Food and Agriculture Organization of the United Nations

AFRICA SUSTAINABLE LIVESTOCK 2050

Livestock growth, public health and the environment

UGANDA

A quantitative assessment

USAID FROM THE AMERICAN PEOPLE

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ONE HEALTH IN ACTION

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1. Introduction

Africa is experiencing a series of simultaneous changes including substantial and unprecedented urban, socio-economic, policy and technological transitions. The United Nations (UN) predicts that, in 2050, the African population will reach 2.5 billion, from 1.2 billion today, and that 56 percent of the population will live in urban areas, vis-à-vis 40 percent today (UN, 2017, 2018). Gross domestic product, currently at USD 4.7 trillion, is estimated to almost triple by 2050 (FAO, 2018), resulting in increased purchasing power for African consumers. An emerging middle class will support the democratization of the continent, further reinforcing economic growth and development (AfDB, 2011). Basic infrastructure, such as power supplies and communications, will be increasingly available, allowing Africa to benefit from technology development and, in the best case, to use technology to leapfrog over some of its current and emerging challenges (Swarth, 2011).

These rapid transitions will have major implications for African agriculture, which will be challenged to supply affordably-priced, nutritious and safe food to an increasingly affluent and urbanized population. Evidence from other regions suggests the sector will undergo two major structural transformations in the coming decades. The first is that, while the quantity and value of agricultural production will increase, the contribution of the sector to GDP and employment will reduce. Currently, in sub-Saharan Africa and North Africa agriculture accounts for 17.5 and 11.7 percent of GDP and contributes 57 and 22.3 percent to total employment, respectively. In high income countries, these shares are less than 2 and about 3 percent, respectively (WDI, 2018). The second transformation is that livestock will become one of the most important sectors of agriculture in value terms. Today, it accounts for 25 percent of agricultural value added in Africa, and for 55 percent and 67 percent in North America and Western Europe, respectively (FAOSTAT, 2018). The reason is that, as economic development progresses, increasingly well-off consumers will move away from a predominantly cereal-based diet and start purchasing the high-value proteins that meat, milk and other livestock products offer, as well as fruits and vegetables. This trend in animal source food consumption pattern, often referred to as Livestock Revolution (Delgado *et al.*, 1999), will profoundly affect the development of African livestock in the coming decades.

A useful approach to help with decision-making in the context of the expected increase in human population numbers and increases in animal production is the concept of One Health, which recognizes the interconnectedness between human and animal health, as well as relationships with the environment. “One Health promotes a whole of society approach by incorporating human medicine, veterinary medicine, public health, and environmental information when developing policy and determining interventions to address current challenges threatening today’s globalized world” (Papadapoulis and Wilmer, 2011).

This report presents long-term scenarios for 2050 as developed by Kenyan national stakeholders and their impact on public health as assessed by the One Health Policy Model developed by the USAID-funded Preparedness and Response project (Moreland *et al.*, 2018). Scenarios contain stories of multiple futures, from the expected to the wildcard, in forms that are analytically coherent and imaginatively engaging. A good scenario elicits attention and says, “Take a good look at this future. This could be your future. Are you going to be ready?” (Bishop *et al.,* 2007, p. 5). The One Health Policy Model, populated with both scenario data and long-term quantitative projections for the livestock sector developed by the FAO Global Perspective Studies Team, provides quantitative evidence on the impact of alternative long-term futures on a variety of societal dimensions, including public health.

The next section presents the cattle and poultry livestock scenarios for Uganda articulated by national stakeholders as part of the implementation of the FAO Africa Sustainable Livestock Project. Section three presents the One Health Policy Model and its application to the livestock sector in Uganda, with a specific focus on the impact of zoonotic diseases on public health in the year 2050. Section four presents conclusions.

2. Uganda livestock projections and scenarios

2.1. Projected increases in the demand and supply of livestock products by 2050

Population growth, urbanization and gains in real per capita income will result in an increased demand for livestock products. In Uganda, in the next 38 years, the aggregate consumption of all livestock products will more than double, with higher growth for poultry, pork and beef. On an annual basis, demand will grow between 3.6 percent for milk to over 4.7 percent for poultry, pork and beef, which translate in major increases in volume terms. For example, the volume of milk and beef consumed will increase by near 3 300 and 750 thousand tons in the next 38 years, respectively, with aggregate consumption estimated at over 4 600 tons for milk and 930 thousand tons for beef in 2050.

Figure 1. Uganda: Current and projected consumption of livestock products, 2012–2030–2050

	Estimated consumption, 000 tons			Growth rate, 2012–2050	
	2012	2030	2050	percentage	annual rate
Milk	1 330.5	2 766.8	4 615.5	247%	3.6%
Beef	185.3	445.7	931.8	403%	4.7%
Mutton & Goat	43.9	97.3	196.2	347%	4.4%
Poultry	61.0	146.2	316.4	419%	4.8%
Eggs	34.2	74.4	136.1	298%	4.0%
Pork	118.5	277.5	606.6	412%	4.8%

Source: FAO Global Perspectives Studies (2018)

As a response to the growing demand for animal source foods, Ugandan livestock producers are anticipated to make investments that increase production and productivity. It is estimated that, between 2012 and 2050, production of all types of meat and that of milk will increase by 164 and 41 percent, respectively. Production will increase from a minimum of 17 percent for beef to 491 percent for poultry meat, with annual growth rates ranging from 0.5 to 5.2 percent. Eventually, demand will increase more than production, worsening both the Ugandan meat and milk trade balance.

Figure 2. Uganda: Current and projected production of animal source foods, 2012–2030–2050

	Estimated production, 000 tons			Growth rate, 2012–2050	
	2012	2030	2050	percentage	annual rate
Milk	1 461	1 816.1	2 065.8	41%	1.0%
Beef	192.0	220.5	225.0	17%	0.5%
Mutton & Goat	45.1	81.6	123.5	173%	2.9%
Poultry	62.1	202.0	366.5	490%	5.2%
Eggs	45.9	143.9	256.5	459%	5.0%
Pork	121.0	230.0	393.0	225%	3.4%

Source: FAO Global Perspectives Studies (2018)

2.2. Scenarios for cattle and poultry production systems in 2050

Quantitative projections inform on the plausible size of the market for animal source foods in 2050. However, they provide little insight on the structure of livestock production systems in 2050, which not only is a determinant of the production level but also determine the public health, environment and livelihoods' impact of the livestock sector on society. For example, the same amount of proteins can be generated either by extensive or intensive livestock producers, whose production practices are markedly different, thereby resulting in different impacts on society.

With the objective to anticipate the possible impacts of livestock production systems on public health, the environment and livelihoods, Uganda stakeholders have articulated long-term (2050) scenarios for the cattle and poultry systems. The scenarios portray, in qualitative way, alternative but all plausible livestock production systems in 2050. In order to develop livestock scenarios stakeholders have:

- Articulated long-term scenarios for Uganda, the assumption being that livestock is more a follower than a driver of economic development and, hence, its future structure will largely depend on how Uganda will be in 2050. To this end, they have identified two key "uncertainties" that are anticipated to influence the overall development trajectory of the country in the years to come. These are the governance system, which can be with strong institutions, complete transparency and open democracy, or instead be autocratic, with total dictatorship and nepotism, and the economic system, which can be good or bad, depending on the grade of diversification, growth and value-addition and state of the infrastructures. Figure 3 provides a narrative of the possible four futures of Uganda associated to alternative interactions between the governance system and the economic system in 2050. Stakeholders named the different scenarios Gifted by Nature (good economy and good governance scenario), Quinine Juice (a reference to a bitter situation –despotic government- that citizens should swallow), Cassava Republic (both economy and governance on the negative extreme) and Drained Pearl (good governance but bad economy).

- Developed a narrative of the poultry and cattle sectors in the different scenarios. Stakeholders have first agreed on the number of share of animals raised in the different production systems (e.g. extensive vs intensive) and then described the characteristics of the different systems in terms of production practices, the animal diseases situation, including specific references to zoonoses and emerging infectious diseases, and the implications for the environment and people's livelihoods. Figure 4 and 5 summarise the narratives for the beef cattle and poultry production systems in the different 2050 scenarios.

The 2050 cattle and poultry scenarios show that, in all possible futures there could be issued associated with zoonoses and emerging infectious diseases. In particular, because of expanded human and animal populations, in all cases the 2050 will be characterized by more intense interactions between animals and humans on the farm, along the value chain and in marketplaces. The risk of outbreaks of endemic zoonotic diseases will be higher. In some scenarios, it will result in higher disease prevalence and incidence in both animals and humans, and greater cost for society at aggregate and per capita level. The relative cost for society to manage zoonoses, therefore, will go up. At the same time, farmers will have incentives to increasingly use antibiotics either to expand their businesses and tap into the growing demand for livestock products, or to reduce the risk of their animals being infected by diseases. If antimicrobial resistance in humans is developed, the cost of society can be massive in terms of human life lost owed to infectious diseases that, today, are effectively treated. In this context, a first step for the government to design effective policies in to have some quantitative assessment of the impact of society of zoonoses or AMR, which helps to assess the cost effectiveness of alternatives programs that can be put in place to prevent, control and manage zoonotic diseases and AMR.

Figure 3. Uganda: 2050 country scenarios

Diversified, value-adding economy with strong growth plus excellent infrastructure

QUININE JUICE

Uganda is a middle-income country with diversified economy but autocratic government. Infrastructures and access to public services are better but there is limited freedom of expression. The middle class is bigger but it is so the gap between rich and poor. Improvement in life expectancy and access to electricity and sanitation facilities. DALYs decreased. Poverty and undernourishment are lower than in the past. Although the environment is much degraded (deforestation and threatened species included) climate smart strategies are adopted.

GIFTED BY NATURE

Uganda is an upper-middle country with diversified, efficient and open economy, and excellent citizen engagement in policy. All adults have employment possibilities and standards of living are much improved. National tech is applied on all sectors. The 95 percent of population is literated and thanks to a solar electrification process, 90 percent of houses can connect to electricity. The major diseases are derived from lifestyle and non–communicable (cancer, infections). Poverty rate is below 5 percent and undernourished below 2 percent. Strong refo-restation process helps coping with climate change. Wildlife sanctuaries, revenues from tourism. Wetlands and forests restored.

Autocratic total dictatorship nepotism

Strong institutions, complete transparency, open democracy

CASSAVA REPUBLIC

Uganda is low income country. Governance is characterized by nepotism, corruption and impunity. Subsistence agriculture is the backbone of the economy (40 percent GPD and 80 percent of employment). Middle class is only the 2 percent of the population. Literacy rate is 50 percent below 15 years-olds. Twenty percent of the population has access to electricity and only 10 percent to basic sanitation services. Av. life expectancy is 45. Main causes of death are HIVS, tuberculosis and malaria. 50 percent of people are poor and 45 percent undernourished. Land is degraded and exhausted. Biodiversity reduced. Climatic variability is high.

DRAINED PEARL

Uganda is a low income country with less income pc than in 2018. Secure country with strong transparent governance. Infrastructures are worse due to the declining economy. The 35–45 percent population is urban (half living in slums). Three percent is middle class and the gap between poor and rich is smaller. Agriculture is the backbone of the economy. Health services are worst (brain drain with doctors migrating) and life expectancy lower than in 2018 (55–60y). Higher communicable diseases. Sanitation services and access to water worsened and AMR increases. Over 21 percent population lives in poverty. Undernourishment increases. Despite good policies, environment is worst. There is more pollution in cities and there is no adequate infrastructure for drainage and waste management.

Extractive, declining economy with collapsed infrastructure

3. Assessing the impact of future livestock systems on public health

3.1. One Health Policy Model

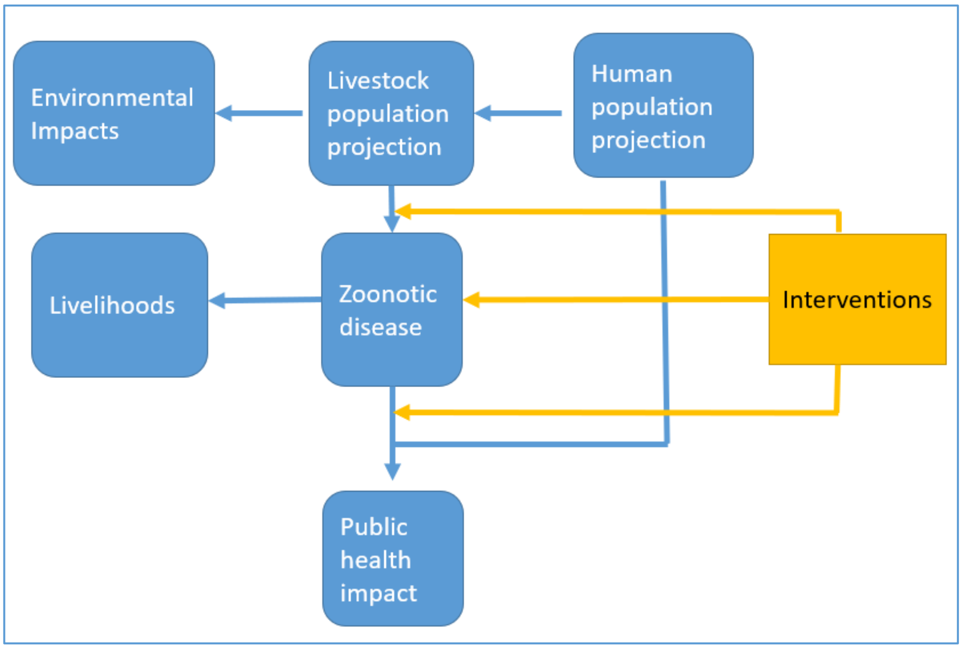
Livestock scenarios, while consistent stories, lack the quantitative dimensions that are needed to better assess the pros and cons of alternative policy interventions.

To provide a framework to explore policy and program options for the challenges of the zoonoses-health paradigm, a policy model using a one health approach was developed by Palladium, a partner on the USAID-funded Preparedness and Response Project (P&R) and implemented using the Kenya livestock scenarios as input. The One Health Policy Model (OHPM) is designed to help decision-makers understand the nature and scale of how changes in the livestock and human populations might impact veterinary, human, and environmental health, including some of the available policy options. As such is a truly One Health Policy Model. The model can generate analytical and scenario-based evidence that will help gain traction with country-specific stakeholders. Because the model takes a tripartite approach to modelling the human population, livestock population, and the environment, it takes a One Health approach and shows the linkages between these three sectors.

Overview of the model's structure

The OHPM measures the impact on human, animal, and environmental health of zoonotic disease, as well as the economic costs. Figure 4 graphically depicts the relationships in the model. The model starts with exogenous projections of the human and animal populations, as well as data that describe the diseases under consideration. Based on the data and projections, the number of animal and human cases of zoonotic disease are calculated; these are used to develop measures of the public health impacts of disease. Environmental indicators are calculated based on the number of animals in each scenario, and economic impacts are calculated based on animal and human health losses due to zoonotic disease.

Figure 4. Overview of the One Health Policy Model



The model can be configured to compare two scenarios for one animal species for up to two diseases. Scenarios are defined by the mix of input parameters as described below. Scenarios may differ according to animal population growth rates or distribution of production systems, people exposed to zoonotic disease, and/or different levels of policy intervention. Policy interventions can affect the animal prevalence rate, the number of people exposed to disease, and the likelihood of those people contracting illness.

A feature of the model is inclusion of program or policy intervention simulations. Interventions affect the prevalence of the disease in animals, the spill over rate and the interface (contact) between animals and humans. For example, a bio-security program that changes the way in which farmers interact with their herd could reduce spill over or a vaccination program could reduce prevalence.

Production systems

Recognizing that different production systems can have drastically different implications for zoonotic disease, the framework can accommodate up to five different production systems. Often production systems vary between less intensive traditional systems and more intensive industrial systems. The user must define the characteristics of each production system, such as the animal population kept in that system, and the base year prevalence for each zoonotic disease. As zoonotic disease is managed differently in different production systems, the user can enter parameter values, such as reduced output of animal commodities per case or reduced fertility of infected animals that are specific to production systems. Production systems can also have different environmental profiles, so the parameters regarding GHG emissions and water footprint per animal may also vary by production system

In the two different scenarios, the overall size of the livestock population changes according to user-specified growth rates. The relative sizes of the different production systems may also change over time. The user can enter different shares of the population between the production systems in the base year and the end year of each of the scenarios. These assumptions reflect programmatic ambitions to scale up livestock production, modernize, or intensify the industry.

Populations at risk

For a zoonotic disease to be contracted by a human, there must be contact with infected animals. How that contact occurs will differ by various classes of humans. The model enables the user to define up to three populations at risk of contracting the given zoonotic disease. These populations are specific groups of people that interact with the livestock in question or animal products originating from them. Often, they are groups that work directly with the animals, such as herders, veterinarians, or market and slaughterhouse workers. Other affected populations that may be relevant in some circumstances are nomadic populations, small-scale farmers, general populations in specific geographic regions, and end consumers of animal protein (such as meat or dairy) for food-borne zoonotic diseases.

For each affected population, the user must enter the percentage of the population in contact with the livestock, the population forecast, and the exposure index. The exposure index is a 0–1 measure of the intensity of exposure of the people in this affected population to the livestock. Veterinarians and slaughterhouse workers would likely have a higher exposure index –for example, 0.9– than would the general population in a given geographic region; for example, an exposure index of 0.3 because they spend a lot of time in direct contact with the animals and their bodily fluids.

Input data

As with any model, several data inputs are necessary to configure the base year of the model and to set future values of key parameters. The OHPM requires data that vary by:

- Production system: Animal prevalence, animal fertility losses per case, and reduced production of animal products per case may all vary across production system. The user specifies the base year number of animals that are kept in each production system.

- Affected population: The human exposure index may vary by affected population. For more information about the exposure index, see the section on ‘Populations at risk’.

- Disease: For each disease, the model requires data on the human and animal health characteristics.

Scenarios

The P&R One Health Policy Model can be used to create scenarios based on alternative assumptions and to see how these assumptions influence outputs. These assumptions pertain to the values of key inputs in the model, some of which may be amenable to control and some purely exogenous. For this model, these are the main parameters that, together, can define a scenario.

- Production system shares: The model computes the base year shares of the animal population, by production system, based on the user-provided population estimates. The user then specifies the share of the animal population in each production system in the end year, which the model uses to construct population forecasts.

- Animal population growth: The user also defines different rates of growth for the overall animal population for each scenario.

- Humans exposed to animals: The user specifies the base year percentage of the human population that falls into each affected population exposed to animals, as well as the end year percentages for each of the scenarios. For example, in a scenario in which the animal population grows faster, the user may assume that more humans become involved in keeping livestock.

- Water and GHG use per animal: These parameters can be entered by production system for the base year and end year for each scenario. This enables the user to consider trends in environmental health associated with the scenarios.

3.2. Results for brucellosis, tuberculosis, and salmonellosis

Scenario inputs

The stakeholder-articulated long-term future scenarios described above in section 2.1 for production systems for cattle and poultry paint a broad vision of Uganda's future for the livestock industry. In order to estimate the likely impact of these scenarios on animal and human health as well as the environment these future qualitative scenarios were translated into quantitative parameters that were then used in the One Health Policy Model to project zoonotic disease in the species considered and its impact on the health of animals, humans and the environment.

Specifically, for each animal species and each disease, key parameters in the model were set by scenario for:

- production system shares;
- animal growth rates by production system;
- the percent of humans exposed to animals in specified risk groups;
- water consumption per animal per year by production system;
- enteric fermentation per animal per year by production system.

We also simulated interventions that affected animal prevalence, spill-over and interface parameters in the model. Rather than focus on specific interventions, we simulated "generic" interventions for prevention and for detection and response.

In order to simplify the results, we limited the modelling to the two extreme future qualitative scenarios corresponding to the upper right-hand quadrant corresponding to good governance and a prospering economy (Scenario Gifted by Nature), and the scenario in the lower left-hand quadrant corresponding to poor governance and a stagnating economy (Cassava Republic). We also simulated a business-as-usual scenario (BAU) that maintained 2015 levels of the model's parameters.

These inputs are presented in Table A1 and A2 in the Appendix which show for each parameter, the baseline (2015) value and the values for 2050 for the two scenarios. Baseline values were drawn either from published data in Uganda or from an expert elicitation exercise conducted by FAO. Expert elicitation consisted of interviews and meetings with local experts and stakeholders who are familiar with the livestock and zoonoses situation. In general, we see that the Gifted by Nature scenario represents a future with more livestock in more intensive systems, higher growth rates of animals and more consumers of animal products. By contrast, the Cassava Republic scenario is interpreted to be a Uganda in which the production systems remain largely traditional, animal population grow more slowly and fewer humans are exposed to animals who may be diseased.

Interventions (not listed in the tables) were set by FAO experts to increase over base for the Gifted by Nature scenario and to decrease for the Cassava Republic scenario.

Impacts on animal and human health and the environment

In this section we present the long-term modelling results for three scenarios. In the business-as-usual scenario (BAU) we held all parameters constant at their 2015 levels. For the Gifted by Nature and Cassava Republic scenarios we used the parameters listed in the tables in the previous section. The results are presented in Table 3 below.

Cattle - brucellosis

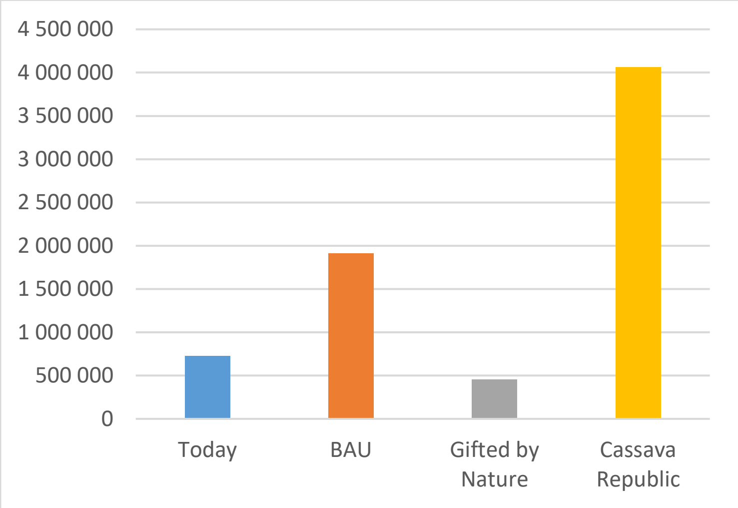
Projection of zoonotic disease and its impacts on animals and humans are affected by the number and prevalence of the disease in animals and the contact between animals and humans (Table 1). For cattle in Uganda the scenarios showed decreased numbers of cattle by 2050 for the business-as-usual scenario compared to the 2015 (Today) population. The Gifted by Nature scenario projects a slightly larger number of animals compared to the business-as-usual and the Cassava Republic scenario projects the same number as Gifted by Nature.

In terms of prevalence, Gifted by Nature has a lower prevalence rate (3.6 percent) in 2050 compared to the BAU and baseline prevalence (10 percent) and Cassava Republic has a higher prevalence of 14.26 percent in 2050.

When the prevalence rates are combined with the projected cattle populations, we see that the number of brucellosis-infected cattle is lower than the current number in the BAU scenario and higher in the Cassava Republic scenario. However, with a lower prevalence rate, the number of infected cattle in the Gifted by Nature scenario is lower, compared to all other scenarios and is less than half that in the Cassava Republic scenario.

Turning to the impact on humans we see that the number of human cases of brucellosis more than doubles under the BAU scenario and is 5 times higher than today under the Cassava Republic scenario. The Gifted by Nature scenario shows a decrease relative to today and is less than half of that in the business as usual scenario and a more than a tenth the projected number of Cassava Republic.

Figure 5. Human cases of brucellosis from cattle



The financial cost of zoonotic disease can be broken down into the costs to the livestock sector and the costs in terms of human public health. Of these two elements, the human health costs component is far and away the largest. In the table we see that all three scenarios show a significantly higher combined cost to society in 2050 compared to today with Cassava Republic being the highest. The Gifted by Nature scenario projects total costs less than a third of those projected for Cassava Republic.

Figure 6. Economic burden of brucellosis

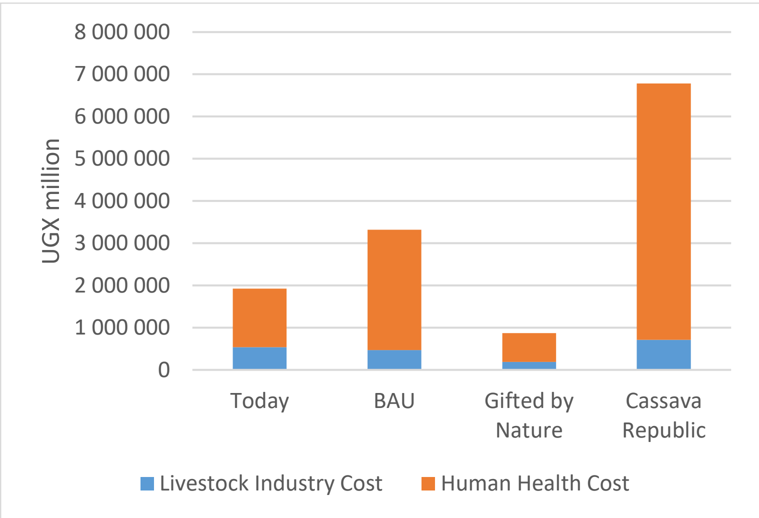


Table 1. Scenario results for beef cattle – brucellosis, water use and greenhouse gas emissions

	2015	2050	2050	2050
	Today	BAU	Gifted by Nature	Cassava Republic
Number of animals	6 745 371	5 862 498	6 400 122	6 400 122
Animal prevalence	10.0%	10.0%	3.63%	14.26%
Number of infected animals	674 537	586 250	232 621	912 500
Number of human cases	727 787	1 911 276	453 007	4 063 188
Livestock industry cost*	535 863	465 726	190 977	708 910
Human health cost*	1 386 412	2 856 271	676 987	6 072 156
Total cost to society*	1 922 275	3 321 997	867 964	6 781 066
Water footprint	2.72%	2.36%	4.04%	2.52%
GHG footprint	22.46%	7.43%	9.32%	8.81%

*UGX million

The environmental impacts are measured by the water and CO_2-equivalent emissions of animals. The water footprint represents the percentage of available water in Uganda consumed by the animals and the GHG footprint is the percentage of expected total CO_2 emissions from all sources. These projections vary by scenario to the extent that the animal population varies by scenario and by production system since GHG and water use per animal are higher in more intensive, industrial (feedlot) systems. Hence, we see that the water footprint of cattle in Uganda for the Gifted by Nature scenario is the highest of all scenarios with a predicted footprint of 4 percent of the available supply in 2050. The GHG footprint for 2050 for Gifted by Nature is lower than that of today (around 9 percent of all projected CO_2 emissions), while the Cassava Republic footprint is slightly lower.

Cattle - bovine tuberculosis

Projected prevalence rates (Table 2) for bovine tuberculosis (TB) in cattle are lower than for brucellosis. Current (2015) prevalence is estimated 4.3 percent and stays flat under the business as usual scenario. However, the scenario inputs predict an increase to 5.7 percent by 2050 with the Cassava Republic scenario and a reduction to 1.5 percent for Gifted by Nature. This results in proportionally fewer infected Cattle in 2050 under Gifted by Nature compared to Cassava Republic.

The human public health impacts follow a similar pattern across scenarios. From an estimated 17 000 cases today, the model shows an increase to over 46 000 human cases by 2050 under the business-as-usual scenario and nearly 90 000 for Cassava Republic. But under the Gifted by Nature scenario the projected number of cases in Uganda in 2050 is less than the number today.

Table 2. Scenario results for cattle – bovine tuberculosis

	2015	2050	2050	2050
	Today	BAU	Gifted by Nature	Cassava Republic
Number of animals	6 745 371	5 862 498	6 400 122	6 400 122
Animal prevalence	4.28%	4.28%	1.48%	5.67%
Number of infected animals	288 469	250 713	94 462	363 601
Number of human cases	17 553	46 097	10 374	91 309
Livestock industry cost*	245 353	213 240	79 182	303 098
Human health cost*	373 510	799 855	180 014	1 584 358
Total cost to society*	618 863	1 013 094	259 197	1 887 455

*UGX million

In terms of the financial burden of bovine TB the total costs are much less than for brucellosis which is expected given the lower prevalence rate. However, we see that the distribution of the cost falls more heavily on public health than on the livestock industry in all scenarios. The Gifted by Nature scenario total costs to society are less than one-sixth those of Cassava Republic and a quarter the costs of Business as Usual.

Poultry - salmonellosis

Turning next to salmonellosis in poultry we can see (Table 3) that prevalence rates in poultry in the base year, and in the scenarios are higher than in the two zoonotic diseases in cattle. The number of infected birds increases in all three scenarios compared to the base year with Cassava Republic having the fewest infections in 2050 due to fewer projected poultry numbers. We see that the number of human cases falls from 16 150 in the base year to 7 699 in 2050 under Gifted by Nature and is less than a tenth of the projected number in 2050 under Cassava Republic (78 944). The Gifted by Nature result may seem counter-intuitive since the number of infected poultry increases while the number of human infections decreases relative to the base year. The reason for this is a combination of factors; first, the number of poultry farmers is reduced in a more intensive system lowering exposure and second, we simulated interventions under Gifted by Nature. The costs to the industry and to human health follow a similar pattern. Environmentally, while the water and GHG footprints increase in most scenarios by 2050 relative to the base year, the footprints are smaller compared to cattle.

Table 3. Scenario results for poultry – salmonellosis

	2015	2050	2050	2050
	Today	BAU	Gifted by Nature	Cassava Republic
Number of animals	34 566 426	154 455 508	173 077 281	47 627 517
Animal prevalence	5.78%	5.78%	2.08%	8.06%
Infected animals	1 998 370	929 450	3 606 619	3 841 038
Human cases	16 150	42 412	7 699	78 944
Livestock industry cost*	45 909	205 139	87 248	83 308
Human health cost*	213 549	458 800	83 285	853 982
Total cost to society*	259 458	663 939	170 532	937 290
Water footprint	0.07%	0.29%	0.47%	0.08%
GHG footprint	1.01%	1.72%	3.39%	0.29%

*in UGX million

Table 4 shows the modeling results for HPAI in poultry. Base year prevalence is estimated to be low, at 0.03 percent. It stays steady under the BAU scenario but is expected to increase to 0.08 percent in the Cassava Republic scenario. Baseline data for Uganda showed no human cases of HPAI so none are projected in the model. This implies that the only costs are those to the poultry industry as show in Table 4. There are no cases of human infection projected.

Table 4. Scenario results for poultry – highly pathogenic avian influenza

	2015	2050	2050	2050
	Today	BAU	Gifted by Nature	Cassava Republic
Number of animals	34 566 426	154 455 508	173 077 281	47 627 517
Animal prevalence	0.03%	0.03%	0.003%	0.08%
Infected animals	10 482	46 839	4 372	36 216
Human cases	0	0	0	0
Livestock industry cost*	473	2 114	197	1 634
Human health cost*	0	0	0	0
Total cost to society*	473	2 114	197	1 634

*UGX million

4. Discussion

Livestock scenarios were developed for cattle and for poultry in Uganda. The Gifted by Nature scenario is a Uganda of the future with good governance and a prospering economy and the Cassava Republic scenario is a Uganda with poor governance and a stagnating economy. The Gifted by Nature scenario envisions a future with livestock in more intensive systems, negative growth rates of cattle and more consumers of animal products. By contrast, the Cassava Republic scenario is a Uganda in which the production systems remain largely traditional, the animal population grows more slowly and fewer humans are exposed to animals who may be diseased. Water use per cattle is also significantly higher in Gifted by Nature than other scenarios. A business-as-usual scenario was also developed that maintained 2015 levels of the livestock scenarios.

Modelling results show significant differences between the impacts of the scenarios over a 35-year timeframe on animal and human health and the environment. Of the three zoonoses studied, the burden of disease is the highest for brucellosis in cattle for all scenarios. In the Cassava Republic scenario almost 900thousand cattle are expected to be infected with brucellosis by 2050 and 4 million people. In the more optimistic Gifted by Nature scenario, more than 232 thousand cattle will be infected with brucellosis and 453 thousand people. The costs of brucellosis are significant reaching 1.3 percent and 0.2 percent of expected GDP by 2050 in the Cassava Republic and Gifted by Nature scenarios respectively. Moreover, the environmental impacts of increased numbers of cattle is worrisome for the Gifted by Nature scenario; water use for cattle is expected to increase by nearly 50 percent and contribute nearly 9 percent of all GHGs in Uganda in 2050.

Poultry scenario projections for salmonellosis show a lower burden of disease but are still of concern. Close to 2.1 million and 8.1 million birds are expected to be infected with salmonellosis by 2050 under the Gifted by Nature and Cassava Republic scenarios respectively. The number of humans infected with salmonellosis is projected as 8 thousand and 79 thousand for the same scenarios in 2050 respectively. No human cases of HPAI are projected with the baseline data available. The total economic burden of salmonellosis and HPAI is expected to reach 0.03 percent and 0.17 percent of GDP for Gifted by Nature and Cassava Republic respectively by 2050.

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Appendix

Figure A1. Uganda: 2050 beef cattle scenarios

QUININE JUICE

In Quinine Juice, the pastoral system (35 percent) comprises the largest share of beef cattle herd, followed by agro-pastoral and commercial ranching (25 percent each). Commercial ranching produce above 45 percent of all beef in the country. Pastoral and agro-pastoral systems reduced because of the smaller land available. In general, there are improvements in breeds, animal health and carcass weights. The general demand for livestock products is higher than in 2018, and this demand is partially satisfied by imports. The domestic production is mainly consumed in the country. Although endemic zoonoses are on decreasing trend, the antimicrobial use is high fuelling the occurrence of antimicrobial resistance, and the increased human livestock interaction might bring RVF or CCHF outbreaks in the commercial ranching systems. There is environmental degradation, loss of biodiversity and in ranching systems, encroachment of forest cover. The revenue contribution to households increased, who benefit from improved standard of living due to increased incomes from cattle.

GIFTED BY NATURE

The number of cattle heads reduced with respect to 2018 (-5 percent), but production increased over 200 percent. Commercial ranching has the largest share of beef cattle herd (30 percent) followed by semi-intensive and pastoral (both 25 percent). A fraction of the total herd transited into intensive systems (feedlot), not present in 2018. The private investment in animal health increased in tandem with the public funds. The access to veterinary services is high in all production systems. Breeds are improved, as well carcasses weights. Demand for livestock products is much higher. Domestic production partially satisfies the domestic demand that is supported by imports and consumption of other meats as game and fish. Endemic zoonoses are lower, but at a high social cost in terms of treatment. Antimicrobial use is high fueling the occurrence of antimicrobial resistance and the risk of emerging diseases is still present, especially in the semi-intensive and ranching systems. Although the high investments in the livestock sector, there is still some environmental degradation, loss of biodiversity, forest cover encroachment and env. pollution. The number of people directly employed on beef cattle rearing is lower but the contribution to income is higher.

CASSAVA REPUBLIC

Beef cattle herd remains slightly lower to 2018 population. Productivity remains the same or slightly lower, with lower carcass weights. Agro-pastoral and pastoral are the largest systems (over 67 and 20 percent of the total beef cattle herd). In this subsistence economic framework, individual cattle herds are generally smaller. In the agro-pastoral, breeds are mainly indigenous and there is limited investment in farm infrastructure and disease control. Pastoral is characterized by ethnic groups and unique challenges. The pastoral system is dominant in the NE districts, the 98 percent of the herd are local breeds with limited access to animal health services and rarely vaccinated. Semi-intensive is below 9 percent share of beef population and farms are located in peri-urban and urban areas. Commercial ranching is the only system with substantive investment in animal health, and it is mainly found in the SW and central regions. Although consumption per capita stagnated, the demand is higher due to the population growth. Production does not satisfy domestic demand and processing and marketing are not well developed. Incidence of zoonoses in humans is higher than in 2018. Raised household expenses on health care, within already constrained conditions. Emerging diseases as well as AMR are causing severe problems. Total GHG emissions didn't change significantly but pastures are severely degraded and biodiversity is greatly reduced. The number of cattle-keeping households marginally increased while the livelihood income declines.

DRAINED PEARL

Beef cattle herd remains close to 2018 population and total meat production increases by 25 percent. The main production system is agro-pastoral (more than 60 percent of beef cattle herd). Commercial ranching and semi-intensive are the two systems that have some improvements in animal health. Group ranches are stablished in previous pastoralist areas. The higher population raises the total demand for meat but the low incomes force the per capita consumption to stagnate. Domestic beef production cannot satisfy the domestic demand and processing is not well developed. The prevalence of zoonotic diseases is lower than that of 2018 due to better access to animal and public health services by low-income livestock keepers and due to targeted government disease control programs. Overall, total GHG emissions from beef systems have not changed significantly with most GHGs attributable to the agro-pastoral system. Grassland degradation has been controlled and even been reversed in some parts of the country as result of sustainable group ranching schemes. The number of cattle-keeping households has marginally increased and the livelihood support provided by cattle to is slightly higher than in 2018 due increased productivity. Employment opportunities along the beef cattle value chain remain limited.

Figure A2. Uganda: 2050 poultry (chicken meat) scenarios

QUININE JUICE

In Quinine Juice, the largest system for poultry meat production will be the intensive (70 percent of national flock) with a sharp reduction on the free range. National poultry flock will growth by 400 percent and the productivity increase will bring unprecedented level of poultry meat production. This scenario attends to the will of the dictatorship to deliberately support the intensive system and poultry meat industry (with a number of state slaughterhouses). Intensive poultry farms are big with modern infrastructures and stringent adherence to set standards of production, processing and marketing. Farms are majorly stated-owned (distorted marked forces) with strict biosecurity measures and adequate financing for this kind of farming. However, the rest of production systems do not benefit from the dictatorship will. Semi-intensive systems in Quinine Juice has limited capital and financing to farmers. Farmers are forced to form cooperatives for ease of marketing, monitoring and processing (coops sell the birds to the state-owned abattoirs, where prices are fixed by the state). In free-range systems, the birds are scavenging and serving the interest of the rural HH. Free ranging birds are only allowed in villages and not allowed in the cities. Farmers collectively better control diseases. In general, consumption per capita of poultry meat increases and the country exports. Prevalence of zoonotic diseases and human mortality is reduced. AMU is regulated and lower, thus reduces the risk of exposure to humans. Overall, the intensive system is impacting more on public health that the others. There is biodiversity loss and water, soil and air pollution because there is a focus on production and not on environment. The no. of households keeping poultry is lower but the income contribution in intensive and semi intensive is higher than in the past. Value-chain employment increases in the intense and semi-intense.

GIFTED BY NATURE

The flock size increases by 400 percent and the productivity increases in all the production systems. The intensive system has the largest share (60 percent of total flock for meat production), followed by semi-intensive (30 percent). In Gifted by Nature, consumers are richer and demand better quality meat, which reflects on all the production systems and it is guaranteed by standards. In the intensive system, chicken are reaching slaughter weight at much lower weeks. There is breeding improvement, which raise carcass weight on average to 2 kg. The size of the farms is bigger but not fully automated because of animal welfare. Biosecurity measures are high and there is limited use of chemicals with a strict regime for suing antimicrobial agents, including adherence to withdrawal periods. Semi-intensive systems serves primarily the domestic market (high-income customers able to discern the different tastes), with a tastier meat than in intensive. Many semi-intensive farms are moved to villages and the average flock size and carcass weight increase. Biosecurity is high, the risk of outbreaks is low and the use of antibiotics is checked at some extend. Free-range decreased, it is present in rural areas but it is maintained because of taste reasons (90 percent of the production is for home consumption). Better housing and feeding. People are knowledgeable about disease control, novel vaccines and drugs are readily available. Consumption pc much higher with formal commercialization (except for free-range). Most people are aware about food safety and animal welfare. Consumption preferences for processed chicken products, which take less time to be prepared. 'Gifted by nature' Uganda is exporting chicken. Control and management of diseases is improved, the strong institutions allow for preventive measures and policies. The overall impact of birds on environment is higher than in the past. The strong institutions regulate waste management properly. Water consumption is higher and sanitary chemicals for cleaning are a risk for the water and soil. In 2050 there are improved breeds and local breeds are in disadvantage. Many farms merge and others disappear, others are forced to shift to rural or peri-urban areas. The number of farmers is lower with higher income.

CASSAVA REPUBLIC

In Cassava republic, the drop in productivity overcomes the growth in flock size, amounting a 5 percent decrease in meat production. 87 percent of national poultry flock for meat is free-range and the intensive is a marginal system (3 percent). Intensive reduced because of the declining economy, reduced demand, high costs of poultry feeds, fake feeds on market, scarce vaccines and drugs, poor housing infrastructure, and high incidence of poultry diseases. Semi-intensive is on a declining trend as well, where prevalence of poultry diseases is high with high impact due to poor disease management. There are frequent thefts and predation. Most birds are sold to the formal market under the semi-intensive. Free-range is kept by 70 percent of HH in Uganda. It is characterized by inappropriate feeding. Disease prevention and control and housing practices are lacking, negatively impacting on high mortality rates due to diseases and parasites. The consumption of chicken per capita is much lower than in the past. The awareness on food safety is low or absent. The demand is not met by the local production. In the free-range, the outbreaks of emerging and re-emerging infectious diseases are on increase due close interaction among birds and neighborhoods. The need of manure as fertilizer reduces their environmental impact, although water consumption and biodiversity might suffer. Free-ranging contribute around 30 percent of HH income, while intensive and semi-intensive benefit a lighter share of the population.

DRAINED PEARL

In Drained Pearl, productivity stagnates or slightly decreases. In addition, the growth rate of the national flock is below population growth and the most spread production system is free-range (72 percent of national flock for meat production). The smallest system is intensive (8 percent flock), it has been on a declining trend over the years due to reducing purchasing power, reduced demand and high cost of feed and unsupportive infrastructure. Intensive system is commercially oriented with high investment in animal health. Up to 100 percent of the farmers use antibiotics under this system. Semi-intensive system has reduced av. flock per farm. The prevalence of poultry diseases is fair because of the good veterinary regulations, and most birds are sold to the informal markets. Free-range are kept by about 60 percent of the HH, usually in small flocks (10–20 birds), for self-consumption (30 percent) or cash (25 percent), with poor animal health and housing practices. In general, the consumption per capita is much lower than in the past. Demand is not met by domestic production and the deficit is met by imports. The awareness on food safety is high and rising. Free-range has the highest public health impact, although mitigated by the regulatory laws. Prevalence of endemic zoonoses is higher but the impact is partially mitigated. Free-range system degrades land because of scavenging. In intensive systems, manure is used in crop lands (lower pollution). A much higher number of HH keep free-range chickens, but flocks are smaller and provide near nil employment opportunities.

Table A1. Uganda - cattle scenarios

Future shares of each production system for each scenario

Animal production systems - Shares	**2015 share**	**2050 share**	**2050 share**
	Baseline	**Gifted by Nature**	**Cassava Republic**
Semi-Intensive	2.2%	25.0%	8.6%
Agro-pastoral	49.2%	20.0%	67.2%
Pastoral	41.0%	25.0%	20.3%
Commercial ranching	7.6%	30.0%	3.9%
Total	100.0%	100.0%	100.0%

Animal population growth rates for each scenario

Animal population growth	**Baseline**	**Gifted by Nature**	**Cassava Republic**
Number of animals	6 745 371	6 408 102	6 400 000
Scenario growth rates	-0.40%	-0.15%	-0.15%

Percent of the population exposed to animals in the present and future

Populations exposed to animals	**Baseline**	**Gifted by Nature**	**Cassava Republic**
% of people in contact with animals	2015	2050	2050
Consumers of animal products	26%	62%	20%
Livestock keepers	28%	10%	30%
Total population	34 131 400	101 872 981	101 872 981

Water use and GHG emissions per animal in the present and the future

Water	**Baseline**	**Gifted by Nature**	**Cassava Republic**
	2015	2050	2050
Total availability in country	285 000 000 000	285 000 000 000	285 000 000 000
Semi-intensive	1 288	1 813	1 240
Agro-pastoral	1 172	1 660	1 123
Pastoral	1 074	1 367	1 025
Commercial ranching	1 340	2 233	1 340
Enteric fermentation (kg CH_4)	2015	2050	2050
Semi-intensive	124.40	124.40	124.40
Agro-pastoral	91.60	91.60	91.60
Pastoral	66.80	66.80	66.80
Commercial ranching	95.20	95.20	95.20
CO_2 per capita (MT/person)	0.13	0.13	0.13
Total GHGs per capita in metric tons	1.54	1.54	1.54

Table A2. Uganda poultry scenarios

Future shares of each production system for each scenario

Animal production systems - Shares	**2015 share**	**2050 share**	**2050 share**
	Baseline	**Gifted by Nature**	**Cassava Republic**
Intensive	24.8%	60.0%	3.0%
Semi-intensive	20.1%	30.0%	10.0%
Free-range	55.1%	10.0%	87.0%
Total	100.0%	100.0%	100.0%

Animal population growth rates for each scenario

Animal population growth	**Baseline**	**Gifted by Nature**	**Cassava Republic**
Number of animals	34 566 426	172 832 130	47 701 668
Scenario growth rates	4.37%	4.71%	0.92%

Percent of the population exposed to animals in the present and future

Populations exposed to animals	**Baseline**	**Gifted by Nature**	**Cassava Republic**
% of people in contact with animals	2015	2050	2050
Consumers of animal products	9%	47%	7%
Livestock keepers	51%	35%	49%
Total population	34 131 400	101 872 981	101 872 981

Water use and GHG emissions per animal in the present and the future

Water	**Baseline**	**Gifted by Nature**	**Cassava Republic**
	2015	2050	2050
Total availability in country	285 000 000 000	285 000 000 000	285 000 000 000
Annual use per animal - Intensive	4.45	7.41	3.34
Annual use per animal - Semi-intensive	5.19	8.34	3.71
Annual use per animal - Free-range	5.93	7.41	5.19
Enteric fermentation (kg CH_4)	2015	2050	2050
Emission factor - Intensive	1.96	1.96	1.96
Emission factor - Semi-intensive	0.20	0.20	0.20
Emission factor - Free range	0.36	0.36	0.36
CO_2 per capita (MT/person)	0.13	0.13	0.13
Total GHGs per capita in metric tons	1.54	1.54	1.54

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