultural production in general is highly vulnerable to climate change, and in the drylands, livestock systems mainly depend on scarce water and vegetation resources. In the future, more frequent and intense extreme events such as drought will exacerbate the challenges faced by livestock keepers in the region. Livestock production is not only affected by climate change but also contributes to it. In many countries in the region, the agricultural sector is the largest source of greenhouse gas (GHG) emissions, a large proportion of which comes from livestock production. Such emissions are released during the digestive process of ruminants, the storage and application of manure, and fodder production. Poor animal health and low-quality feeds leading to low productivity contribute to the GHG burden.

The Program for Climate-Smart Livestock Systems (PCSL), funded and coordinated by the German Corporation for International Cooperation GmbH (GIZ) and implemented by the International Livestock Research Institute (ILRI) in partnership with the World Bank, was set up to support the identification and uptake of interventions to increase the contribution of livestock production to the three key pillars of climate smart agriculture (CSA): increased productivity, mitigation of GHG emissions, and adaptation to climate change (Lipper et al., 2014). The program, running from 2018 to 2022, is being implemented across major livestock productions systems in three focus countries: Kenya, Ethiopia and Uganda. The objective of the program is that key livestock stakeholders will increasingly direct their practices, sector strategies and policies and investments towards more climate-smart livestock systems. PCSL is supporting governments, the private sector, and local stakeholders in realizing their development objectives. The program is supporting countries to improve their monitoring and reporting of their Nationally Determined Contributions (NDCs) in the livestock sector, helping them to achieve their adaptation and mitigation goals.

This document focuses on Uganda. Section 2 summarises information on the prevailing livestock systems in the country, along with their baseline performance. The livestock systems in the PCSL study region are briefly characterised. Section 3 contains a stocktake of what is known about the impacts of climate change on livestock production and livestock systems in the country. A summary of adaption and mitigation options in Ugandan livestock systems is presented in section 4. Section 5 summarises some recent work on foresight and the future of livestock systems and the livestock sector in Uganda. Section 6 considers the national livestock policy environment, and in section 7, the paper concludes with a consideration of system intervention points and major gaps in knowledge, to help guide future project activities. This stocktake draws on a large amount of existing information assembled from different sources.

2. Livestock systems and their characterisation

Uganda is a lower-income country with a current population of about 43 million and an expected GDP per capita of about USD 770 in 2019 (World Bank, 2019). The population is growing at about 3.3 percent per year, equivalent to a doubling of the population in 21 years. The GDP of Uganda grew 5.7 percent on average annually from 2008 to 2017, expanding by nearly 60 percent in real terms. Agriculture is a major sector in the country, contributing nearly 25 percent to GDP and 71 percent to employment. Industry and services contribute around 20 percent and 47 percent to GDP, respectively (FAO, 2019). Agriculture in Uganda comprises a great mix of farm sizes and different levels of efficiency, although small-scale producers dominate, growing cereals, coffee, plantains, cassava, sweet potatoes and beans. Many keep cattle, small ruminants, poultry and pigs. Beekeeping and aquaculture are gaining in importance (FAO, 2019). More than 40 percent of the agricultural land of the country is semi-arid, a major constraint to agricultural productivity.

Nearly 42 percent of the population live below the poverty line (World Bank, 2019). The country is overwhelmingly rural: 78 percent of the population live in the rural areas, although the rate of urbanisation is more than 5 percent per year: projections indicate that by 2040, more than 20 million people in Uganda will live in cities. More than 40 percent of the population are undernourished, and 25 percent are food insecure. Low rainfall and droughts affect Uganda regularly, particularly the Karamoja region in the northeast of the country (Figure 1). Currently, about 4 percent of the wetlands and forests are converted to agricultural use annually.

Approximately 6.3 million or 23 percent of Uganda’s rural population (2010 estimates) were classified as poor livestock keepers, when poverty lines are determined nationally (see Table 1a). Livestock sector activities account for nearly 25 percent of the total contributions from all agricultural activities to national income in Uganda. There are around 14 million cattle, 4.5 million sheep, 16 million goats, 4.1 million pigs and nearly 48 million poultry birds (Table 1b). The livestock sector accounts for around 4 percent income of the general economy, and contributes 1-1.5 percent to the country’s export trade value, mostly via dairy products and eggs.

Table 1a-d. Selected statistics for Uganda and livestock

Table 1a. Selected macro-indicators

Total human population (million)	Rural population (% total)	Poor livestock keepers (% rural population)	Annual GDP per capita (constant 2010 USD)	GDP growth (% annual, avg. 2008-2017)	Population growth (% annual, avg. 2008-2017)
42.8	78%	23%	770	5.7	3.37

Sources: Estimates are for 2017 and come from the World Bank Indicators (World Bank, 2019). Estimates of the % of rural people and of percent who keep livestock and live below nationally defined poverty lines are from Robinson et al. (2011).

Table 1b. Contribution of livestock to national income (GDP) and stocks of live animals

Contribution of livestock sector to agricultural GDP (%)	Agricultural GDP to national GDP (%)	Contribution of livestock sector to GDP (%)	Livestock population (millions)				
			Cattle	Sheep	Goats	Pigs	Poultry birds
24.6[3]	25.0[3]	4.2[3]	15.39 (14.37)[3]	2.06 (4.20)[3]	15.67 (16.03)[3]	2.64 (4.11)[3]	35.68 (47.58)[3]

Source: Data retrieved from FAOSATAT (2019). [3]Uganda Bureau of Statistics

Table 1c. Selected measures of livestock production, food availability and nutrition

Meat production ('000 MTs)	Dairy & egg production ('000 MTs)	Per capita supply of LDF (Kg / person / year)	LDF % of food supply (Kcal / person / day)	LDF % of protein supply (g / person / day)	Prevalence of underweight children <5 (%)
445.28	1,506.23	50.94	8.6%	23.4	13.1%

Sources: data on prevalence of underweight is a 3-year average (World Bank, 2019). The data on the other indicators are 3-year averages of published national statistics (FAOSTAT, 2019).

Table 1d. Number of 'poor livestock keepers' by system

Pastoral	Mixed crop-livestock	Other	All systems
85,000	6,073,000	196,000	6,354,000

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

Cattle are spread throughout the country in a variety of different livestock production systems (Figure 1), based on the classification system of Seré and Steinfeld (1996). Grassland-based systems are those in which more than 90 percent of dry matter fed to animals comes from rangelands, pastures, annual forages and purchased feeds and less than 10 percent of the total value of production comes from non-livestock farming activities. The mixed systems are those in which more than 10 percent of the dry matter fed to animals comes from crop by-products or stubble, or more than 10 percent of the total value of production comes from non-livestock farming activities (Seré and Steinfeld, 1996). The mixed systems are further split into those that are rainfed and those that are irrigated. These three major system types (mixed crop-livestock rainfed, mixed crop-livestock irrigated, and pastoral / agropastoral) are then broken down on the basis of temperature and length of growing period (Robinson et al., 2011).

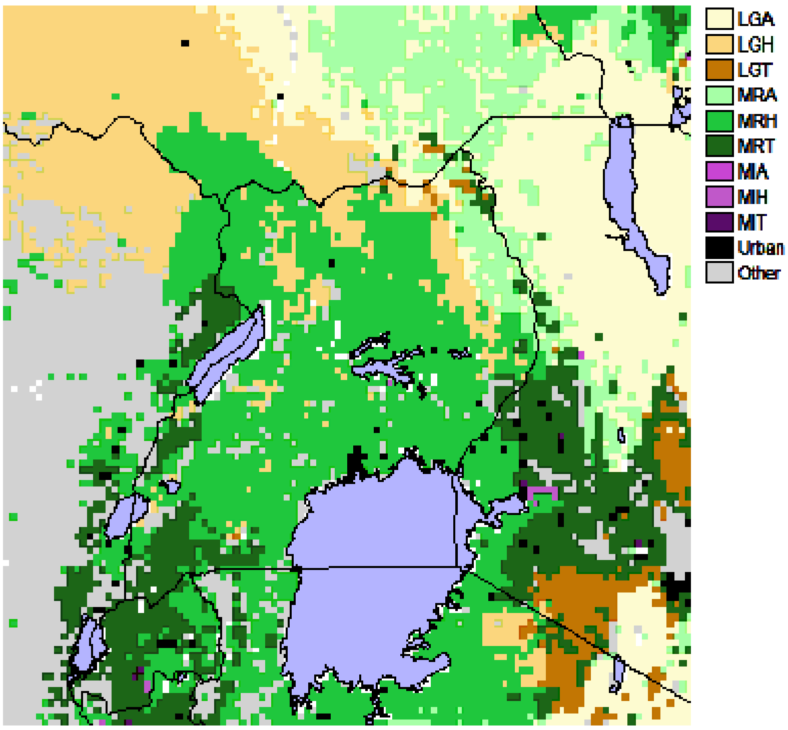


Figure 1. Livestock systems of Uganda, according to the classification of Sere and Steinfeld (1996) mapped in Robinson et al., (2011).

LG, pastoral / agro-pastoral systems (in which >90 percent of dry matter fed to animals comes from rangelands, pastures, annual forages and purchased feeds and <10 percent of the total value of production comes from non-livestock farming activities.

M, mixed crop-livestock systems (MR, rainfed; MI, irrigated) in which >10 percent of the dry matter fed to animals comes from crop by-products or stubble, or >10 percent of the total value of production comes from non-livestock farming activities.

A, arid / semi-arid; H, humid / subhumid; T, tropical highland.

UBOS (2014) estimated that there are more than 8.5 million people living in households keeping cattle and producing some beef. Using a somewhat different (but closely related) livestock classification system, ASL (2018) estimate that there are about 5.7 million people raising cattle in agro-pastoral (mixed) systems with 49 percent of the national herd, 2.5 million in pastoral systems with 41 percent of the national herd, and 0.4 million in semi-intensive (mixed) systems, with 2 percent of the national herd (Table 2; Figure 2). The ranching systems account for about 8 percent of the national cattle herd. Off-farm and non-farm income are important sources of income for all of the three major cattle systems, contributing 11-25 percent of household income (ASL, 2018), via employment generated along the beef value chain. Milk sales make up 20-48 percent of cattle income in the three systems.

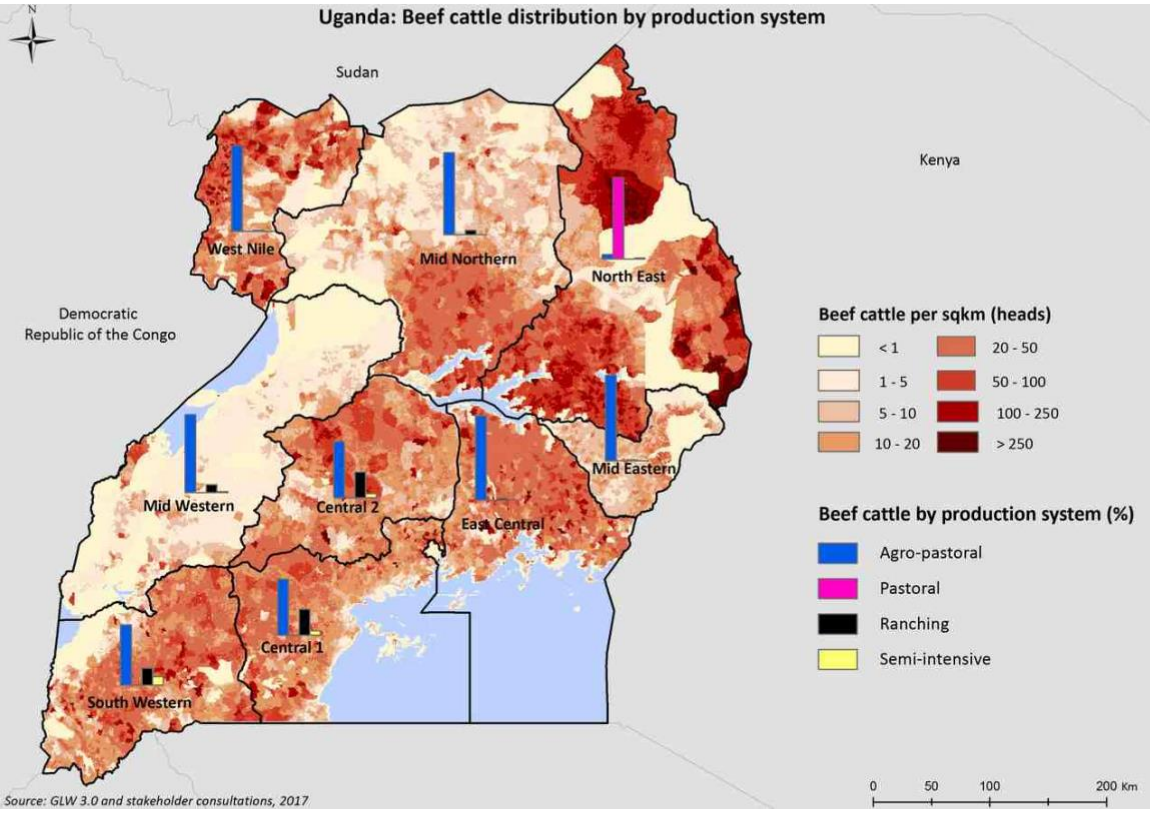
The study region identified for PCSL project activities is in the Southwestern region of the country. Some household characteristics of this broad area using existing survey data are shown in Box 1.

Table 2. Short description of cattle production systems in Uganda (ASL, 2018).

Production system	Short description	Number of people living in cattle-keeping households
Ranching	Farmers keep large number of animals (500-3000 per holding) in perimeter fencing, paddocked structures and grazing fields. They keep a mixture of indigenous, cross and exotic beef animals and make substantial investment in animal health management, to produce and market beef, with milk as a by-product. The system is prevalent in the Southwest and the Central 2 sub-regions.	No estimate
Pastoral	In pastoral or free grazing systems, farmers move cattle from place to place in search of pastures and water. They keep indigenous breeds, with herd size ranging from few to 100 heads. Main products include beef, milk, blood, hides, manure and horns. This system is dominant in the Northeastern sub-region.	2,447,490
Agro-pastoral (mixed)	Farmers graze mostly indigenous cattle in both private and public pastures and also feed them with crops by-products.	5,697,300

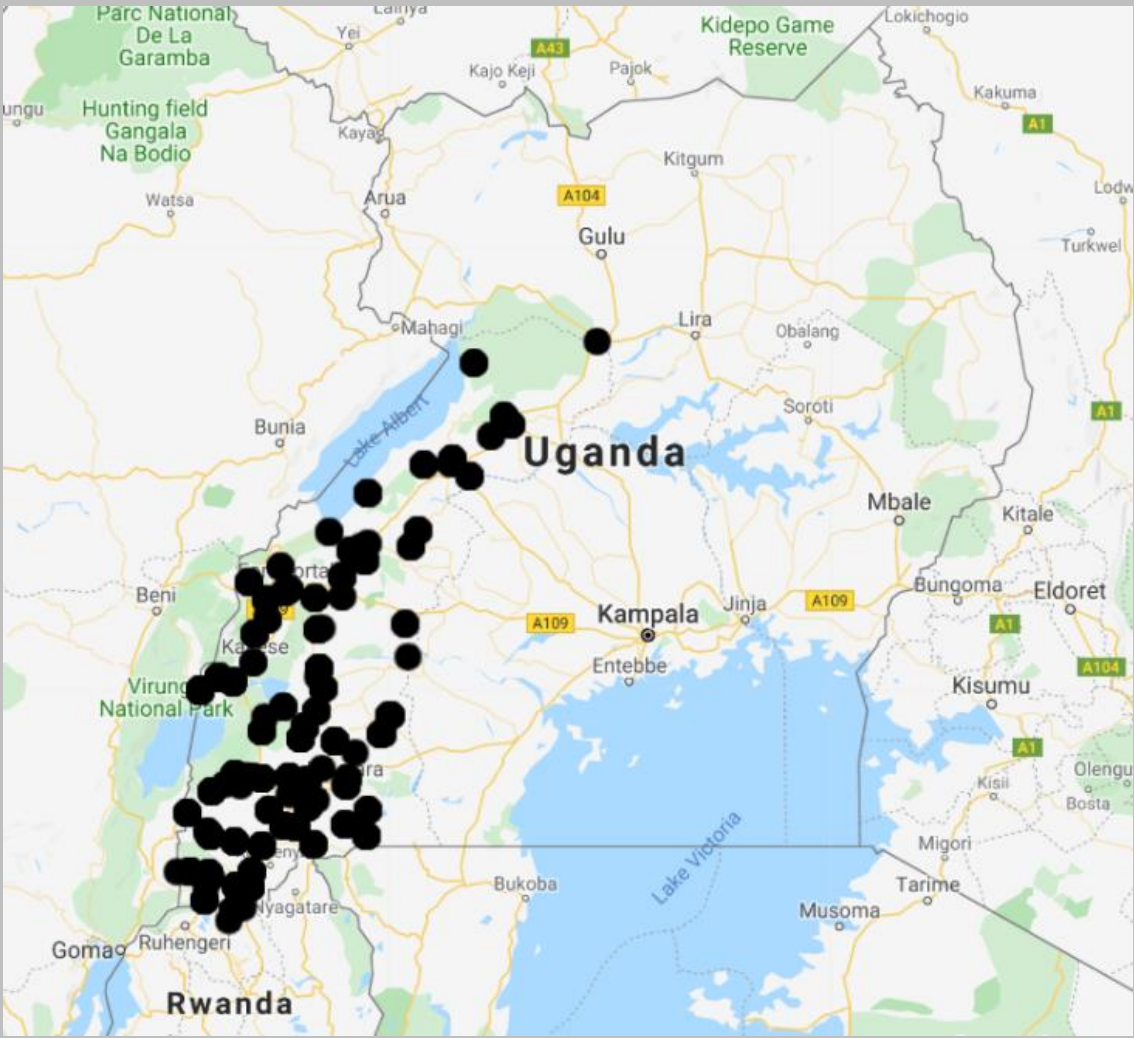
	Cattle produce beef and milk, hides, manure and horns and draught power. Investments in improved husbandry practices, including animal health, are none to minimal. This system is present in the Eastern, Central 2, Western, North and West Nile Sub-regions.	
Semi-intensive (mixed)	Farmers keep cattle, mainly cross-bred, confined in kraals, paddocks and cattle barns/stalls and feed them with compound feed. They also make significant investments in animal health, such as in vaccination and deworming. Cattle produce milk and beef. This system is mainly found in Central 1 and 2 and the Southwest subregions.	370,060

Figure 2. Beef cattle distribution in Uganda by production system (ASL, 2018).



Box 1. Data summary sheet for Western Uganda

A. Location of 553 households surveyed (LSMS ISA survey, 2011–2012)



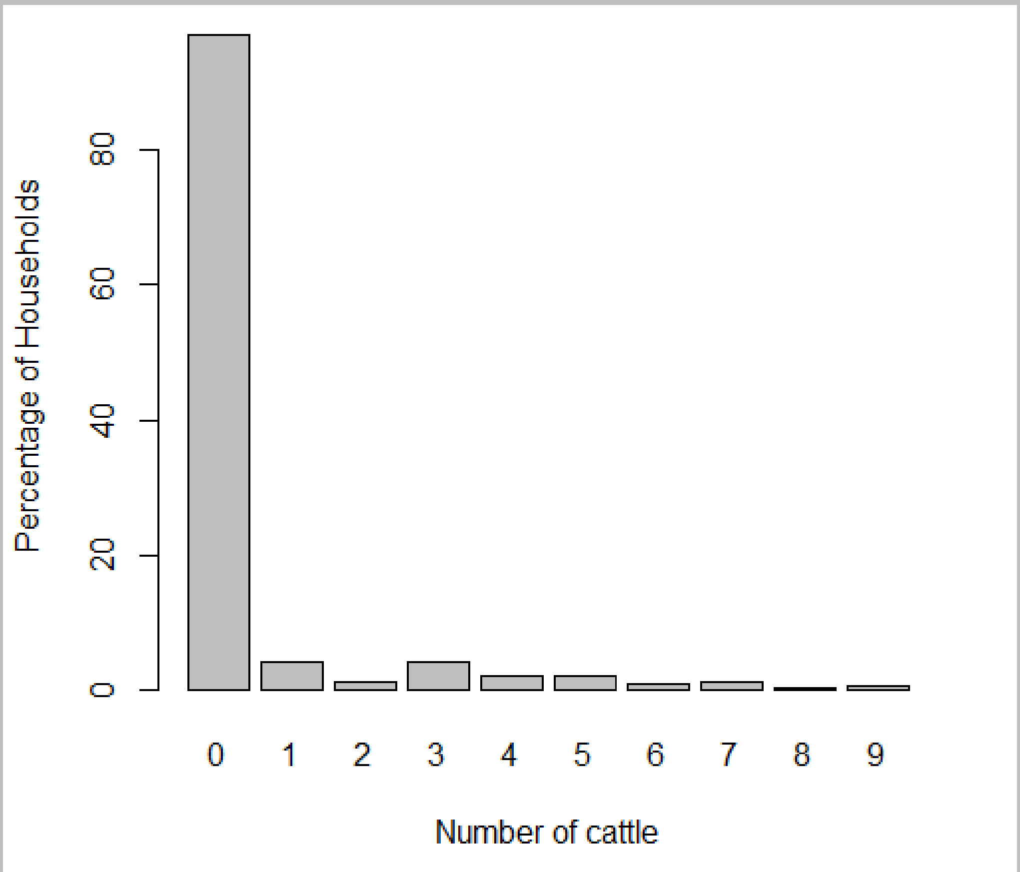
B. Key information

Variable	Value
Average farm size [ha] (stdev)	1.0 (1.0)
Average livestock holding [tlu]	1.8 (4.5)
Average number of cattle	1.1 (2.5)
Average number of chicken	2.7 (4.6)
Average number of goats	2.6 (4.2)

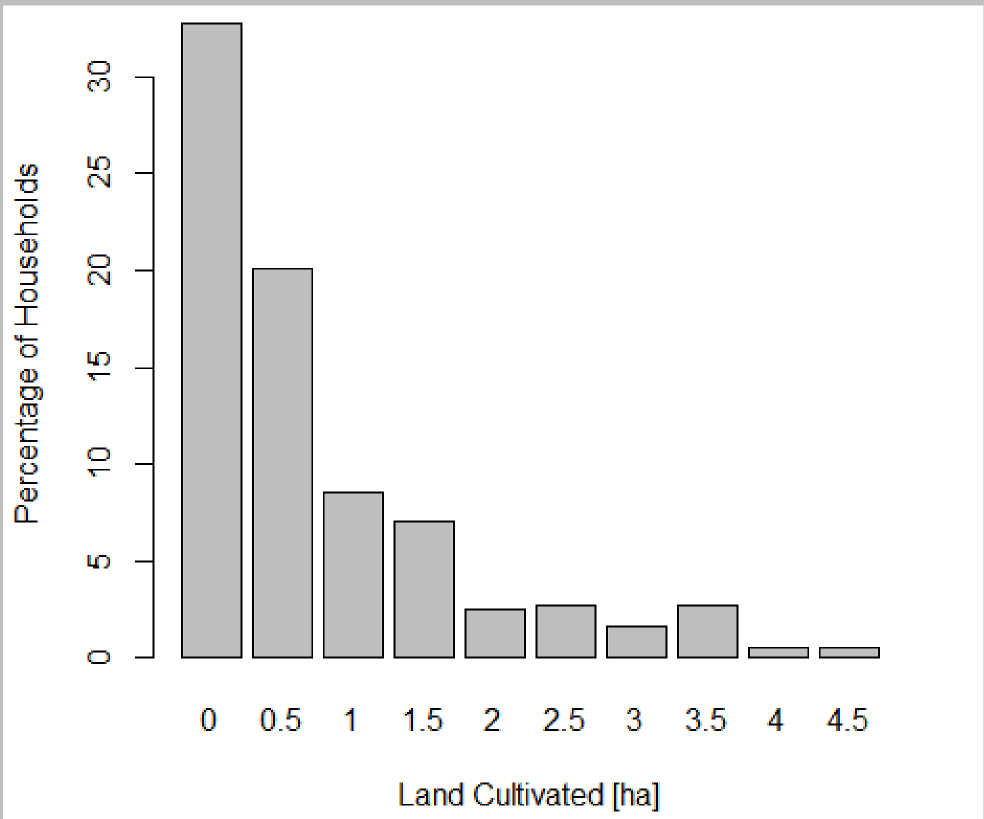
Average number of sheep	0.2 (1.0)
Total farm income generated [USD PPP corrected per household per yr]	298
Total livestock income generated [USD PPP corrected per household per yr]	73.4
Total value of livestock produce consumed [USD PPP corrected per hh per yr]	24.7
Average milk production per cow (l/producing animal/day)	1.2 (0.9)
Milk production per cow of 10 percent best producing farms (l/producing animal/day)	2.8 (0.3)
Average egg production per chicken [d^{-1}]	0.1 (0.14)
Egg production per chicken of 10 percent best producing farms	0.4 (0.3)

Source of info: World Bank Living Standard Measurement Survey – Integrated Survey on Agriculture in Uganda in 2011/12; 553 households were surveyed in Western Uganda.

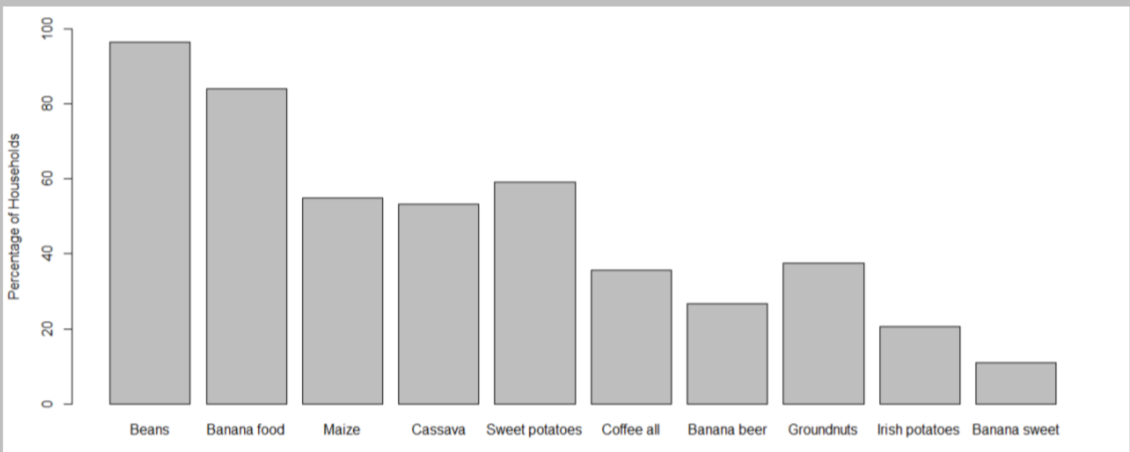
C. Distribution of cattle holdings per household



D. Distribution of cultivated land size per household



E. Major crops grown by households



3. Impacts of climate change on livestock systems and livestock production

Temperatures in Uganda are relatively moderate throughout the year, with a mean of about 21 °C, with the average monthly temperatures ranging from a minimum of 15 °C in July to a maximum of 30 °C in February. Higher temperatures occur in the North and North-East, with lower temperatures across the South. There has been significant warming: an average temperature increase of 0.28 °C per decade between 1960 and 2010, January and February being most affected by this warming trend, averaging an increase of 0.37 °C per decade (CIAT, 2017). The frequency of hot days in the country has increased significantly, while the frequency of cold days has decreased.

Annual rainfall varies between 500 mm to 2800 mm, the wettest districts being located within the Lake Victoria Basin, eastern and the north-western parts of the country. Rainfall is bimodal in the south to central parts of Uganda, with two rainy seasons from March to June and from October to January. The northeast region has one rainy season. Floods and droughts are the most frequent climate hazards. The drylands are prone to drought, and the northern region in particular is especially vulnerable to both floods and droughts. While trends are uncertain and data remain limited, the main climate change impacts expected to affect agriculture in Uganda in the future include higher temperatures, more erratic and heavy rainfall, changes in the timing and distribution of rainfall, and an increase in the frequency and duration of droughts.

Climate projections for the country based on the CMIP5 models of the Intergovernmental Panel on Climate Change (IPCC) project an increase in temperatures of 2 °C to the middle of the century and 2.5 °C to 2100, under Representative Concentration Pathway (RCP) 4.5. For RCP 8.5 the projected temperature increases are 2.5 °C and 4.5 °C for the same time horizons, respectively. Rainfall projections are highly uncertain, but some increases in total annual rainfall are indicated over much of the country under both RCP 4.5 and RCP 8.5. Crop suitability areas are projected to change as a result of shifts in rainfall amounts and patterns and increases in temperatures. Beans are projected to be particularly badly affected, with up to 25 percent reduction in suitable area to the middle of the century. Small reductions are projected for sorghum and maize suitability, with small increases for cassava, millet, banana and groundnut (CIAT, 2017). Overall, however, Uganda is highly vulnerable to climate change and weather variability. Parts of the country already experiences unreliable rainfall, frequent drought and periodic floods.

For the livestock systems, projections indicate some increases in net primary productivity in the highlands, and some reductions in the drier areas, though less extensive reductions than in the Sahel and parts of southern Africa, for example (Boone et al., 2018). Other projections indicate widespread negative impacts on forage quality and thus on livestock productivity, with cascading impacts on incomes and food security (Thornton et al., 2015; Thornton et al., 2018). In addition to climate change effects on the quantity and quality of feeds, other effects are anticipated on water availability in livestock systems, and on the distribution and severity of livestock diseases and their vectors (see, for example, reviews in Rojas-Downing et al., 2017; Mbow and Rosenzweig, 2019).

Other, more indirect effects of climate change on agriculture and food systems are gaining in importance. Recently, Smith and Myers (2018) projected that the effects of elevated CO_2 concentrations by the 2050s on the sufficiency of dietary intake of iron, zinc and protein an additional 175 million people will be zinc deficient and an additional 122 million people will be protein deficient. The mechanism is via more carbohydrates being produced in C3 crops at the expense of other nutrients such as protein, iron and zinc. Similar effects on forage quality have been found in forages (Augustine et al., 2018). About 57 percent of grasses globally are C3 plants (Osborne et al., 2014) and thus susceptible to CO_2 effects on their nutritional quality. These impacts will result in greater nutritional stress in grazing animals as well as reduced meat and milk production. Another impact of climate change is that of higher temperatures on the capacity of people to work in the fields (Watts et al., 2017) and on the ability of livestock to cope with heat stress. Both may have major implications for livelihoods based on livestock keeping; for Uganda, preliminary analyses indicate that heat stress in cattle may become a widespread and serious problem, particularly for dairy systems, as the century progresses (Thornton et al., 2020).

While there is growing evidence that the risk of extreme events will increase in the future, the ways in which these risks will manifest themselves and affect agricultural systems are not always that clear (Thornton et al., 2014). Increasing climate variability and extremes have been identified as one of the key drivers behind the recent rise in global hunger and a leading cause of severe food crises (FAO, 2018), affecting both crop and livestock systems. Forage production and animal stocking rates can be significantly affected by drought intensities and durations as well as by long-term climate trends. After a drought event, herd size recovery times in semi-arid rangelands may span years to decades in the absence of proactive restocking through animal purchases, for example (Godde et al., 2019). Indeed, increasing climate variability may threaten the long-term viability of agriculture-based livelihoods in many places.

A summary of some of the climate hazards in Uganda is shown in Figure 3 (from Thornton et al., 2019). The areas of vulnerability were projected for the 2050s based on RCP 8.5, a high GHG emission scenario, using the methods in Jones and Thornton (2013; 2015), overlaid on cropland and pastureland from the data set of Ramankutty et al. (2008). In these areas of cropland, pastureland or mixed land-use, hazards were mapped with respect to three main hazards:

- Areas where the coefficient of variation of annual rainfall (the standard deviation divided by the mean, expressed as a percentage) is currently greater than the median value for the global tropics (24 percent). In lower latitudes, climate change is projected to increase this variability, making both cropping and rangeland production more risky. Because there is little information on the nature of this variability change, current variability is used as a proxy for future variability.

- A reduction in the number of reliable crop growing days per year below 90, a critical threshold for rainfed cropping (Nachtergaele et al.,2002), mostly due to changes in rainfall distributions and amounts.
- Increases in average maximum temperature during the primary growing season above 30 ºC), a critical threshold for several major crops (Boote et al., 1998; Prasad et al., 2008).

Areas where more than one of these hazards is projected to be present are also shown in Figure 3.

Two other important climate hazards are the frequency and severity of drought and of flood. Figure 4 shows relative drought risk and flood hazard distribution maps for the East African region, from Dilley et al. (2005), CHRR/CIESIN (2005), and CHRR/CIESIN/IRI (2005).

Table 3 lists the PCSL intervention sites in Uganda with respect to agro-ecological zone, livestock system, and the climate hazards shown in Figure 3 and Figure 4. The location of the districts containing these intervention sites are shown in Figure 5.

Table 3. PCSL intervention districts in Uganda.

Site	Region	District	Predominant Agro-Ecological Zone	Livestock system	Climate hazard(s)
1	Western	Bushenyi	Lower Highland, Sub-humid	Mixed rainfed crop-livestock / agro-pastoral	Low flood risk High flood risk
2	Western	Kiruhura	Upper Midland, Semi-humid to semi-arid	Mixed rainfed crop-livestock / agro-pastoral	Low flood risk Medium-high flood risk
3	Western	Isingiro	Upper Midland, Semi-humid to semi-arid	Mixed rainfed crop-livestock / agro-pastoral	Growing season reduction Low flood risk Medium-high flood risk

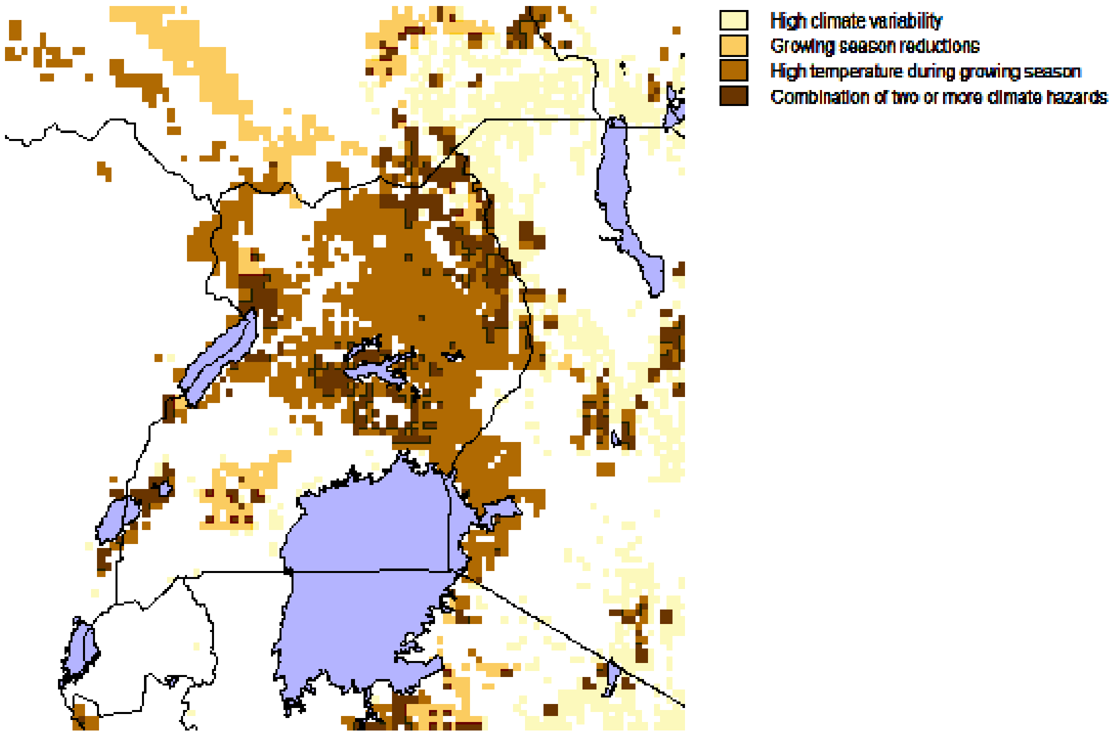


Figure 3. Areas of high agricultural risk for selected climate hazards in vulnerable areas of Uganda (from Thornton et al., 2019).

Areas of vulnerability are projected for the 2050s based on RCP 8.5 overlaid on cropland and pastureland (Ramankutty et al. 2008) with respect to: (1) areas where the coefficient of variation of annual rainfall is currently greater than the median value for the global tropics; (2) reduction in the number of reliable crop growing days per year below 90 mostly due to changes in rainfall distributions and amounts; (3) increases in average maximum temperature during the primary growing season above 30°C. Methods as in Jones and Thornton (2013; 2015) using an ensemble mean of 17 climate models from the Coupled-Model Inter-comparison Project 5 (CMIP5) of the IPCC.

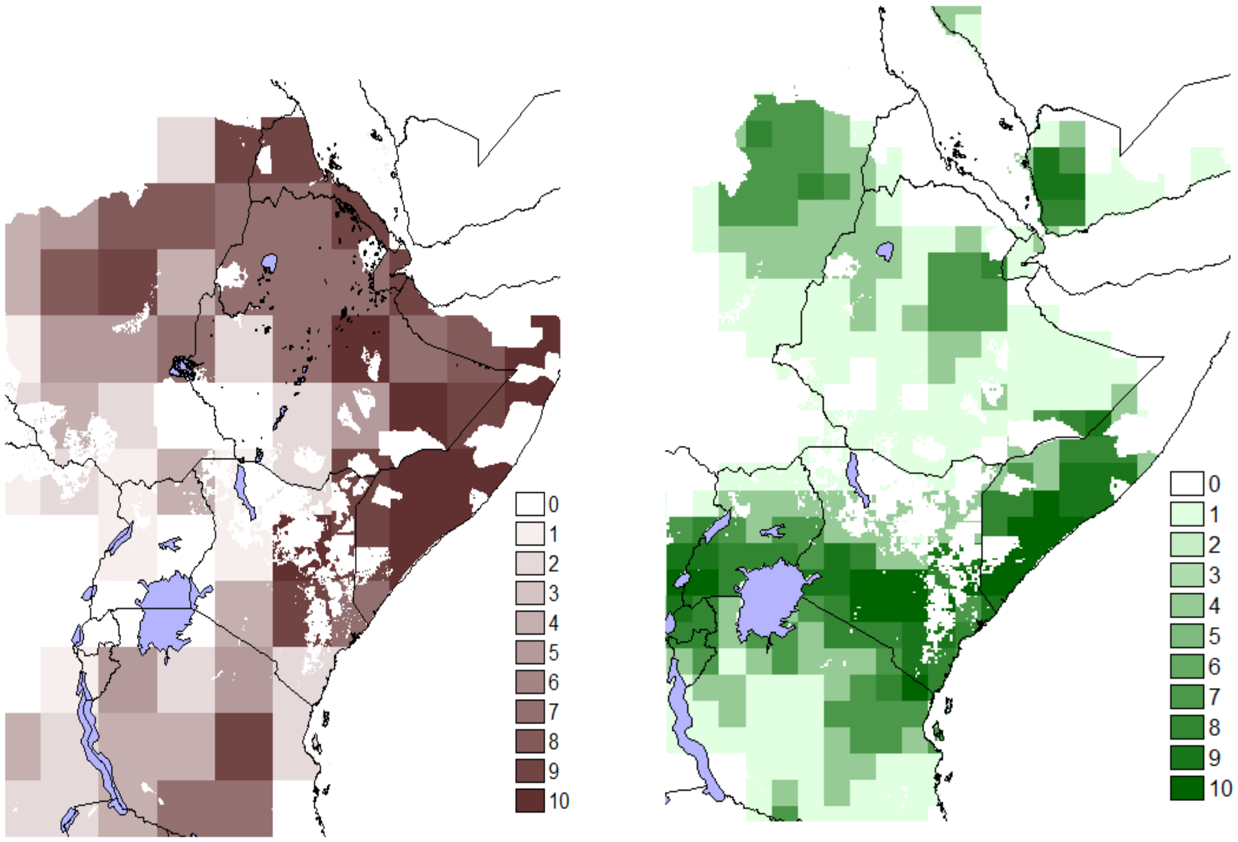


Figure 4. **Left**: drought risk, 1989-2000, deciles (1 low, 10 high). Source: Dilley et al. (2005), CHRR/CIESIN/IRI (2005)

Right: flood hazard frequency and distribution, 1985-2003, deciles (1 low, 10 high). Source: Dilley et al. (2005), CHRR / CIESIN (2005).

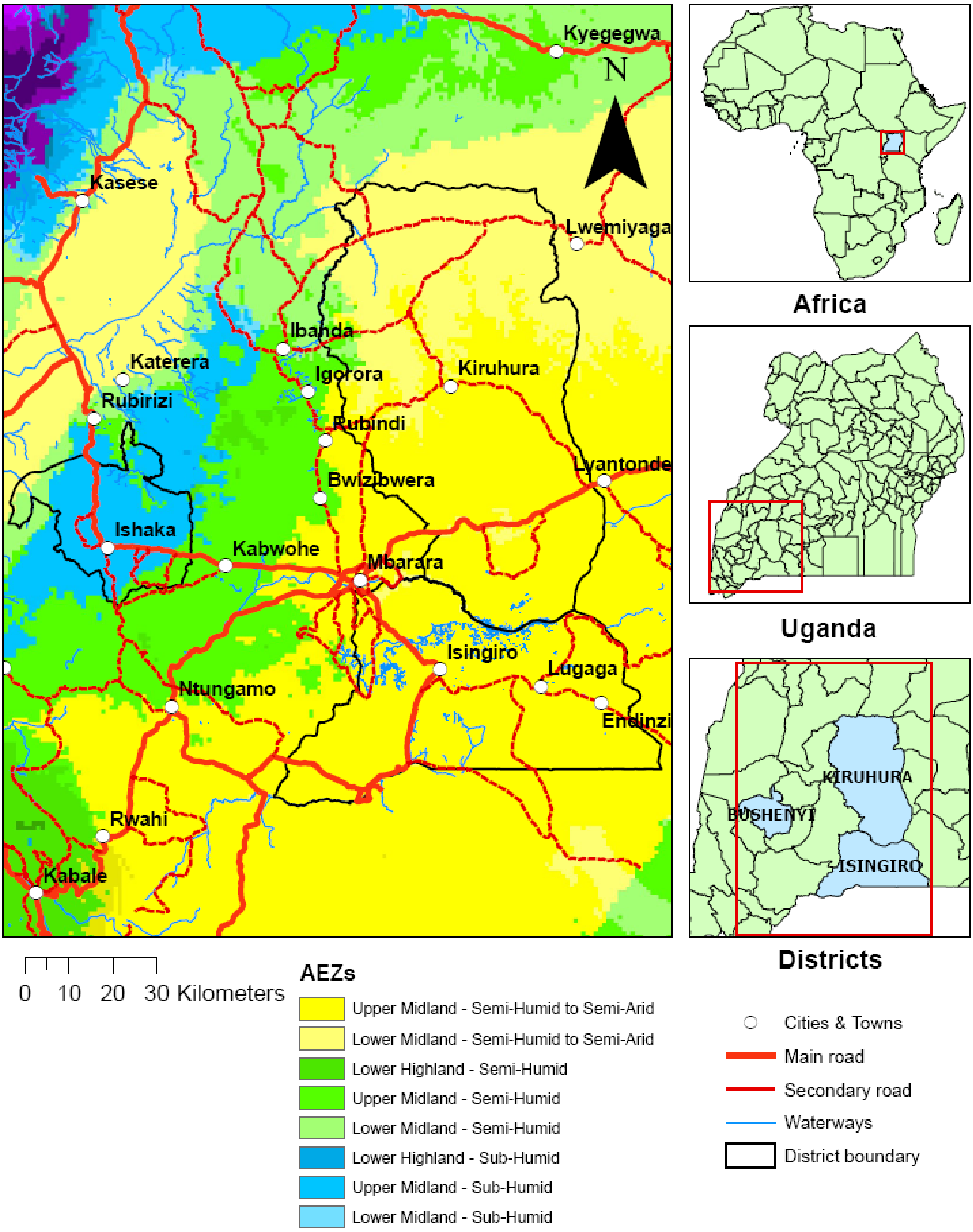


Figure 5. PCSL intervention districts in Uganda

Lower Highland: mean temp 15-18 °C, 1829-2438 m altitude. Upper Midland: mean temp 18-21 °C, 1219-1829 m altitude. Lower Midland: mean temp 21-24 °C, 914-1219 m altitude.

Sub-humid: 9-12 wet months per year, 1200-1500 mm annual rainfall. Semi-humid: 6-9 wet months per year, 950-1200 mm annual rainfall. Semi-humid to semi-arid: 4-6 wet months per year, 500-1000 mm annual rainfall.

Agro-ecological zones modified from Karanja (2006).

4. Adaptation and mitigation options

From a technical viewpoint, there is a wide range of interventions in livestock systems that can help livestock keepers adapt and become more resilient to climate change; many of these have mitigation co-benefits too. Table 4 from Bell et al. (2018) lists some of these practices, scored for their potential to address climate risks including those shown in Figure 3.

Table 4. Interventions in livestock systems and their potential to address different climate hazards. From Bell et al. (2018).

Livestock	Addressing Climate Risks				
Practices	Increased growing season temperature	Intra-seasonal droughts	Shortening of growing seasons	Unpredictable seasons	Increased rainfall intensity
	Diet Management				
Non-conventional feeds	+	+	+	+	+/-
Improved feed quality	+/-	+	+/-	+/-	+/-
Improved digestibility	+/-	+	+/-	+/-	+/-
Improved protein content	+/-	+	+/-	+/-	+/-
Improved supplements	+	+	+/-	+	+/-
	Improved Pastures				
Planting N-fixing legumes	+/-	+/-	+/-	+	+
Fodder shrubs	+/-	+	+/-	+	+
	Rangeland Management				
Rotational grazing	+/-	+	+/-	+	+
Cut-and-carry	+/-	+	+	+	+/-
	Manure Management				
Manure collection	+/-	+/-	+/-	+/-	+/-
Improved manure storage	+	+/-	+/-	+/-	+/-
Manure treatment	+	+/-	+/-	+/-	+/-
Vaccines	+	+	+/-	+/-	+/-
Changing breeds	+	+	+/-	+	+/-
Artificial insemination	+	+/-	+/-	+/-	+/-
Wells (boreholes)	+	++	+/-	+	+/-

Direction (+, -) relates to whether a practice has a positive (ameliorating) or negative (exacerbating) impact on the climate risk. Magnitude is shown by the intensity of the color in the gradient and the number of symbols, where more symbols is a larger impact. Boxes with a +/- sign indicate practices that either (1) do not address the climate risk, (2) there is not enough known to make a recommendation, or (3) the effect may be highly context specific.

Figure 6 shows two CSA practices with reasonable climate smartness scores according to expert evaluations, from a more extensive list developed for Uganda: rotational grazing, and use of silvopastoral systems, both in the southwest cattle corridor and in central Uganda. The average climate smartness score is calculated based on the individual scores of each practice on eight climate smartness dimensions that relate to the CSA pillars: yield (productivity); income, water, soil, risks, information (adaptation); energy, carbon and nutrients (mitigation). A practice may have a positive or zero impact on a selected CSA indicator, with 5 indicating a very large effect and 0 indicating no change, not applicable or no data. The two interventions below, along with others, if implemented at scale, could have positive impacts on the three CSA pillars of productivity, adaptation and mitigation. Given the major transformation that Uganda is expected to undergo in the coming decades (see below), such interventions will be crucial in identifying appropriate development trajectories for the Uganda livestock sector in the future.

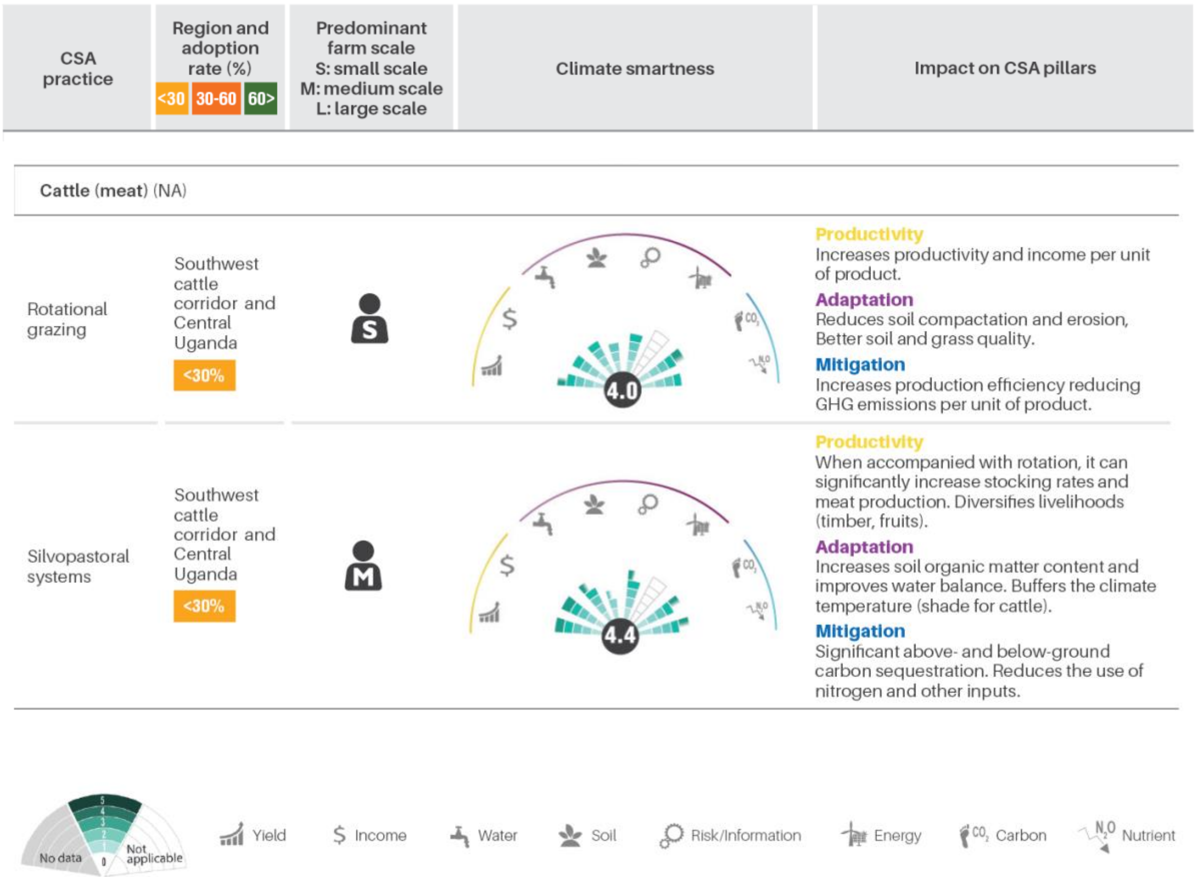


Figure 6. “Smartness” assessment for two ongoing CSA practices in cattle meat production systems as implemented in Uganda. From CIAT (2017).

There is considerable scope in East African livestock systems for substantial improvements in both productivity and GHG emission intensities. For example, using household data from several sites, Herrero et al. (2016) identified yield gaps in dairy production in Ethiopia (the difference between what is typically achieved and what is possible) of between 65 percent and 350 percent, depending on the type of intervention package considered. Large production increases are achievable with interventions such as better feeding and wider use of crossbred animals (Herrero et al., 2016). In many places, overcoming biomass constraints will be key to achieving such productivity increases. Cross-breeding dairy animals can substantially raise milk productivity, with the prospect of achieving production targets with fewer animals; but this will only work if higher quality feed is available (Herrero et al., 2016; Mayberry et al., 2017).

In Ugandan dairy systems, forage grasses may be important feed sources during both wet and dry seasons. Climate change will have impacts on the suitability of different forage grasses in the future. Kekae et al. (2019) shows that in some parts of the region, Buffel grass is likely to be negatively affected by climate change in some regions of the country, while Rhodes grass and Napier grass are likely to have improved suitability under future climates. Improved tropical grasses for the mid-altitude areas of Uganda include Chloris, Brachiaria, Cenchrus and Panicum, for example. Such forage grasses in the future could contribute substantially to national feed demands, although adoption of improved forages is currently low. The impacts of climate change on forage species' nutritional density (and hence changes in their value as livestock feed) are still not known with any certainty and warrant further research.

Many adaptation options are available, and often there are mitigation co-benefits associated (Thornton and Herrero, 2014; Bell et al., 2018; ERA, 2019). Uganda's GHG emissions are approximately 36.5 million tonnes of carbon dioxide per year, about 0.01 percent of global emissions (ASL/FAO, 2018). The cattle sector accounts for about 38 percent of Uganda's emissions, mostly from enteric fermentation and manure management. Poultry emissions amount to about a third of a million t CO_2 per year, mostly from feed production (ASL/FAO, 2018). As seen in Figure 5, improved pasture management using rotational grazing or other methods of reducing open grazing can have mitigation benefits through decreasing the emission intensity of milk and meat. Combining livestock with agroforestry can increase livestock productivity and carbon sequestration in the system. Feed improvement, forage development, and livestock breed improvement can all have substantial effects on emissions intensity reduction as well as increasing the productivity and resilience of livestock systems (Njeru et al., 2016).

Targeting such interventions at broad scale remains challenging because of the variation in local agro-ecological and socio-economic contexts. In addition, there are several barriers to widespread uptake of livestock interventions in Uganda. For the diary systems of Southwestern region, for example, farmers reported a range of issues, including limited capital, animal diseases, difficulties posed by an unpredictable climate, poor quality veterinary drugs, and lack of capacity development (de Vries, 2019). There may also be limits to the agricultural adaptation that is achievable at the household level: Call et al. (2019) suggest that in the future, smallholders in parts of Uganda will struggle to maintain their livelihood portfolio and agricultural productivity during extended periods of heat stress, and new livelihood strategies may be necessary.

As the agricultural sector in Uganda transforms in the future, FAO (2019) highlight one issue concerning the increased prevalence of urban, peri-urban middle-scale commercial livestock operations and value chains. These entities will frequently be operating near densely populated urban areas, and these hotspots of human-animal interaction will need to be properly regulated, as any disease outbreak would escalate rapidly in such densely populated areas (FAO, 2019). The national-to-local policy environment is a key enabler of uptake; this is considered in section 6 below.

5. Livestock systems in the future

Several studies have investigated the possible futures associated with livestock systems in countries of sub-Saharan Africa (e.g., Herrero et al., 2014; FAO, 2019). Enahoro et al. (2019) extracted a set of global projections for Uganda, and this section draws on and summarises that work.

Projections of demand and supply of livestock-derived food in 2030 and 2050 were developed by Enahoro et al. (2019) for several countries including Uganda using the IMPACT model, an integrated modelling 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 (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. For the results briefly discussed below, several scenarios were simulated, based on 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 determinizing energy, land use and related trajectories globally; while the RCPs are trajectories of greenhouse gas concentrations. Simulations were carried out for 16 scenarios (Table 5); the scenario with moderate economic growth and no climate change assumed (alphabet codes A and C in Table 6) was selected as the baseline. All other scenarios were compared with the year 2010 and 2030/50 results for this baseline. IMPACT generates country-level outcomes of food production, demand, and prices. These are reported below, along with livestock feed demand linked to production. Food supply was used as a proxy for average consumption and intake (thus in effect using the three terms interchangeably). However, only food availability can be inferred from the aggregate data that are readily available (FAO national statistics and IMPACT measures).

Table 5. Descriptions of IMPACT model scenarios included in the analysis (Enahoro et al., 2019).

Alphabet code	Scenario Code	Pace of economic growth	Year(s)	RCP simulation	Earth System Model (ESM)[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 Marin-Earth Science and Technology (www.geosci-model-devdiscuss.net/4/1063/2011/gmdd-4-1063-2011.pdf). From Robinson et al. (2015).

In 2010, the supply of livestock derived foods in Uganda was around 141 kcal per person per day (Table 6). This supply was 54 percent meat, 44 percent milk and 2 percent eggs. Of the meat supply, pork made up 54 percent, beef 30 percent, and lamb and poultry each around 8 percent. Under the scenario of moderate economic growth and constant climate change (the baseline), LDF supply increased to 181 kcal in 2030 (28 percent from 2010) and 246 kcal in 2050 (104 percent from 2010), thus more than doubling by 2050. The share of all meats in LDF demand increases in 2050 to 64 percent (while dairy declines to 34 percent from 44 percent). Within the meat demand, however, share of pork goes down while the shares of other meat types, i.e., poultry, beef and lamb go up. The supply of poultry increases the most (by 3 percent) in relative terms.

The IMPACT model projects aggregate pork demand of 124,400 MT in Uganda in 2010. This is projected to increase to 630,000 MT in 2050 under the baseline scenario, i.e., a 406 percent increase from 2010. Pork production, which is 113,400 MT in 2010, is projected to increase by 166 percent to 2050. Figure 7 presents pork demand and production for the economic growth and climate change scenarios simulated using IMPACT. National production of pork is 91 percent of the total demand by households in 2010, but down to 48 percent on average in 2050. The gaps between aggregate demand and production are not very variable for the different scenarios of 2050. What is consistent is that large increases are anticipated in pork importation given the projected trends in household consumption and national production.

Table 6. Projections of the supply of different livestock-derived food (LDF) types in Uganda in 2010, 2030 and 2050*

	2010	**2030**	**2050**
	(kilocalories per person per day)		
Beef	23.0	32.9	49.8
Pork	41.5	54.4	75.3
Lamb	6.4	9.3	15.0
Poultry	5.9	9.7	17.0
Dairy	62.4	71.8	84.7
Eggs	2.1	2.8	3.9
All meats	76.9	106.2	157.0
All LDF	141.4	180.8	245.7

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

The model projections of dairy demand and production are presented in Figure 8. Demand for dairy is 1.203 million MT in 2010 and 4.6 million MT in 2050 when the baseline scenario is considered. Uganda is a net importer of dairy products, by a small margin (9 percent of demand) in 2010. In 2050, dairy imports are at least 48 percent of the total household demand for dairy, under all scenarios tested. Household demand as a percentage of national production, is highest for the low growth scenarios (i.e., E, F, G, H) and lowest for the high or fast economic growth scenarios (i.e., M, N, O, P).

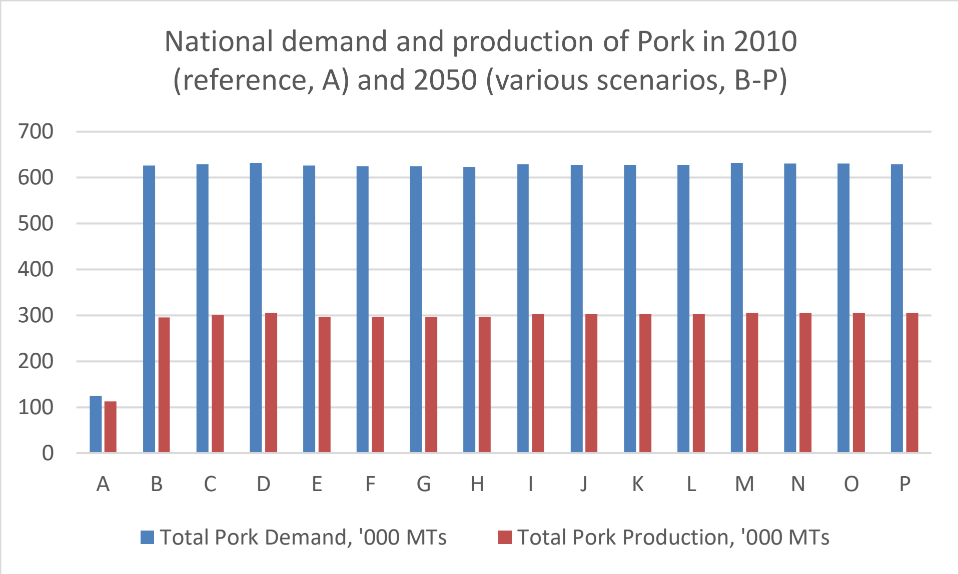


Figure 7. Model projections of pork demand and production in Uganda

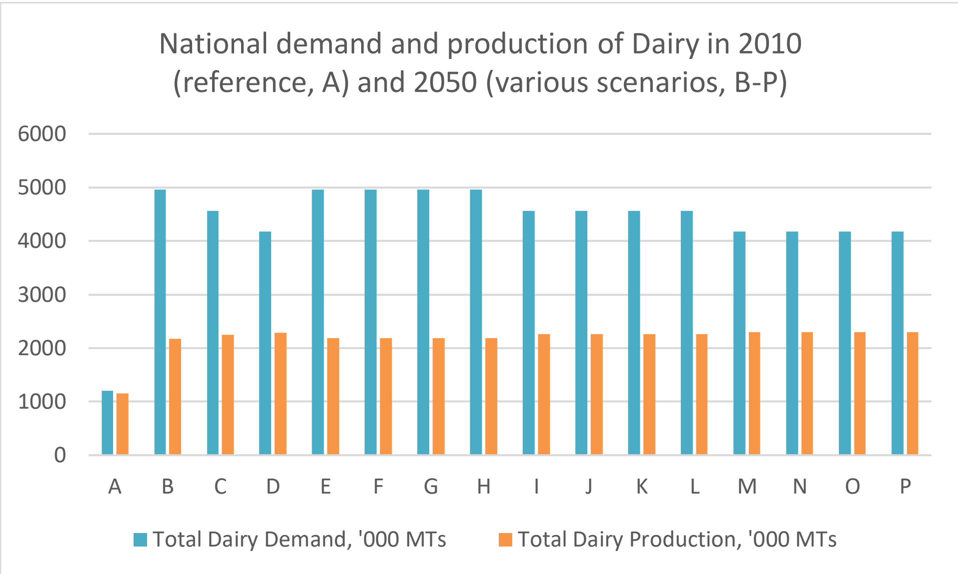


Figure 8. Model projections of dairy demand and production in Uganda

While household demand quantity of beef, lamb and poultry are much lower than that of pork in 2050, demand for these meat types also show significant changes from 2010. Aggregate demand is higher in 2050 by around 500 percent for beef, 550 percent for lamb and nearly 700 percent for poultry. As with dairy and pork, national production of these meat types in Uganda does not keep in step with the demand, and large import quantities are projected for all scenarios of 2050 considered. For the moderate economic growth or baseline scenario, beef net imports increase from 12,500 MT in 2010 to 489,000 MT in 2050; Lamb imports from 2,900 MT to 181,000 MT; and poultry meat imports from 5,600 MT to 244,000 MT. Imports as percentage of demand increases for all three meat types, from eight or nine percent in 2010, to more than 55 percent by the end year of the model simulations. Figure 9 presents the model simulations on net imports of beef, lamb and poultry relative to their aggregate demands.

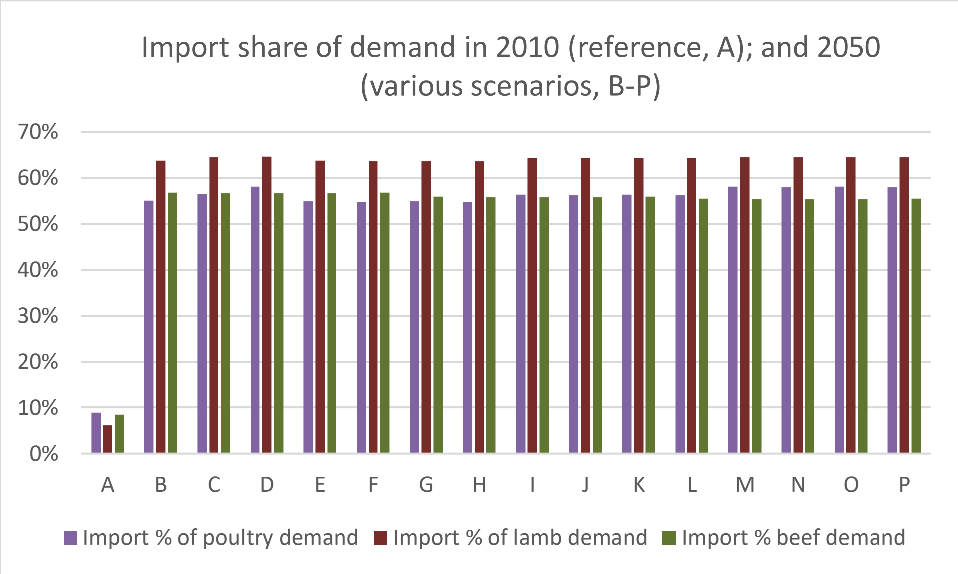


Figure 9. Model projections of poultry and lamb imports in Uganda

There is not much variation in the import shares of demand for beef, poultry and lamb under the different scenarios of 2050. The projected changes in all LDF demand in Uganda however lead to important changes in the demand for livestock feed biomass (Figure10).

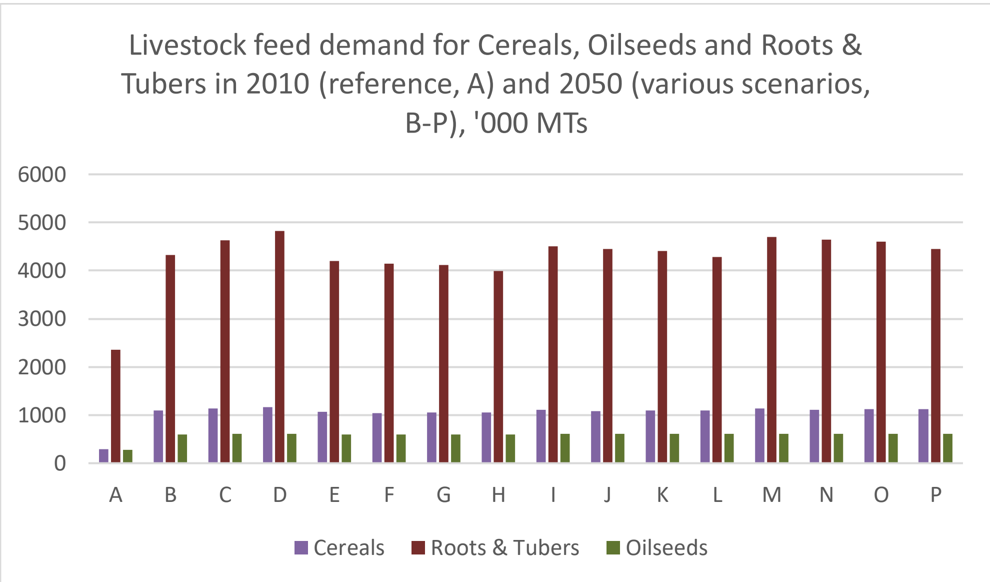


Figure 10. Model projections of livestock feed demand in Uganda

Although use of other feed biomass such as field residues and kitchen wastes that are common in e.g., pig production, have not been included, the projections of changes in livestock feed demand are substantial for Uganda. Aggregate feed demand grows 120 percent on average from 2010 to 2050. In addition to the cereals and oilseeds commonly used in other countries in the sub-region, root and tuber crops are key sources of livestock feed biomass in Uganda. Under the baseline scenario, root and tuber crops constitute 81 percent of the combined demand for cereals, roots and tubers, and oilseeds as feeds in 2010; and 73 percent in 2050. Cereal use is 10 percent in 2010 and 18 percent in 2050 while oilseeds make up 10 percent of feeds in both years. The make-up of feed use does not vary by much for the different assumptions of economic growth. Climate change simulations however result in observed changes wherein feed use may shift slightly (< 1 percent) away from cereals and/or oilseeds, to roots and tubers (this is not apparent in the figure).

The IMPACT model results demonstrate relatively muted effects of climate change on the livestock sector at the national level for Uganda, given the assumptions made and the limitations of the modelling approach. This can be seen in Figures 7-10, for example, by comparing simulated results of the slow economic growth scenario baseline (B, with no climate change included) with the four "with climate change" scenarios (E, F, G, H, utilising different climate models; Table 5); of baseline D with scenarios M, N, O and P for the rapid economic growth simulations. There are several reasons for this. First, the climate change effects that are included in this modelling work to the 2030s, and even to the 2050s (changes in temperature and rainfall patterns and amounts), are themselves relatively modest under the GHG emission scenario used; it is only in the second half of the current century that temperature effects (in particular) become much more pronounced, with concomitant effects on livestock production and productivity. Second, the relatively aggregated nature of the results from the IMPACT model also hide what may be relatively high levels of spatial variability, i.e. between the higher-productivity livestock systems in the highlands compared with the arid-semiarid lowlands. Third, the shorter-term impacts of climate change on livestock systems, i.e. increased frequency and severity of extreme events such as drought and heat waves, are not captured in this modelling work. These reasons combine to indicate that the effects of climate change on livestock systems in Uganda to the middle of the century are being under-estimated.

Nevertheless, results do give some initial indications about areas in which policies that emanate from or affect the livestock sector in Uganda may need to evolve. 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 be central in livestock sector planning. These issues are briefly returned to in section 7 below.

In Uganda, it appears the demand for livestock-derived foods will be more diversified in 2050 compared with 2010. Dairy and pork demand decrease relative to non-pork meat types. Possibly these trends may be explained by demographic factors such as income growth and urbanization, but they need to be explored better through research. An understanding of what drives LDF diversification in a country will be important for assessing what changes can be anticipated in food and nutrition security, economic welfare, and environmental impacts as livestock sector-related determinants change.

Assuming the quantitative scenarios used have adequately captured the essence of key assumptions about the future, the results here suggest that country-level solutions that effectively manage the livestock sector under one future will do so in event of the other – at least with respect to factors that impact directly on LDF supply (though see para above on limitations of the IMPACT analysis). Robust policies, i.e., those that will hold up under all/most of the identified possible futures may however not be so straightforward to attain. For one, the analysis has focused on country-level interactions within the livestock sub-sector, and national aggregates of indicators. Additional analyses will be needed to understand how the results will play out at more disaggregated levels. For example, to understand who the losers and winners are from increasing production gaps, what categories of livestock producers and production need to be better supported, managed or regulated, and how different livestock value chains and end consumers may possibly be affected differently by the status quo and by interventions.

6. The national livestock policy environment

This section is taken from Ashley (2019) and Enahoro et al. (2019).

In Uganda, agriculture is overseen by the ministry of Agriculture, Animal industry and Fisheries (MAAIF), a cabinet-level ministry of the government, charged with creating an enabling environment in the agricultural sector. Its role is to support, promote and guide production of crops, livestock and fisheries to ensure qualitative and quantitative supply of these products for domestic consumption, food security and export. As noted above, the livestock sector is important to the livelihood of many households in Uganda. Uganda’s policy record on the intersection of the livestock sector and climate change has been strengthened by the recent NAP-Ag framework of 2018. Uganda’s Nationally Appropriate Mitigation Action (NAMA) for climate-smart dairy livestock value chains (2017) provides robust and thorough mitigation approaches many of which have relevance beyond the dairy sector. Generally, however, development, agriculture, land, and environment policies have limited integration of livestock-climate considerations.

Uganda has long recognised the threat of climate change as evidenced in the National Environmental Policy, 1995. Across policy areas, there is consistent recognition of climate risks and impacts to the country’s agricultural production. There is less dedicated attention, however, to the livestock sector. Uganda’s NAP-Ag, 2018, notes that livestock contributes just 1.9 percent to the country's GDP, which may account for the somewhat limited attention devoted to the sector across policy areas. Climate adaptation strategies in the livestock sector are referenced but rarely well-elaborated outside of the recent NAP-Ag framework. Meanwhile, livestock sector mitigation strategies are absent or nascent across policy areas outside of the country's REDD+ Strategy, 2017, and NAMA for the dairy sector, 2017. In contrast to Kenya and Ethiopia, where development policy fairly strongly integrates climate-livestock issues, Uganda's national development policies (NDP II, Green Growth Development Strategy) give them less attention. Uganda did, along with Ethiopia, join the Global Research Alliance on Agricultural Greenhouse Gases in 2018.

Uganda's climate dedicated policies began somewhat later than those in Kenya or Ethiopia, outside of the 2007 NAPA. After the NAPA, the National Climate Change Policy (NCCP), 2015, was the next climate policy and is the foundation of the country's climate action. The policy notes that, like the EAC regional policy, it emphasises adaptation over mitigation. The NCCP includes agriculture as a priority sector and provides brief treatment of a range of livestock sector adaptation strategies from improving natural resource management and water availability, to supporting value chains and breeding, to better climate information services and early warning systems. The NCCP also aims to mainstream mitigation in agriculture but provides just one mitigation strategy for the livestock sector (sustainable rangeland management).

Uganda's development and agriculture policies aim to commercialise agriculture and increase agricultural exports three-fold from 2015 to 2020. These ambitious goals are important for economic development, but the lack of policy focus on integrating mitigation measures and limited recognition of the role of pastoralists create two distinct risks: dramatically increasing livestock sector emissions and excluding pastoralists from development and resilience initiatives. Uganda's livestock sector is guided by the Agriculture Sector Strategy Plan (ASSP), 2015, and NAP-Ag framework in addition to development policy. The ASSP provides numerous strategies for livestock breeding and feeding that provide important opportunities for adaptation and mitigation, but strategies tend to target productivity with little explicit integration of climate resilience or mitigation. The ASSP does reference a national climate smart agriculture initiative and the NAP-Ag released in 2018 could shift government focus toward adaptation and mitigation co-benefits. This provides a robust approach to livestock sector adaptation action and well-detailed strategies. The framework includes a thorough evaluation of current and projected climate change impacts, the policy context for agriculture, and strategies responsive to the climate and policy context.

Uganda's National REDD+ Strategy and Action Plan, 2017, and NAMA for climate-smart dairy livestock value chains, 2017, provide the most detailed rational, strategies, and implementation guidance for mitigation. These policies address important potential adaptation co-benefits particularly related to increasing livestock productivity through improving feed and water quality and availability (REDD+) and improved feed and value chains (NAMA). The NAMA explicitly aims to improve climate resilience in the dairy sector in addition to permanently reducing GHG emissions through a value chain approach. Uganda's NDC references livestock under "additional mitigation ambition" with the strategy of livestock breeding research and manure management. Livestock breeding is also referenced in REDD+ Strategy and manure management in the NAMA for the dairy sector but not in other policies as a mitigation strategy.

Uganda is participating in the Climate Investment Funds Pilot Programme on Climate Resilience (PPCR). The Strategic Programme on Climate Resilience component includes proposed investment projects for climate smart agriculture (including for livestock), improved natural resource management, and strengthening climate information services (CIF, 2017).

Livestock adaptation and mitigation efforts in Uganda face the constraints of the overall livestock sector. This includes the lack of a holistic government approach to agriculture until recently (NAMA, 2017). The ASSP, 2015, identifies specific constraints on the sector including:

- a weak policy and regulatory framework,
- production constraints including limited availability of quality feeds,
- land tenure and water rights issues that affect water availability for agricultural production,
- weak monitoring and evaluation system and statistics,
- poor post-harvest handling and processing capacity,
- poor markets and marketing infrastructure, and
- limited technical capacity among government agriculture staff.

The NAP-Ag further examines constraints related to overlapping mandates among government entities leading to conflicts or lack of accountability and weak institutional coordination among the Ministry of Agriculture and Ministry of Water and Environment. The NAP-Ag notes that the Climate Change Department faces low staffing and that skewed budget allocations leave climate impacted sectors including agriculture, natural resources, and land management with the smallest proportion of the budget. Additionally, national policies rarely include adequate consideration of community-level social, cultural, environmental and economic challenges and contexts (NAP-Ag, 2018).

Ampaire et al. (2017) found that in Rakai district, many climate related policy strategies were not being implemented due to a disconnect between national and district level authorities, inadequate consultation with stakeholders, lack of technical capacity to implement adaptation strategies, insufficient budgets, and political interference.

The NAMA identifies additional conditions inhibiting the dairy sector, many of which are also relevant for broader livestock sector adaptation and mitigation including:

- low animal productivity due to poor feeding and animal health;

- low level of commercialisation and lack of regulation of hay and concentrated feed production;
- low adoption of improved management practices and technologies;
- no standards or labelling for animal feeds;
- extremely limited infrastructure for collection, storage and chilling of milk across the country;
- limited incentives for smallholders and informal milk traders to participate in the formal segment; and
- no quality control, standards, or labelling for milk production.

In addition to issues of support for mobility, an issue of concern in rangelands is that a rush to secure mineral and oil mining deposits is threatening communal rangelands including through cases of land grabbing. Many customary owners lack formalised rights over land and are unable to exclude mining interests or benefit from royalties sharing (Land Policy, 2013). There are concerns that communal land holders are being displaced with inadequate compensation and resettlement options. While customary tenure remains the primary type of tenure in much of Uganda, traditional institutions of land governance and management have not been legally accepted and integrated (Land Policy, 2013). The REDD+ Strategy identifies the lack of adoption of the Draft Rangeland Management and Pastoralism Policy (2014) as a disabling condition. Additionally, the country does not have a dedicated livestock policy.

Policy coherence

Ashley (2019) examined each policy area for integration of livestock sector climate change adaptation and mitigation and alignment with the Sustainable Development Goals (SDGs; UN, 2015) and national development goals. Policies were scored for extent of integration of livestock sector adaptation and mitigation, and results are summarised in Table 7. Higher scores designate more dedicated and detailed climate related strategies for the livestock sector. From this analysis, Ashley (2019) identified several opportunities for engagement with climate-livestock policy in Uganda, in relation to synergies, gaps and potential conflicts.

Strongest synergies across policies:

- Improving natural resource management (including rangeland management and sustainable land management) is the most commonly identified adaptation strategy and one of the most prominent mitigation strategies.
- Uganda’s focus on commercialisation, particularly across agriculture and development policy, is likely to make value chain and market system interventions appealing. The NAMA

for the dairy sector, “Climate-smart dairy livestock value chains in Uganda,” takes this approach.

- The NAP-Ag, 2018, provides the most holistic approach to livestock sector adaptation, is aligned with NDP II, and has synergies with adaptation strategies across policy areas.

Table 7. Uganda policy integration of livestock sector adaptation and mitigation summary (Ashley, 2019).

Uganda	Livestock Adaptation score	Livestock Mitigation score
Climate Policy		
Climate Average	2.3	1.7
NAPA, 2007	3	1
National Climate Change Policy, 2015	3	1
NDC, 2015	2	1
National REDD+ Strategy and Action Plan, 2017	1	2
NAMA, Climate-smart dairy livestock value chains in Uganda, 2017	2	3
NAP-Ag, 2018	3	2
Livestock & Agriculture Policy		
Livestock & Agriculture Average	2	0.5
National Agriculture Policy, 2013	2	0
Agriculture Sector Strategic Plan 2015-2020	2	1
Development Policy		
Development Average	1.5	1
National Development Plan (NDP II), 2015/16-2019/20 (Vision 2040)	2	1
Green Growth Development Strategy 2017/18 – 2030/31	1	1
Land & Environment Policy		
Land & Environment Average	1.5	0.5
National Land Use Policy, 2006	2	0
National Land Policy, 2013	1	1

Key gaps:

- There is a need to better integrate livestock into climate policies and climate into livestock policies for adaptation and mitigation objectives.
- Robust strategies for mitigation in the livestock sector are absent or nascent across policy areas outside of the REDD+ Strategy and NAMA for the dairy sector.

- Robust options to support adaptation in extensive livestock systems are lacking including insufficient attention to mobility, protecting rangelands from encroachment and degradation, and improving feeding in pastoral production. The focus on commercialisation and agricultural intensification and limited attention to pastoralism risks leaving pastoralists behind.
- Efforts to explore livestock insurance options are minimal; agriculture insurance is only referenced in the NCCP, NDP II, and NAP-Ag.

Potential conflicts:

- Uganda's National Agriculture Policy, 2013, has a focus on commercialisation of agriculture with limited integration of mitigation strategies; this could lead to increasing GHG emissions.
- The NAP-Ag framework, 2018, discusses the limited relevance for many smallholders of focusing on commercialisation in agriculture (the aim of the National Agriculture Policy). With the NAP-Ag released only in November 2018, it remains an open question whether the NAP-Ag or National Agriculture Policy will drive government interventions.

7. Conclusions: system intervention points

Uganda faces some major challenges to the middle of the century. These include a population growing from 42 to 106 million people, more than 40 percent of whom will live in urban areas. Calorie consumption from livestock-derived food is expected to increase by 70 percent, which will entail a quadrupling of beef and chicken meat production and a trebling of milk and egg production. By 2040, Uganda's vision is to transform the country from a predominantly low-income one to a competitive upper middle-income country with a per capita income of USD 9,500. These are ambitious targets, particularly in the context of climate change, and achieving these targets through a sustainable and equitable development pathway will require considerable investment and prioritisation.

There is relatively little literature on the national impacts of climate change on Ugandan livestock production, though regional and continental analyses from the IPCC and other sources show clearly what can be expected. Increased frequency and severity of extreme events such as drought and heat will increasingly test the resilience of livestock keepers and their animals, particularly in the pastoral and agropastoral lands. Substantial knowledge gaps exist on the impacts of climate change on non-ruminants, its potential effects of water availability in livestock systems, and effects on zoonotic and other livestock diseases. Preliminary research suggests that rising temperatures will result in marked increases in heat stress in cattle. Such considerations highlight the need for characterisation of species and breeds of livestock that may have high adaptive capacities to climate change.

At the same time, a wide range of adaptation options is available, particularly to address increasing climate risk, and many of these have mitigation co-benefits. Targeting these at broad scale is challenging because of the variation in local agro-ecological and socio-economic contexts. In addition, there are several barriers to widespread uptake of livestock interventions in Uganda. For the diary systems of Southwestern region, for example, farmers reported a range of issues, including limited capital, animal diseases, difficulties posed by an unpredictable climate, poor quality veterinary drugs, and lack of capacity development (de Vries, 2019). There may also be limits to the agricultural adaptation that is achievable at the household level: Call et al. (2019) suggest that in the future, smallholders in parts of Uganda will struggle to maintain their livelihood portfolio and agricultural productivity during extended periods of heat stress, and new livelihood strategies may be necessary.

With respect to the policy and enabling environment, several opportunities exist for engagement with climate-livestock policy in the country. The national focus on commercialisation, for example, particularly across agriculture and development policy, brings considerable opportunities for interventions along different value chains. Multiple policy documents refer to improving natural resource management (including rangeland management and sustainable land management) as a key adaptation and mitigation strategy. At the same time, livestock could be better integrated into climate policies and climate into livestock policies for adaptation and mitigation objectives. In view of the considerable expansion of the beef sector envisaged, robust strategies for mitigation across the livestock sector need to be developed. The focus on commercialisation and agricultural intensification runs the risk of leaving pastoralists behind; increased attention may need to be paid to mobility, protecting rangelands from encroachment and degradation, improving feeding in pastoral production, and implementing risk protection instruments such as insurance.

References

Ampaire EL, Jassogne L, Providence H, Acosta M, Twyman J, Winowiecki L, Van Asten P, 2017. Institutional challenges to climate change adaptation: A case study on policy action gaps in Uganda. Environmental Science & Policy, 75, 81-90.

ASL (African Sustainable Livestock), 2018. Livestock and livelihoods spotlight: Uganda. ASL 2050, FAO, Rome.

ASL (African Sustainable Livestock), FAO, 2018. Livestock and environment spotlight: Uganda cattle and poultry sectors. ASL 2050, FAO, Rome.

Ashley L, 2019. Climate and livestock policy coherence analysis in Kenya, Ethiopia and Uganda. CCAFS Working Paper no. 268. Wageningen, the Netherlands: CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS). Available online at: www.ccafs.cgiar.org

Augustine D, Blumenthal D, Springer T, et al., 2018. Elevated CO2 induces substantial and persistent declines in forage quality irrespective of warming in mixed grass prairie. *Ecological Applications* 28 (3): 721–735.

Bell P, Namoi N, Lamanna C, Corner-Dollof C, Girvetz E, Thierfelder C, Rosenstock TS, 2018. A Practical Guide to Climate-Smart Agricultural Technologies in Africa. CCAFS Working Paper no. 224. Wageningen, the Netherlands: CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS). Available online at: www.ccafs.cgiar.org

Boone RB, Conant RT, Sircely J, Thornton PK, Herrero M, 2018. Climate change impacts on global rangeland ecosystem services. Global Change Biology 24(3), 1382-1393.

Boote KJ, Jones JW, Hoogenboom G, Pickering NB, 1998. The CROPGRO model for grain legumes. In: Tsuji GJ, Hoogenboom G, Thornton PK, eds. Understanding Options for Agricultural Production. Dordrecht, The Netherlands: Kluwer, p. 99–128. http://www.springer.com/gp/book/9780792348337

Call M, Gray C, Jagger P, 2019. Smallholder responses to climate anomalies in rural Uganda. World Development 115, 132-144.

Center for Hazards and Risk Research (CHRR), Center for International Earth Science Information Network (CIESIN), 2005. Global Flood Hazard Frequency and Distribution. Palisades, NY: NASA Socioeconomic Data and Applications Center (SEDAC). https://doi.org/10.7927/H4668B3D.

Center for Hazards and Risk Research (CHRR), Center for International Earth Science Information Network (CIESIN), International Research Institute for Climate and Society (IRI), 2005. Global Drought Hazard Frequency and Distribution. Palisades, NY: NASA Socioeconomic Data and Applications Center (SEDAC). https://doi.org/10.7927/H4VX0DFT.

CIAT, 2017. Climate-Smart Agriculture in Uganda. CSA Country Profiles for Africa Series. International Center for Tropical Agriculture (CIAT); Bureau for Food Security, United States Agency for International Development (BFS/USAID), Washington, DC. 26 p.

De Vries M, 2018. Vulnerability and adaptation strategies of dairy farming systems to extreme climate events in southwest Uganda. Results of CSA-PRA workshops. Wageningen Livestock Research, Wageningen, the Netherlands.

Dilley M, Chen RS, Deichmann U, Lerner-Lam AL, Arnold M, Agwe J, Buys P, Kjekstad O, Lyon B, Yetman G, 2005. Natural Disaster Hotspots: A Global Risk Analysis. Washington, D.C.: World Bank. https://doi.org/10.1596/0-8213-5930-4.

Enahoro D, Njuri N, Thornton P, Staal SS, 2019. 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). CCAFS Working Paper no. 262. Wageningen, the Netherlands. Available online at: www.ccafs.cgiar.org

ERA, 2019. Evidence for Resilient Agriculture (ERA): an online platform that delivers data and tools designed to pinpoint what agricultural technologies work where. https://era.ccafs.cgiar.org/about/

FAO, 2019. The future of livestock in Uganda. Opportunities and challenges in the face of uncertainty. Rome, FAO, 46 pp.

FAOSTAT, 2019. Food and agriculture data. FAO, Rome. http://www.fao.org/faostat/en/#home

Godde CM, Dizyee K, Ash A, Thornton P, Sloat L, Roura E, Henderson B, Herrero M, 2019. Climate change and variability impacts on grazing herds: Insights from a system dynamics approach for semi-arid Australian rangelands. Global Change Biology 25, 3091-3109.

Herrero M, Havlik P, McIntire J, Palazzo A, Valin H, 2014. African livestock futures: Realizing the potential of livestock for food security, poverty reduction and the environment in sub-Saharan Africa. Geneva, Switzerland: Office of the Special Representative of the UN Secretary General for Food Security and Nutrition and the United Nations System Influenza Coordination.

Herrero M, Mayberry D, van de Steeg J, Phelan D, Ash A, Dizyee K, Robinson T, Henderson B, Gilbert M, van Wijk M, Godde C, Blummel M, Prestwidge D, Stephenson E, Power B, Parsons D, 2016.

Understanding Livestock Yield Gaps for Poverty Alleviation, Food Security and the Environment:

The LiveGAPS Project Final Report, December 2016.

Jones PG, Thornton PK, 2013. Generating downscaled weather data from a suite of climate models for agricultural modelling applications. Agricultural Systems 114, 1-5. http://dx.doi.org/10.1016/j.agsy.2012.08.002

Jones PG, Thornton PK, 2015. Representative soil profiles for the Harmonized World Soil Database at different spatial resolutions for agricultural modelling applications. Agricultural Systems 139, 93-99. http://dx.doi.org/10.1016/j.agsy.2015.07.003

Karanja FK, 2006. CROPWAT model analysis of crop water use in six districts in Kenya. CEEPA DP35, University of Pretoria, South Africa.

Kekae K, Brychkova G, Mckeown PC, Hanson J, Jones CS, Thornton PK, Spillane C, 2019. Climate change impacts on future availability of forage grass species for Ethiopian dairy systems. Agricultural Systems (submitted).

Lipper L, Thornton PK, Campbell B, Baedeker T, Braimoh A, Bwalya M, Caron P, Cattaneo A, Garrity D, Henry K, Hottle R, Jackson L, Jarvis A, Kossam F, Mann W, McCarthy N, Meybeck A, Neufeldt H, Remington T, Sen PT, Sessa R, Shula R, Tibu A, Torquebiau EF, 2014. Climate smart agriculture for food security. Nature Climate Change 4, 1068-1072.

Mayberry D, Ash A, Prestwidge D, Godde CM, Henderson B, Duncan A, Blummel M, Reddy YR, Herrero M, 2017. Yield gap analyses to estimate attainable bovine milk yields and evaluate options to increase production in Ethiopia and India. Agricultural Systems 155, 43-51.

Mbow C, Rosenzweig C, 2019. Chapter 5: Food security. IPCC Special Report on Climate Change and Land, online at https://www.ipcc.ch/site/assets/uploads/2019/08/2f.-Chapter-5_FINAL.pdf

Nachtergaele FO, Zanetti M, Bloise M, Ataman E, 2002. TERRASTAT global land resources GIS models and databases for poverty and food insecurity mapping. FAO Land and Water Digital Media Series #20. Rome, Italy: FAO

Njeru E, Grey S, Kilawe E, 2016. Eastern Africa Climate-Smart Agriculture Scoping Study: Ethiopia, Kenya and Uganda. FAO, Addis Ababa, Ethiopia

Osborne CP, Salomaa A, Kluyver TA, et al., 2014. A global database of C4 photosynthesis in grasses. New Phytologist 204: 441-446.

Prasad PVV, Staggenborg SA, Ristic Z. 2008. Impacts of drought and/or heat stress on physiological, developmental, growth, and yield processes of crop plants. In: Ajuha LR, Reddy VR, Saseendran SA, Yu Q, eds. Response of crops to limited water: understanding and modelling water stress effects on plant growth processes. Madison, WI, USA: ASA/CSSA/SSSA, p. 301–356. Available online at: https://portal.sciencesocieties.org/resources/files/downloads/pdf/b40721.pdf

Ramankutty N, Evan AT, Monfreda C, Foley JA, 2008. Farming the planet: 1. Geographic distribution of global agricultural lands in the year 2000. Global biogeochemical cycles, 22(1).

Riahi K, 2014. The RCP/SSP Framework. Arctic Scenarios Workshop, 19-20 May. IIASA, Austria.

Robinson TP, Thornton PK, Franceschini G, Kruska RL, Chiozza F, Notenbaert A, Cecchi G, Herrero M, Epprecht M, Fritz S, You L, Conchedda G, See L, 2011. Global livestock production systems. Rome, FAO; ILRI, Nairobi. 152 pp.

Robinson S, Mason d'Croz D, Islam S, Sulser TB, Robertson RD, Zhu T, … Rosegrant MW, 2015. The International Model for Policy Analysis of Agricultural Commodities and Trade (IMPACT): Model description for version 3 (IFPRI Discussion Paper No. 1483). Washington, DC. Retrieved from http://ebrary.ifpri.org/cdm/ref/collection/p15738coll2/id/129825

Rojas-Downing MM, Nejadhashemi AP, Harrigan T, Woznicki SA, 2017. Climate Change and Livestock: Impacts, Adaptation and Mitigation. Climate Risk Management 16: 145–63.

Seré C, Steinfeld H, 1996. World livestock production systems: Current status, issues and trends. FAO Animal Production and Health Paper 127. FAO (Food and Agriculture Organization of the United Nations), Rome, Italy.

Smith MR, Myers SS, 2018. Impact of anthropogenic CO2 emissions on global human nutrition. *Nature Climate Change* 8: 834–839.

Thornton PK, Herrero M, 2014. Climate change adaptation in mixed crop–livestock systems in developing countries. Global Food Security, 3(2), 99–107. https://doi.org/10.1016/j.gfs.2014.02.002

Thornton PK, Boone RB, Ramirez-Villegas J, 2015. Climate change impacts on livestock. SBSTA submission for the AGN, March 2015. CCAFS WP 120.

Thornton PK, Dinesh D, Cramer L, Loboguerrero AM, Campbell BM, 2018. Agriculture in a changing climate: keeping our cool in the face of the hothouse. Outlook on Agriculture 47 (4), 283-290.

Thornton PK, Loboguerrero AM, Campbell BM, Kavikumar KS, Mercado L, Shackleton S, 2019. Rural livelihoods, food security and rural transformation under climate change. Rotterdam and Washington, DC. Available online at www.gca.org.

Thornton PK, Jones PG, Nelson G, 2020. Global projections of cattle heat stress during the twenty-first century. To be submitted.

UBOS, 2018. Statistical abstract 2018. Uganda Bureau of Statistics. Kampala, Uganda.

United Nations, 2015. *Transforming our world: the 2030 Agenda for Sustainable Development*. Online at https://sustainabledevelopment.un.org/post2015/transformingourworld

Watts N, Amann M, Ayeb-Karlsson S et al., 2017. The Lancet Countdown on health and climate change: from 25 years of inaction to a global transformation for public health. The Lancet 391: 581–630.

World Bank, 2019. World Bank Indicators. Retrieved from http://databank.worldbank.org/data/ home.aspx