Food and Agriculture
Organization of the
United Nations

AFRICA SUSTAINABLE LIVESTOCK 2050

Livestock growth, public health and the environment

ETHIOPIA

A quantitative assessment

USAID
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Preparedness&Response
ONE HEALTH IN ACTION

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Food and Agriculture Organization of the United Nations
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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 Ethiopian 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 Food and Agriculture Organization (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 livestock scenarios for Ethiopia 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 cattle sector in Ethiopia, with a specific focus on the impact of zoonotic diseases on public health in the year 2050. Section four presents conclusions.

2. Ethiopia 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 Ethiopia, in the next 35 years, the aggregate consumption of all livestock products will more than double, with higher growth for poultry (eggs and meat), pork and milk. On an annual basis, demand will grow between 2.2 percent for milk to over 4.4 percent for poultry, which translate in major increases in volume terms. For example, the volume of milk and beef consumed will increase by 5 128 and 855 thousand tons in the next 35 years, respectively, with aggregate consumption estimated at almost 9 600 thousand tons for milk and 1 300 thousand tons for beef in 2050.

Figure 1. Ethiopia: Current and projected consumption of livestock products, 2015-2030-2050

	Estimated consumption, 000 tons			Growth rate, 2015–2050	
	2015	2030	2050	percentage	annual
Milk	4 458.3	6 987	9 586	115%	2.2%
Beef	444.7	773.1	1 299.6	192%	3.1%
Mutton & Goat	173.0	282.2	457.5	164%	2.8%
Poultry	71.8	124.9	217.3	203%	3.2%
Eggs	30.4	62.6	94.3	210%	3.3%
Pork	2.2	3.8	6.7	205%	3.2%

Source: FAO Global Perspectives Studies (2018)

As a response to the growing demand for animal source foods, Ethiopian livestock producers are anticipated to make investments that increase production and productivity. It is estimated that, between 2015 and 2050, production of all types of meat and that of milk will increase by 203 and 234 percent, respectively. Production will increase from a minimum of 157 percent for mutton and goat meat to 377 percent for poultry meat, with annual growth rates ranging from 2.7 to 4.6 percent.

Figure 2. Ethiopia: Current and projected production of animal source foods, 2015-2030-2050

	Estimated production, 000 tons			Growth rate, 2015–2050	
	2015	2030	2050	percentage	annual
Milk	3 711.2	6 616	12 378.1	234%	3.5%
Beef	341.9	565.6	957.5	180%	3.0%
Mutton & Goat	183.4	299.3	470.8	157%	2.7%
Poultry	92.3	229.8	440.2	377%	4.6%
Eggs	62.7	150.5	280.2	347%	4.4%
Pork	2.4	4.5	7.5	209%	3.3%

Source: FAO Global Perspectives Studies (2018)

2.1. Scenarios for cattle 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, Ethiopia stakeholders have articulated long-term (2050) scenarios for the cattle 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 Ethiopia, 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 Ethiopia 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 good or bad depending on the level of inclusiveness, accountability and stability of the government, and the economic system, which can be resilient and growing or fragile and stagnant. Figure 3 provides a narrative of the possible four futures of Ethiopia associated to alternative interactions between the governance system and the economic system in 2050. Stakeholders named the different scenarios Wakanda Dreamland (reference to the ideal country of Wakanda in the movie Black Panther), Yebeyi Temelkach (an Amharic expression for some are eating, while others are watching), Ergiman (an Amharic expression for being cursed) and Ita Fentash (an Amharic expression for someone trying to do something but being out of luck and not succeeding).
- Developed a narrative of the cattle sector in the different scenarios. Stakeholders have first agreed on the number and share of animals raised in the different production systems 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 summarises the narratives for the cattle production systems in the different 2050 scenarios.

The 2050 cattle scenarios show that, in all possible futures there could be issues associated with zoonoses and emerging infectious diseases. In particular, because of expanded human and in some scenarios, animal populations, in all cases 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 spread 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 owing to infectious diseases that, today, are effectively treated. In this context, a first step for the government to design effective policies is to have some quantitative assessment of the impact of zoonoses or AMR on society, which helps to assess the cost effectiveness of alternative programs that can be put in place to prevent, control and manage zoonotic diseases and AMR.

Figure 3. Ethiopia: 2050 country scenarios

Governance: Highly stable, open democracy

Collapsed and fragile economy

Booming, resilient economy

ITA FENTASH

Ethiopia has significantly better rule of law and higher participation of citizens' in decision making. Infrastructure is poor due to lack of resources, but available to everyone. The country aspires to reach lower-middle income level. There is a slight increase of the middle class, poverty is still high. Agriculture is fragile due to the challenges coming coupled with climate change. Importation is high and consists of mainly food products. Health services have become better as well as awareness of food safety issues.

WAKANDA DREAMLAND

Ethiopia has guaranteed rule of law and a stable democratic system. The country achieved a lower-middle income country status. The middle class includes 10 percent of the population. The 45 percent of Ethiopians dwell in urban centers and adult literacy has reached 80 percent. The population stabilized at 150 million thanks to good family planning. Agriculture accounts for 30 percent of the GDP, the economy is diverse and trade balance has improved. Access to health services, disease prevention and control have improved, and life expectancy is high. The country developed a well working environmental protection programme.

ERGIMAN

The rule of law is not respected and the safety of citizens is threatened. Ethiopians hardly participate in democratic processes. Infrastructure and public services are in terrible condition. Ethiopia is a low-income country with deteriorating per capita income. There is no family planning, the population is above 200 million, with high poverty rates. High degree of rural-urban migration and emigration. The failing agricultural sector contributes less to GDP and employment. Access to health services has deteriorated, 90 percent doesn't have access to basic sanitation services. There is no policy to protect the environment.

YEBEYI TEMELKACH

Ethiopia's rule of law is worse than in 2015, and there is rampant lawlessness. Participation in democratic processes is low. There is however an improvement in infrastructure due to booming economy. The country achieved a lower middle-income status that comes coupled with much inequality. The poverty rate slightly declines. Fifty percent of the population are urban dwellers. The share of agriculture in GDP and employment declined. There are very good private health services but many cannot afford them. Pollution is high due to population, urbanization and industrialization.

Governance: Highly unstable and monstrously corrupt

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

3.1. One Health Policy Model

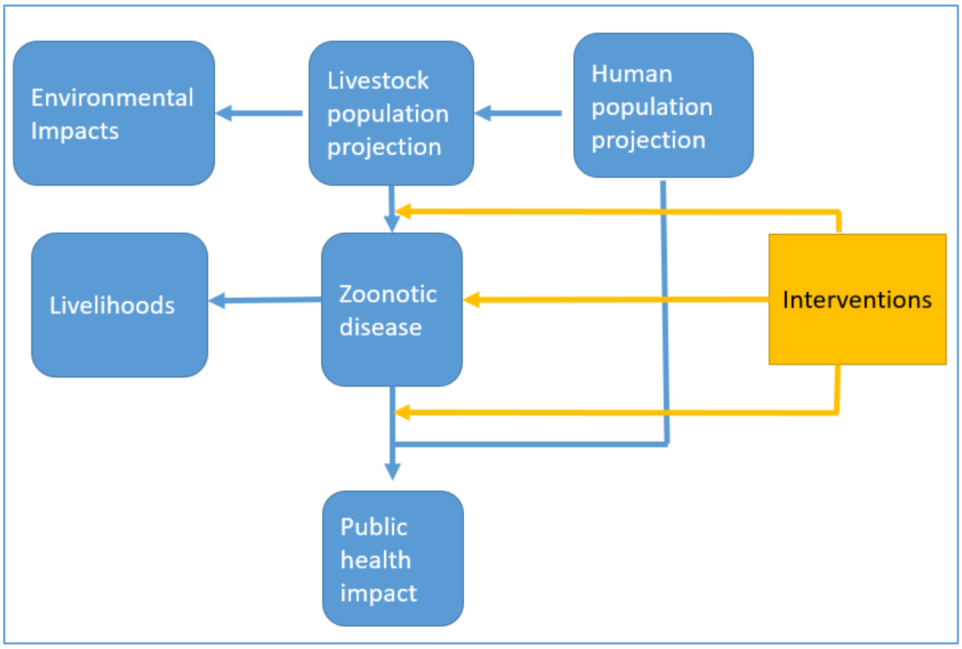
Livestock scenarios, while consistent stories, lack the quantitative dimensions that are needed to better assess the pros and cons of alternative policy interventions.

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 greenhouse gas (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, animal products originating from them, or both. 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 systems. 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 use and GHG emission 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, bovine tuberculosis, salmonellosis and anthrax

Scenario inputs

The stakeholder-articulated long-term future scenarios described above in section 2.1 for production systems for beef and dairy cattle paint a broad vision of Ethiopia'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 the 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 Wakanda Dreamland), and the scenario in the lower left-hand quadrant corresponding to poor governance and a stagnating economy (Ergiman). We also simulated a business-as-usual scenario (BAU) that maintained 2015 levels of the model's parameters.

These inputs are presented in the Table A1 in the appendix which shows 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 Ethiopia 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 Wakanda Dreamland 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 Ergiman scenario is interpreted to be an Ethiopia 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 Wakanda Dreamland scenario and to decrease for the Ergiman 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 Wakanda Dreamland and Ergiman scenarios we used the parameters listed in the tables in the previous section. The results are presented in Table 2 below.

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 intensive dairy and beef cattle in Ethiopia the Wakanda Dreamland and the business-as-usual scenarios showed increased numbers cattle by 2050 compared to the 2015 (Today) population. Overall, the Wakanda Dreamland scenario projects a slightly lower number of animals compared to the business-as-usual and the Ergiman scenario even fewer.

In terms of prevalence, Wakanda Dreamland has a lower prevalence rate (0.75 percent) in 2050 compared to the BAU and baseline prevalence (1.11 percent) and Ergiman has a higher prevalence of 1.70 percent in 2050.

When the prevalence rates are combined with the projected beef and dairy cattle populations in intensive production systems, we see that the number of brucellosis-infected cattle is higher than the current number in both the BAU and Ergiman scenarios. However, with a lower prevalence rate, despite a higher cattle population, the number of infected cattle in the Wakanda Dreamland scenario is lower, even compared to today.

Turning to the impact on humans we see that the number of human cases of brucellosis nearly doubles under the BAU scenario and is nearly four times the estimated current number by 2050 under the Ergiman scenario. The Wakanda Dreamland scenario, however, shows a slight decline relative to today, despite an increase in both cattle and human populations.

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 Ergiman being the highest. It should be noted that human costs increase proportionally more than the number of human cases; largely because the costing of DALYs is a function of the assumed growth in per capita income, which is significant over a 35-year period. The Wakanda Dreamland scenario projects total costs of less than a quarter of those projected for Ergiman.

Figure 5. Human cases of brucellosis

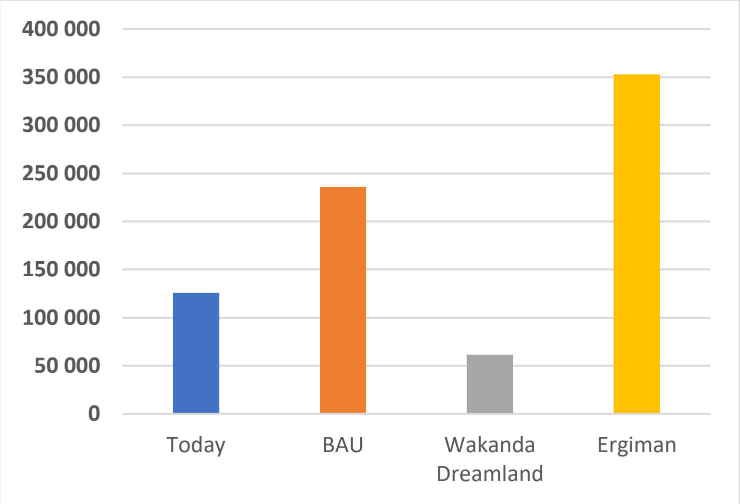
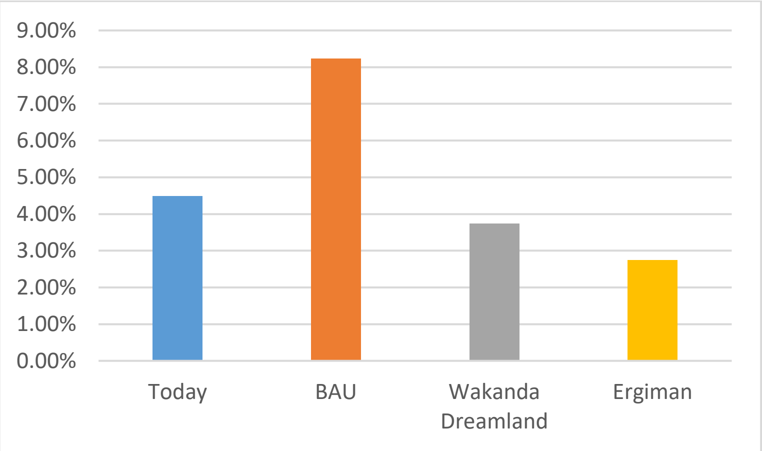


Table 1. Scenario results for cattle brucellosis, water use and greenhouse gas emissions

	2015	2050	2050	2050
	Today	BAU	Wakanda Dreamland	Ergiman
Number of animals	56 682 162	104 028 189	40 155 837	42 791 246
Animal prevalence	1.11%	1.11%	0.75%	1.70%
Infected animals	627 594	1 151 817	300 523	728 351
Human cases	125 719	236 141	61 337	352 898
Livestock industry cost*	5 442	9 998	2 841	5 966
Human health cost*	7 592	98 115	25 485	146 627
Total cost to society*	13 035	108 103	28 326	152 592
Water footprint	4.49%	8.24%	3.73%	2.75%
GHG footprint	32.4%	31.7%	15.4%	12.8%

*ETB million

Figure 6. Water footprint of cattle



The environmental impacts are measured by the water footprint and CO_2-equivalent emissions of animals. The water footprint represents the percentage of available water in Ethiopia 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 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 Ethiopia for the Wakanda Dreamland scenario, is higher than that of Ergiman (3.7 percent vs 2.7 percent respectively) in 2050. The GHG footprint for 2050 for Wakanda Dreamland is less than half that of today (around 44 percent of all projected CO_2 emissions), while the Ergiman footprint is the lowest.

Bovine tuberculosis

Projected prevalence rates (Table 2) for bovine tuberculosis (TB) in cattle are higher than for brucellosis. Current (2015) prevalence is estimated at 5.4 percent and stays flat under the business as usual scenario. However, the scenario inputs predict an increase to 6.9 percent by 2050 with the Ergiman scenario and a decrease to 4.8 percent for Wakanda Dreamland. This results in more infected cattle in 2050 under Wakanda Dreamland compared to Ergiman even though the number of cattle is less.

The human public health impacts follow a similar pattern across scenarios. From an estimated 4 835 cases today, the model shows an increase to over 9 000 human cases by 2050 under the business-as-usual scenario and over 10 000 for Ergiman. But under the Wakanda Dreamland scenario the projected number of cases in Ethiopia falls to 3 100.

Table 2. Scenario results for beef and dairy cattle – bovine TB

	2015	2050	2050	2050
	Today	BAU	Wakanda Dreamland	Ergiman
Number of animals	56 682 162	104 028 189	40 155 837	42 791 246
Animal prevalence	5.39%	5.39%	4.84%	7.27%
Number of infected animals	3 052 600	5 338 410	1 942 745	2 961 504
Number of human cases	4 835	9 082	3 135	11 912
Livestock industry cost*	45 403	83 327	37 525	39 221
Human health cost*	2 716	35 384	12 215	46 411
Total cost to society*	48 119	118 711	49 740	85 631

*ETB million

In terms of the financial burden of bovine TB the total costs are higher in 2050 under all three future scenarios compared to the base year with Wakanda Dreamland being the lowest of the three. The distribution of the costs between livestock industry and human health costs varies with the distribution of cases between animals and humans. So, we see that under Ergiman human health care costs are higher than livestock industry costs. But in Wakanda Dreamland and BAU human health costs are less than for the livestock industry.

Salmonellosis

Projected prevalence rates (Table 3) for salmonellosis in cattle are lower than for bovine TB. Current (2015) prevalence is estimated at 1.3 percent and stays flat under the business as usual scenario. However, the scenario inputs predict a slight increase to 1.92 percent by 2050 with the Ergiman scenario and a decrease to 1.27 percent for Wakanda Dreamland. With the projected growth in the cattle population on the business as usual scenario and a constant prevalence rate the number of infected cattle more than double by 2050 compared to current levels. The Ergiman scenario shows a small increase in the number of infected cattle relative to today despite the reduced cattle population because of the increase in prevalence. Wakanda Dreamland projects a smaller number of infected cattle.

The human public health impacts follow a similar pattern across scenarios. From an estimated 59 921 cases today, the model shows an increase to over 112 000 human cases by 2050 under the business-as-usual scenario and over 157 000 human cases for Ergiman. Under the Wakanda Dreamland scenario the projected number of cases in Ethiopia increases over the base year to just over 54 000 cases. This is driven largely by the increase in the population over the projection period.

In terms of the financial burden of salmonellosis, the total costs to society increase over the base year for all three scenarios with Wakanda Dreamland having the lowest overall costs in 2050. The 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.

Table 3. Scenario results for beef and dairy cattle – salmonellosis

	2015	2050	2050	2050
	Today	BAU	Wakanda Dreamland	Ergiman
Number of animals	56 682 162	104 028 189	40 155 837	42 791 246
Animal prevalence	1.34%	1.34%	1.27%	1.92%
Infected animals	757 551	1 390 326	509 841	820 840
Human cases	59 921	112 551	54 951	157 040
Livestock industry cost*	5 899	10 826	4 272	6 260
Human health cost*	5 424	70 708	34 522	98 658
Total cost to society*	11 323	81 534	38 794	104 918

*ETB million

Anthrax

Projected prevalence rates (Table 4) for anthrax in cattle are lower than for the other three zoonoses. Current (2015) prevalence is estimated at around 0.47 percent and again stays flat under the business as usual scenario. However, the scenario inputs predict a slight increase to 0.78 percent by 2050 with the Ergiman scenario but a similar decrease to 0.29 percent for Wakanda Dreamland. With the projected growth in the cattle population on the business as usual scenario and a constant prevalence rate the number of infected cattle almost doubles by 2050 compared to current levels. The Ergiman scenario shows a small increase number of infected cattle relative to today despite the reduced cattle population because of the increase in prevalence. Wakanda Dreamland projects an even smaller number of infected cattle because the projected prevalence rate is lower as is the number of cattle.

The human public health impacts follow a similar pattern across scenarios. From an estimated 11 487 cases today, the model shows an increase to over 21 thousand human cases by 2050 under the business-as-usual scenario and over 34 thousand human cases for Ergiman. Under the Wakanda Dreamland scenario the projected number of cases in Ethiopia decreases over the base year to fewer than 6 thousand cases. This, despite a larger population.

In terms of the financial burden of anthrax, the total costs are much higher than for brucellosis because of the high human mortality rate. This causes the distribution of the cost to fall more heavily on public health than on the livestock industry.

Table 4. Scenario results for beef and dairy cattle – anthrax

	2015	2050	2050	2050
	Today	BAU	Wakanda Dreamland	Ergiman
Number of animals	56 682 162	104 028 189	40 155 837	42 791 246
Animal prevalence	0.47%	0.47%	0.29%	0.78%
Infected animals	266 136	488 436	115 757	333 167
Human cases	11 487	21 576	5 091	34 782
Livestock industry cost*	2 590	4 754	1 127	3 242
Human health cost*	15 941	208 119	49 103	335 495
Total cost to society*	18 531	212 873	50 229	338 738

*ETB million

4. Discussion

Alternative scenarios were developed for Ethiopia and its cattle systems. The Wakanda Dreamland scenario is an Ethiopia of the future with good governance and a prospering economy and the Ergiman scenario is an Ethiopia with poor governance and a stagnating economy. A business-as-usual scenario was also developed that maintained 2015 levels of the livestock scenarios. The Wakanda Dreamland scenario envisions a future with livestock in more intensive systems, negative growth rates of cattle, increased productivity, and more consumers of animal products. By contrast, the Ergiman scenario is an Ethiopia in which the production systems remain largely traditional, the animal population and productivity grow also at a negative rate and fewer humans are exposed to animals which may be infected with zoonotic diseases. Water use per cattle is slightly higher in Wakanda Dreamland compared to Ergiman but significantly lower than that of BAU scenario.

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 four zoonotic diseases studied, the burden of disease is the highest for brucellosis in cattle for all scenarios. In the Ergiman scenario almost 728 thousand cattle are expected to be infected with brucellosis by 2050 and 352 thousand people. In the more optimistic Wakanda Dreamland scenario, more than 300 thousand cattle will be infected with brucellosis and 61 thousand people.

Bovine-TB is expected to infect around 3.1 million cattle in both scenarios by 2050 while infections of humans is lower than in brucellosis at 3 thousand and 12 thousand for Wakanda Dreamland and Ergiman respectively. Salmonellosis will affect 510 thousand and 820 thousand cattle in the end year respectively for the same scenarios. Anthrax has the lowest number of cattle infected in both scenarios, but the potential for the most human mortality.

The burden of the zoonotic diseases studied is significant. Environmentally, even with a declining cattle population, Ethiopia faces challenges in terms of water use and GHG emissions. The water footprint of cattle is expected to reach 3.7 percent of available water in 2050 under Wakanda Dreamland vs. 2.7 percent under Ergiman. Similarly, GHG emissions from cattle are projected to reach 46 and 38 percent of all CO_2 emissions in 2050 for the same two scenarios, respectively. The higher footprints under Wakanda Dreamland are a result of a more industrial-type production system which means each animal consumes more water or generates more methane.

The monetary costs to Ethiopia's economy of the four zoonotic diseases combined are expected to be significant. Modelling results show that the impact will reach over 1.2 percent and nearly 0.3 percent of expected GDP by 2050 in the Ergiman and Wakanda Dreamland scenarios, respectively, for all four zoonotic diseases combined.

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Appendix

Figure A1. Ethiopia: 2050 cattle scenarios

ITA FENTASH

There is a 15 percent increase in animal population with respect to 2015. The mixed crop-livestock sector's share decreased to 60 percent though it is still the largest production system. There is some increase in the share of pastoral/agro-pastoral (19 percent) and urban/peri-urban (18 percent) systems. Due to lack of large investments, there is no expansion of the commercial dairy and feedlot systems. The lack of resources do not allow significant improvements in productivity parameters, the only change is in the mixed crop-livestock system: the share of producing animals increased and some crossbred animals appeared, though the yields stay low due to lack of feed. There are no significant changes in animal health service availability due to lack of resources. However, there will be some improvement thanks to the government's low-cost awareness raising efforts. In case of an outbreak, the response from outside will be trade bans (though trade is not that strong due to the struggling economy). In the absence of competent veterinary services, endemic diseases will be present. Vaccines might not be transported due to lack of good infrastructure. Pastoralists are mostly affected by transboundary diseases, bovine TB remains a major issue in commercial dairy and urban/peri-urban systems, and brucellosis is still endemic, mostly prevalent in mixed-crop livestock systems. There is only some improvement in mortality rates due to diseases in the (semi-)intensive systems. Production losses due to zoonoses remain substantial. There are no significant changes in marketing practices. Due to lack of resources, the infrastructure is still not at a good quality level that makes reaching further markets difficult for farmers mainly in extensive systems. The level of antibiotics usage is high, and the drugs are obtained via informal channels in the extensive systems.

WAKANDA DREAMLAND

The cattle population in Wakanda Dreamland has significantly been reduced by 62 percent and reached about 40 million heads. This reduction, however, is accompanied by increases in herd sizes and productivity in the intensive commercial systems (dairy and beef) which usually keep improved genotypes. There is modest improvement of productivity in mixed crop-livestock and pastoral systems too where predominantly improved indigenous, some crossbreds and unimproved indigenous keep playing important roles. Water is readily available from natural as well as man-made sources. Productivity is high and milk yield per lactation usually ranges, on average, from 270 kg in pastoral to 3 500 kg in commercial dairy. Off-take rate is between 15 percent in mixed crop-livestock to 98 percent in feedlots and carcass yield per slaughtered animal ranges from 110 kg in pastoral to 180 kg in feedlot. Cattle systems generate 21 million tonnes of milk and 1.6 million tonnes of beef annually. Specialized veterinary services and standard vaccination and tick control are in place and are usually provided by private veterinarians. Public sector veterinary service plays only regulatory role. There is moderate to high level biosecurity and farm hygiene. Incidence of non-zoonotic diseases is generally less but due to high production levels, there is increased incidence of production diseases mainly in the intensive systems. Due to good and effective health regulatory frameworks in place, many of the endemic zoonotic diseases have been controlled but diseases like salmonellosis increase in prevalence. In Wakanda Dreamland, mortality and production loss due to diseases have dramatically decreased; however, new diseases are likely to emerge due to intensification. Producers have good awareness on AMR and its consequences and hence they follow proper use of antimicrobials.

ERGIMAN

Cattle population in Ergiman has significantly been reduced by 58 percent and reached about 42.5 million heads. This reduction, however, is not accompanied by increases in herd sizes and productivity. The contraction is due mainly to extremely fragmented and fragile land holdings. Productivity has generally deteriorated in all cattle systems and has worsened in crop-livestock and pastoral systems. Feed resources have been degraded and there is acute shortage of feed. Grazing is the predominant feeding system - animals scavenge whatever is available on degraded pastures, crop aftermath, and even road sides. Water is not readily available from natural as well as man-made sources. Productivity is low and milk yield per lactation usually ranges, on average, from 200 kg in pastoral to 2 000 kg in commercial dairy. Off-take rate is between 15 percent in pastoral to 30 percent in feedlots and carcass yield per slaughtered animal ranges from 80 kg in pastoral to 150 kg in feedlot. Cattle systems generate only about 2.1 million tonnes of milk and 0.7 million tonnes of beef annually. Veterinary services, standard vaccination and tick control are in bad shape; private sector service is non-existent. Farm biosecurity and hygiene are lacking. Incidence of non-zoonotic diseases is generally high and endemic zoonotic diseases are rampant. Mortality and production loss due to diseases have dramatically increased. Producers have less or no awareness on AMR and its consequences and hence they do not bother to follow proper use of antimicrobials.

YEBEYI TEMELKACH

As a result of governmental push, there is an increase in the share of commercial dairy (7 percent) and feedlot systems (10 percent). The cattle population has nearly doubled to 90 million heads. There are no significant productivity improvements, the only exception is the carcass weight in feedlots (180 kg/head). There is however a significant increase in the share of producing animals in all systems. Total milk production reaches 15 million tones, and total beef production is at 5 million tones. In terms of animal health services, there is an improvement in semi-intensive and intensive systems, no change in extensive systems. The government supports those systems that ensure the export. There is a decrease in animal disease (both endemic and (re-)emerging) prevalence, mortality and hence production losses in commercial dairy, feedlot and urban-peri-urban systems, while the situation in mixed crop-livestock and pastoral/agro-pastoral systems worsened. Antibiotics use decreased in the semi-intensive and intensive systems while it remained moderate in extensive systems. There are no significant changes in marketing practices. Feedlots are very concentrated on exports.

Table A1. Ethiopia - cattle scenarios

Animal population by production system (%) for each scenario

Livestock production system	Baseline	Wakanda Dreamland	Ergiman
Commercial dairy	2.54%	22.0%	1.0%
Feedlot	0.05%	5.0%	0.3%
Urban/Peri-urban	6.71%	5.0%	5.0%
Mixed crop livestock	76.84%	54.0%	83.8%
Pastoral/Agro-pastoral	13.87%	14.0%	10.0%
Total	100.0%	100.0%	100.0%

Animal population growth rates for each scenario

Animal population growth	Baseline	Wakanda Dreamland	Ergiman
Number of animals	56 397 526	40 000 000	42 529 791
Scenario growth rates	1.75%	-0.98%	-0.80%

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

Populations exposed to animals	Baseline	Wakanda Dreamland	Ergiman
	2015	2050	2050
Consumers of animal products	16%	63%	19%
Livestock keepers	68%	25%	39%
Total population (approximate)	101 000 000	150 000 000	188 000 000

Water use and greenhouse gas emissions per animal in the present and the future

Water	Baseline	Wakanda Dreamland	Ergiman
	2015	2050	2050
Total availability in country	936 000 000 000	936 000 000 000	936 000 000 000
Commercial dairy	740.98	1 010.43	673.62
Feedlot	1 010.43	1 212.51	1 010.43
Urban/Peri-urban	740.98	943.06	606.26
Mixed crop livestock	740.98	808.34	606.26
Pastoral/Agro-pastoral	740.98	740.98	538.89
Enteric fermentation (kg CH_4)	2015	2050	2050
Commercial dairy	218.00	218.00	218.00
Feedlot	472.96	472.96	472.96
Urban/Peri-urban	142.00	142.00	142.00
Mixed crop livestock	126.48	126.48	126.48
Pastoral/Agro-pastoral	170.12	170.12	170.12
CO_2 per capita (MT/person)	0.12	0.12	0.12
Total GHGs per capita in metric tons	2.02	2.02	2.02

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