Understanding the value and causes of mortality and production losses for beef cattle in East Java, Indonesia

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Abstract

Beef production is an important industry in Indonesia, especially in East Java. Understanding the economic value and causes of production losses can be used to inform investments into animal health. This study estimated the total value of animal health loss in beef cattle production in East Java and attributed this loss to infectious diseases, non-infectious diseases and external causes. Beef cattle population, reproductive performance, mortality, offtake and productivity were analysed using official statistics and values from the literature. Expert elicitation was used to estimate productivity in an Ideal Health scenario, free from disease impacts. The value of total cattle health loss in 2021 was estimated using the GBADs dynamic population model. Attribution of this loss to infectious diseases, non-infectious diseases and external causes was done using an expert elicitation process. Compared to the Ideal Health scenario, the total animal health loss was estimated at 961 million USD in 2021. For the burden attributions of the mortality loss, infectious diseases were believed as the major reasons (38 - 45% in all age groups), followed by non-infectious diseases (32 – 39 % in all age groups) and external causes (20 - 30% in all age groups). Similar results were seen on the burden attributions of the production loss. The study provides an initial estimate of the value and causes of animal health losses for beef cattle in East Java. These data can be used to inform policy and as a basis for further health investment in the beef cattle industry.

Keywords

Cattle, herd model, animal health loss, GBADs

1. Introduction

The beef industry holds notable economic importance for Indonesia. The value of the national beef herd and annual production are equivalent to around 15% of the national agricultural Gross Domestic Product (GDP) and almost 2% of overall GDP (Smith et al., 2024; USDA, 2024). At a more local level, beef production directly contributes to the income and livelihoods of millions of farmers through the sale of animals for meat and hides, and the use of manure as fertiliser. The industry also provides employment opportunities across the supply chain to farm labourers, animal health workers, butchers, and those involved in the transportation, processing, and retail sectors.

While beef cattle are raised nation-wide, the province with the largest cattle population is East Java, which is home to 3.1 million head and 31% of the national beef cattle herd (Statistics Indonesia, 2023). Most beef cattle in East Java are raised in intensive cut and carry systems based on crop residues and byproducts (Priyanti et al., 2015; Cowley et al., 2020). Farms are predominantly traditional smallholder cow-calf production systems, with some specialised growing and fattening operations, and a small number of commercial feedlots. Although there are no official statistics on the percentage distribution of smallholders and commercial beef farms in the province, it was estimated that 90% of cattle in Indonesia are from smallholders (Agus and Mastuti Widi, 2018).

For smallholders, beef cattle are a form of financial security and regular cash income used to support household needs (e.g., school fees, health costs, fertiliser) (Priyanti et al., 2015). Cattle are typically sold to village traders and prices are determined between farmers and traders based on liveweight, body condition score, breed and sex (Priyanti et al., 2012b) . Traders collect cattle at the village scale and then sell them at sub-district/district markets, where they are purchased by butchers. Butchers arrange slaughter and the beef is then sold by wet markets, food vendors, restaurants and sometimes supermarkets (Mahendri et al., 2012). Commercial cattle feedlots may contract directly with larger butchers, meat wholesalers or supermarkets (Waldron et al., 2012). Ante-mortem and post-mortem inspection are conducted at licensed slaughterhouses, although many cattle are slaughtered in unlicensed facilities where inspections are lacking.

Strong local demand for beef provides potential opportunities to grow the Indonesian beef industry, with associated improvements in food security and livelihoods. Domestic supply of beef products currently meets less than half of national demand (Agus and Mastuti Widi, 2018), and the Indonesian Government has multiple programs and policies aiming to increase local production. However, many smallholder farmers are still unable to fully capitalise on this opportunity, with productivity levels constrained by low cattle growth and reproduction rates and high calf mortality (Mayberry et al., 2016). Addressing these production challenges necessitates a thorough understanding of their scale and underlying causes (e.g., infectious diseases, parasites, or sub-optimal nutrition and management).

The Global Burden of Animal Diseases (GBADs) programme (Huntington et al., 2021; Rushton et al., 2021) provides a framework to quantify the volume of production losses and animal mortalities associated with different causes, and the cost of lost production and expenditure on health care at the farm gate. The difference between current production and what could be achieved in the absence of animal health problems (an Ideal Health scenario) is defined as the Animal Health Loss Envelope (AHLE) (Gilbert et al., 2023). Whilst not practically attainable under real world conditions, the AHLE provides an envelope for estimating disease burdens without double-counting the contributions of different causes (Gilbert, 2024). Using the GBADs approach, the aim of this study was to estimate the AHLE for beef cattle production in East Java in 2021 and to attribute the loss between infectious diseases (e.g., brucellosis), non-infectious diseases (non-contagious health issues e.g., malnutrition) and external causes (e.g., predation, heat stress)(Hughes et al., 2024). This information offers evidence to inform future animal health investments.

2. Methods

The AHLE for beef cattle production in East Java in 2021 was estimated using the modelling approach described by Meyer et al. (2025b) and Gilbert et al. (2023). This was then attributed to either infectious, non-infectious or external causes using an expert elicitation process as per (Larkins et al., 2023). The study focused on the beef cattle sector only and the other species present on beef farms were not included in the modelling. Loss estimations on other species were conducted in other case studies of GBADs.

2.1 Modelling approach

We modelled farm-gate gross margin of beef production under current conditions (Current scenario) and for two theoretical scenarios (Zero Mortality and Ideal Health) using the GBADs population dynamics model (https://github.com/GBADsInformatics/GBADsDPM.R) version 1.5 (Hughes et al., 2024). The total AHLE was calculated as the difference between the Ideal Health and Current scenarios (Figure 1). The value of production and mortality losses were then calculated as the difference between the Ideal Health and Zero Mortality, and Zero Mortality and Current scenarios, respectively.

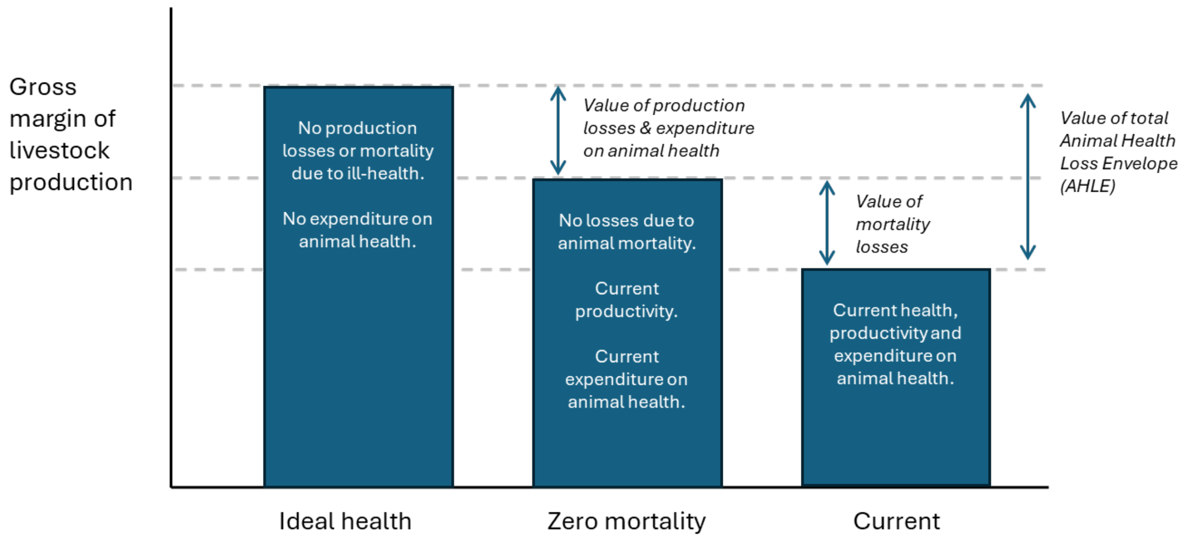

Figure 1. Schematic representation of the three modelled scenarios used to calculate the animal health loss envelope (AHLE) for beef cattle in East Java

The GBADs dynamic population model (Gilbert et al., 2023) is a modified version of the Dynmod herd dynamic model (Lesnoff, 2008), implemented in R (R Core Team, 2021; Hughes et al., 2024). The model uses data on population size and structure and production parameters to simulate changes in livestock population, resource use and output production. For the purposes of simulating the Indonesian beef production system the model was run using a monthly time step for 12-time steps to simulate a year of production and resource use. The medians from 10,000 iterations of modelling were used for calculation of the AHLE.

To represent the Indonesian beef industry, the population is split into 6 age-sex groups (male and female juveniles (<1 year), subadults (1-2 years old) and adults (>2 years old). Animals move from juvenile to subadult and subadult to adult groups at a constant rate (1/12). Reproduction from adult females generates new juveniles that are split 50:50 between juvenile male and female groups. Animals leave the population at age-group specific mortality rates (all), planned offtake rates (subadults and adults) and cull rates (adults).

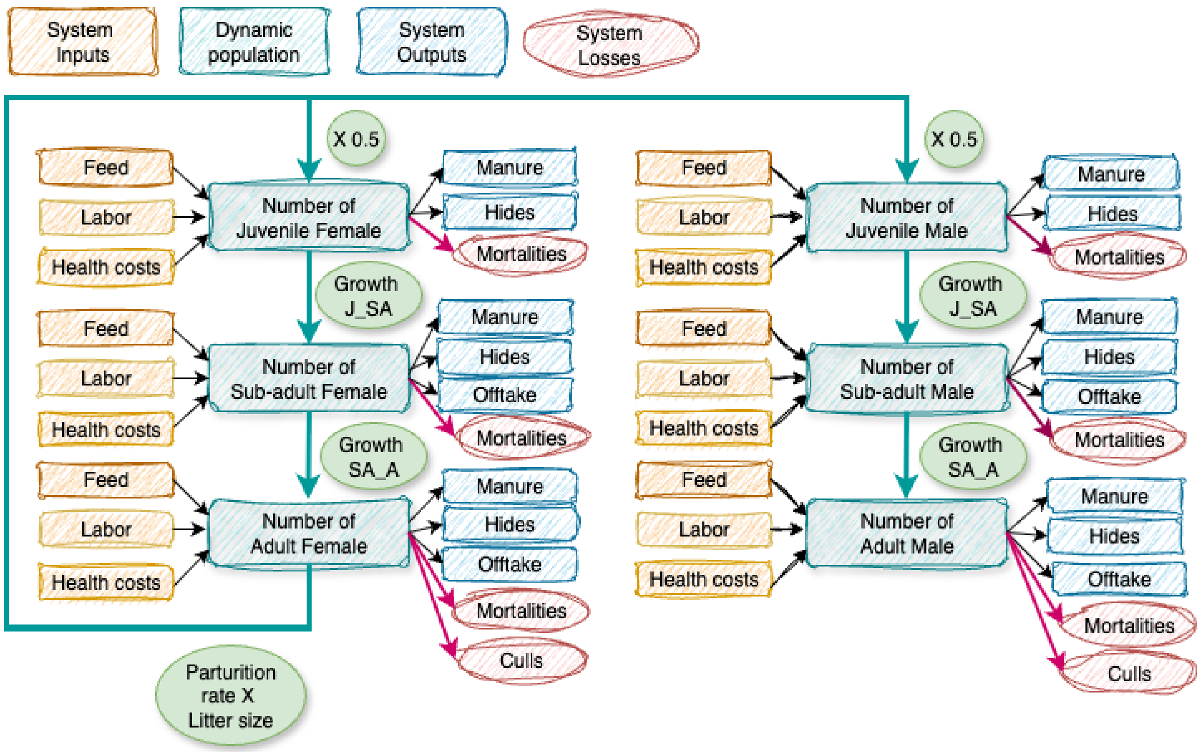

Figure 2. Schematic illustration of the GBADs Dynamic population model adapted for the Indonesian beef population

Within the model, reproductive performance is defined by parturition (number of births per year) and prolificacy (number of calves per birth) rates. Offtake rate is the number of cattle leaving a subgroup, minus the number of cattle entering the herd, then divided by the total number of cattle in the herd. In this analysis, cattle departing from the herd is based on slaughter rates and excludes those that die unexpectedly or are lost/stolen – these are captured under mortalities. The number of cattle joining the herd include those that have been purchased but excludes births.

Outputs produced by the system include changes in liveweight and value of the standing population, offtake liveweight and value, production of hides and manure from each age-sex group. Resources used by the system include, for each age-sex group; labour, feed and health costs (Fig 2). Labor cost specifically refers to worker's wages for the average time spent on animal husbandry tasks. Healthcare cost encompasses expenses related to healthcare, such as vaccines, drugs, and vitamins. Capital cost covers infrastructure expenses per head, which include land lease, rental of animal housing, machinery, tools, and transportation for production purposes.

The value of beef cattle production is then calculated as the value of the animal population (asset value) and products (slaughtered cattle, hides, manure), minus the costs associated with feed, labour, healthcare, and capital (Table 1).

2.2 Defining the model scenarios

2.2.1 Current Scenario

Parameters used to define the livestock populations, productivity, income and expenditure of the Current scenario were based on data from government databases and the literature. Where possible, we used data relating specifically to 2021. However, this was not always available, especially for parameters which relied on assumptions from the literature. In these cases, we used data relating to the most recent year available.

Data on the total beef cattle population in East Java in 2021 were obtained from Statistics Indonesia (Statistics Indonesia, 2022a) and are consistent with those used by Smith et al. (2024). The number of cattle in each age/sex group (Table 1) was calculated based on the proportion of male and female juvenile, subadult and adult cattle reported by Statistics Indonesia (Statistics Indonesia, 2022a).

The population of beef cattle in East Java is comprised of multiple breeds (e.g., Ongole, Madura, European crossbreds) with varying liveweights. The average liveweight for subadult and adult cattle was estimated based on values published in the literature and adjusted for differences between breeds of cattle as per Smith et al. (2024). The liveweights for juvenile cattle were obtained directly from the literature because there was a significant disparity observed between the calculated weights and those typically observed for individuals within the 0 to 1 year age range.

The price of live cattle per head is determined by multiplying the average liveweight of the cattle by the farm gate price of cattle per kilogram (Table 2). Farmgate prices per kilogram for slaughter cattle are assumed to be equivalent to the average prices per kilogram for live cattle of all ages (Smith et al., 2024).

The parturition rate (Table 3) was triangulated from literature (Priyanti et al., 2015; Mayberry et al., 2016; Baker et al., 2017; Kusuma et al., 2017), in which it was calculated by either dividing the annual count of new calves by the total number of cows for that year, or dividing 12 months by the average calving interval of cows. The prolificacy rate was set as one calf per parturition.

The monthly offtake rate of subadult and adult cattle was calculated based on annual slaughter rates reported by (Statistics Indonesia, 2022b). The official statistics do not report the age group of animals slaughtered, and in the absence of any other data it was assumed that 80% of slaughtered animals were adults. Cows were culled at 8 years and bulls at 5 years old. Offtake of juvenile cattle is set to zero as calves are rarely slaughtered.

Table 1. Population and production parameter values used for all scenarios.

Parameter	**Current Value**	**Source**
Initial Population (heads)		
Juvenile female	387,702	(Statistics Indonesia, 2022a)
Juvenile male	445,489	(Statistics Indonesia, 2022a)
Subadult female	664,773	(Statistics Indonesia, 2022a)
Subadult male	620,323	(Statistics Indonesia, 2022a)
Adult female	2,409,183	(Statistics Indonesia, 2022a)
Adult male	410,421	(Statistics Indonesia, 2022a)
Fertility		
Prolificacy rate (number calves/birth)	1	Default value

Monthly offtake rate		
Juvenile female	0	Defined by authors
Juvenile male	0	Defined by authors
Subadult female	0.003	Calculated from slaughter rates
Subadult male	0.013	Calculated from slaughter rates
Adult female	0.0008	Calculated from slaughter rates
Adult male	0.019	Calculated from slaughter rates
Productivity		
Carcass yield	0.51	(Statistics Indonesia, 2022b)
Hides rate (average proportion of getting a hide from an animal)	1	Default value
Hide rate from animals that die from diseases and accident	0.5	Default value
Manure (kg/head/day) - Juvenile	Pert distribution (0.5, 0.8, 0.65)	default value; (Behnke, 2010)
Manure (kg/head/day) - Subadult	Pert distribution (0.8, 1.5, 1.15)	default value; (Behnke, 2010)
Manure (kg/head/day) - Adult	Pert distribution (1.5, 2.3, 1.9)	default value; (Behnke, 2010)
Feeding		
Feed requirements (kg dry matter/head/day)	0.023	Default value
Proportion of livestock keepers that purchase feed	0.24	(Hanifah et al., 2010; Priyanti et al., 2012a)
Proportion feed paid for	0.55	Defined by authors
Dry matter in feed	0.785	(Mayberry et al., 2016).

Prices of farm inputs were taken from official statistics (Table 2). The latest available data of 2017 were used, and the prices were converted to the price of 2021 using the inflation rates between 2017 to 2021(Statistics Indonesia, 2025). Costs were converted from Indonesian Rupiah (IDR) to US Dollars (USD) using the average exchange rate for 2021 of 14,306 IDR to 1 USD (Exchange-rates.org, 2024).

Table 2. Prices (USD) used to estimate value of beef cattle production and net margin in East Java

Parameter	**Value**	**Source**
Value of live animals and their outputs		
Live animals (USD/kg liveweight)	5.30	(Smith et al., 2024)

Hides (USD/per hide)	17.66	(Statistics Indonesia, 2022b)
Manure (USD/kg, dry weight)	0.02	(Zulkarnain et al., 2020)
Cost of herd inputs		
Feed cost (USD/kg)	0.08	(Statistics Indonesia, 2024)
Farm labour (USD/head/year)	79.06	(Statistics Indonesia, 2024)
Health expenditure on prevention (USD/head/month)	4.99[1]	(Statistics Indonesia, 2024)
Health expenditure on treatment (USD/head/month)	0.41[1]	(Statistics Indonesia, 2024)
Interest rate (%)	1.56	(Macrotrends, 2024)
Infrastructure per head (USD)	1.63	(Statistics Indonesia, 2024)

[1]set to 0 in Ideal Health scenario

2.2.2 Zero Mortality Scenario

In the Zero Mortality scenario, mortality rates for all age/sex groups were set to zero to reflect improved animal survival in the absence of disease. All other input parameters were the same as in the Current scenario (Table 1).

2.2.3 Ideal Health Scenario

The Ideal Health Scenario was defined as a scenario where perfect animal health conditions are achieved. In this scenario, animals are free of any diseases and are in an optimal environment without any stress. They have all the nutrients they need so they can reach to the full potential in growth. Thus, there are no morbidity and mortality due to diseases and outside stressors. No health expenditures such as costs of veterinary care, antimicrobial treatment and vaccination were included in this scenario.

To achieve this, mortality rates and expenditure on animal health were set to zero, and liveweight, reproductivity, productivity values were revised to reflect improved production in the absence of disease (Table 3). These parameters were estimated using an expert elicitation process (described below) as there was no literature available on productivity parameters in the theoretical Ideal Health scenario.

Table 3. Population and production parameter values for the Animal Health Loss Envelope analysis. Parameter values for the Current scenario are from the literature, and values for the

Ideal Health scenario are from the expert elicitation process. Parameter values for pert distributions are (min, max, mode).

Parameter	Current Scenario	Zero Mortality	Ideal Health	Source
Fertility				
Annual parturition rate	Pert distribution (0.52, 0.61, 0.54)	Pert distribution (0.52, 0.61, 0.54)	Pert distribution (0.68, 0.87, 0.78)	(Priyanti et al., 2015; Mayberry et al., 2016; Baker et al., 2017; Kusuma et al., 2017)
Monthly Mortality				
Juvenile	Pert distribution (0.0025, 0.00375, 0.00267)	0	0	(Hanifah et al., 2010; Deblitz et al., 2011; Mayberry et al., 2016)
Subadult	Pert distribution (0.00075, 0.0018, 0.00125)	0	0	(Mobius et al., 2011)
Adult female	Pert distribution (0.0005, 0.0035, 0.002)	0	0	(Mobius et al., 2011)
Adult male	Pert distribution (0.0005, 0.0035, 0.002)	0	0	(Makanuwey, 2009)
Average liveweight (kg)				
Juvenile female	82	82	90	(Baliarti, 1991)
Juvenile male	82	82	100	(Baliarti, 1991)
Subadult female	234	234	266	(Statistics Indonesia, 2011, 2022a; Smith et al., 2024)
Subadult male	260	260	263	(Statistics Indonesia, 2011, 2022a; Smith et al., 2024)
Adult female	341	341	388	(Statistics Indonesia, 2011, 2022a; Smith et al., 2024)
Adult male	397	397	475	(Statistics Indonesia, 2011, 2022a; Smith et al., 2024)

2.3 Expert elicitation process

An expert elicitation process was used to define characteristics for the Ideal Health scenario and attribute the AHLE to infectious, non-infectious and external causes. The process followed the same structure as has been used by other GBADs studies in Ethiopia and Senegal (Larkins et al., 2023; Meyer et al., 2025a) following the IDEA protocol (Hemming et al., 2018).

A one-day face-to-face workshop was conducted in Surabaya, East Java, in November 2023. The participants included nine experts in beef cattle production (veterinary professionals, livestock companies, academia and farmers) identified by local colleagues based on their knowledge of local beef production systems. All the experts have a work experience of more than five years in livestock and veterinary fields and at least eight of them are post-graduate professionals. The workshop included discussions on the following items: 1) introduction to the GBADs project, 2) a survey to define characteristics of an Ideal Health scenario in relation to current productivity, and 3) a questionnaire to attribute production and mortality losses to different causes Participants were asked to specifically consider smallholder beef production systems in their responses as this is the most predominant production system of beef cattle raisers in East Java. Agreement between experts was assessed using the Overall Concordance Correlation Coefficient (OCCC) applied separately to the 5th , 50th , and 95th percentiles of their estimates on ideal productivity values.

2.3.1. Quantification of the Ideal Health scenario

Participants were asked to individually complete a survey defining production parameters for Current and Ideal Health scenarios based on their field experience on beef cattle production in East Java. Results from the survey were aggregated and then presented back to the group, leading to a group discussion where experts shared insights and reasoning to achieve consensus. After the group discussion, participants had the opportunity to revise their estimates, and the collective data were used for the final analysis following an adjustment process that weighted the likely accuracy of parameters provided by each expert.

The questionnaire included questions on production parameters in beef cattle under the Current scenario (41 questions) and Ideal Health scenario (38 questions) (see supplementary section). Questions relating to the Current scenario (average liveweight for each age/sex group, average parturition rate) were used to generate seed values to assess the performance of each participant. Answers from experts who had greater accuracy in estimating seed values were given greater weighting in calculating the final aggregated values of the production performance in the Ideal Health scenario. Questions relating to the Ideal Health scenario included average liveweights of different age/sex subgroups, reproduction rates, mortality and time spent by farmers addressing animal health issues. Participants were asked to give their estimations on the minimum, most likely and maximum values for each parameter.

The adjusted values derived from the expert elicitation process were calculated using Cooke's Classical Model (Cooke and Goossens, 2000) implemented in EXALIBUR (v.1.6.1 Pro, LightTwist Software). The parturition and mortality rates used in the models were defined as Pert distributions to address the uncertainty when estimating values. The mean values of the experts' final inputs of the minimum, most likely and maximum of a parameter were used as the fifth quantile, ninety-fifth quantile (thus they defined the 90% of the interval) and the most likely value of a distribution.

2.3.2 Attribution of loss

Workshop participants were asked to individually estimate the proportion of mortality and productivity losses for each cattle age/sex group attributable to infectious diseases, non-infectious diseases and external causes, focusing on 2021. They were also asked to justify their responses and identify major animal health problems impacting local beef farms within each category.

Similar to the process used to define parameters of the Ideal Health scenario, participants completed the questionnaire individually prior to group discussions. They were given the option to revise their inputs individually and the final inputs were collected for analysis.

Data were analysed using Qualtrics (Qualtrics, 2005; Larkins et al., 2023). The average attributional values and their confidence intervals were reported where possible. Agreement between experts was assessed using the Overall Concordance Correlation Coefficient (OCCC) applied separately to the minimum, average, and maximum estimates.

3. Results

3.1 Expert elicitation results

All the experts estimated a better performance in the Ideal Health scenario compared to the Current scenario. For example, the parturition rate increased from 54% in the Current scenario to 78% in the Ideal Health scenario. The liveweights of cattle increased between 1% to 20% in the Ideal Health scenario compared to the Current scenario (Table 3). Agreement among experts was high across all quantiles of ideal productivity, with mean OCCC values of 0.91 for the 5th percentile, 0.90 for the 50th percentile, and 0.90 for the 95th percentile. These results indicate strong consistency among experts in their lower-bound, best-estimate, and upper-bound elicited values.

For the loss attribution, the level of agreement varied across the estimated minimum, mean and maximum percentages. Overall, the OCCC analysis indicates that expert judgement was most consistent for maximum values and least consistent for minimum values, with considerable dispersion in responses across all elicited ranges. For the minimum estimates, expert agreement was low (OCCC = 0.17), with low precision (0.32) and moderate accuracy (0.52), indicating substantial variability among experts regarding the lower bound of expected impacts. For the average estimates, the OCCC was 0.33, reflecting low-to-moderate concordance. These estimates demonstrated good accuracy (0.84) but continued to exhibit low precision (0.40). The maximum estimates from the experts showed the highest level of agreement (OCCC = 0.37) with modest precision (0.48) and good accuracy (0.77).

3.2 Animal Health Loss Envelope

The total gross margin of beef cattle production in East Java in 2021 was estimated to be 1,299 million USD (Table 4). Compared to the Ideal Health scenario, the estimated value of total animal health loss in the beef cattle sector in East Java was 962 (90% CI: 947 - 972) million USD. The loss was 43% of the total gross margin in the Ideal Health scenario, and it was 74% of the total gross margin of that year. Compared to the Zero Mortality scenario, the estimated value of total animal health loss in the beef cattle sector in East Java was 197 (90% CI: 190 - 203) million USD. While the highest gross margins in all scenarios were for adult males, the greatest economic losses from both mortality (Current - Zero Mortality) and productivity (Zero Mortality - Ideal Health) were for adult females. This is likely due to the large contribution of adult females to the total population. Economic losses from all other age/sex groups were small.

Table 4. Total gross margin and economic losses in different age/sex groups between scenarios. Values are million USD.

Age/sex groups	Total gross margin for each scenario			Economic loss	
	Current	Zero-mortality	Ideal Health	Current – Zero mortality	Current – Ideal Health
Overall	1,299	1,496	2,260	197	962
Juvenile Female	27	34	143	7	115
Juvenile Male	10	14	124	4	114
Subadult Female	-214	-197	-160	17	54
Subadult Male	-119	-103	33	16	152
Adult Female	566	682	978	116	411
Adult Male	1,028	1,066	1,142	38	114

The greatest losses were due to production loss, which was 736 (90% CI: 715 - 755) million USD. Mortality loss was 197 (90% CI: 190 - 203) million USD, and expenditure on animal health was 27.8 (90% CI: 27.7-27.9) million USD. The loss was largely due to the increased herd value and saved labour cost in the Ideal Health scenario (Figure 3).

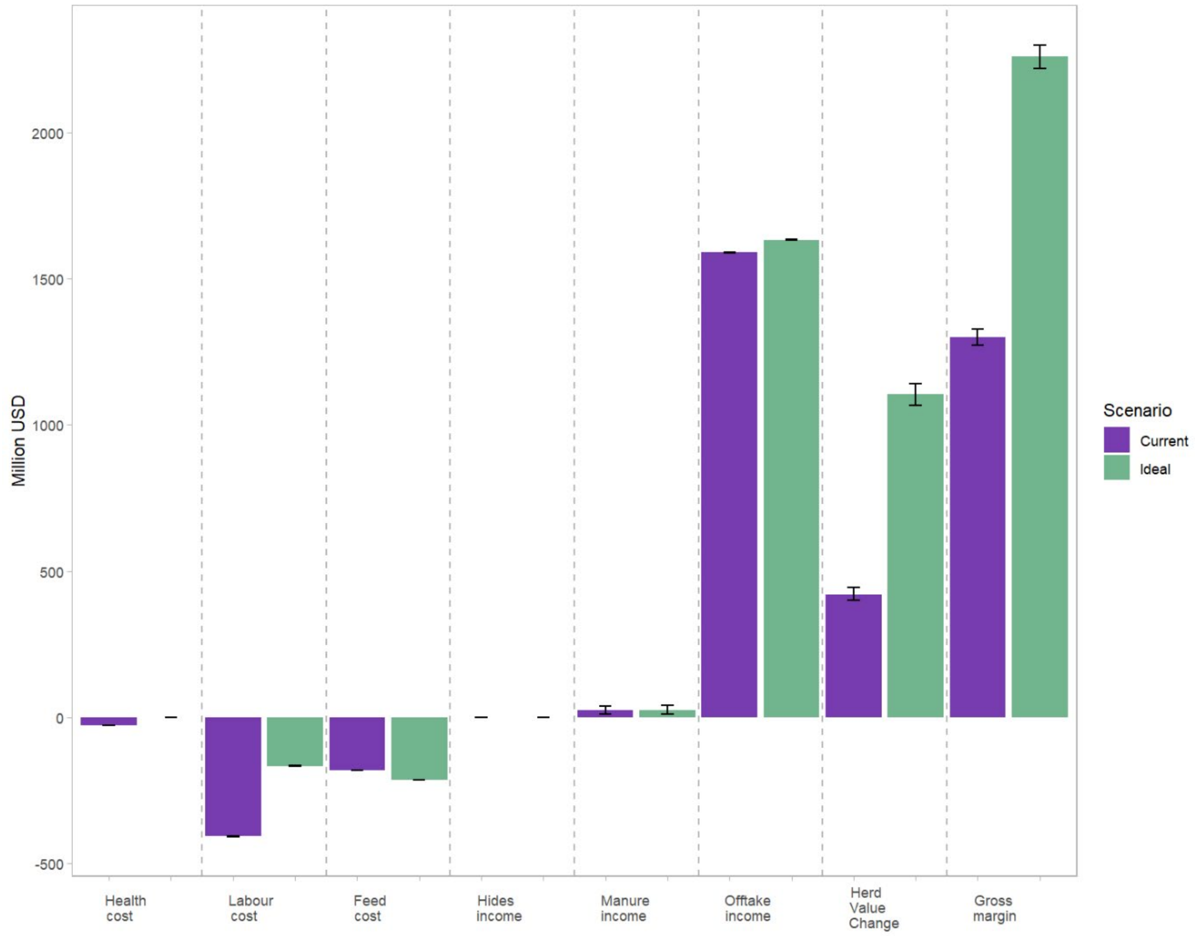

Figure 3. Annual costs, revenue and gross margins for the Current and the Ideal Health scenarios of beef production in East Java, 2021. Values presented are mean and 90% confidence intervals.

3.3 Loss attribution

For the burden attributions of the mortality loss, the expert group identified infectious diseases as the major cause of loss (38 - 45% in all age groups), followed by non-infectious diseases (32 - 39% in all age groups) and external causes (20 - 30% in all age groups) (Figure 4). Infectious diseases were also identified as the major cause of production losses (43 - 49% in all age groups), followed by non-infectious diseases (31 - 34% in all age groups) and external causes (20 - 25% in all age groups).

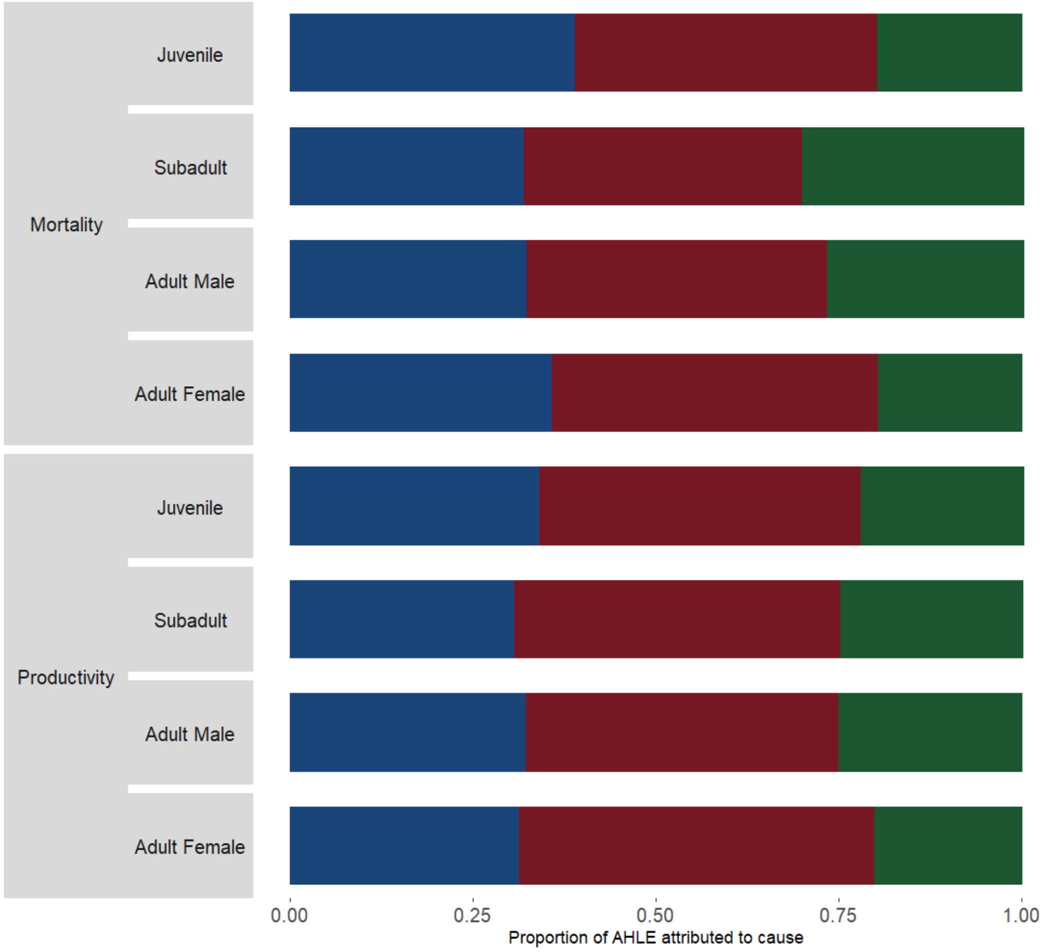

Figure 4. Proportion of cattle mortality and production losses attributed to non-infectious (blue), infectious (red), and external (green) causes by age/sex group.

A range of causes were identified by the expert group as causes of mortality and production losses. These included infectious diseases, malnutrition, reproductive issues, genetics, poor management and accidents. Rather than identifying specific diseases, most of the expert responses focused on syndromes or groups of diseases (e.g., infectious digestive diseases). In addition, despite productivity losses causing the greatest economic losses, very few causes of production losses were identified, especially for non-infectious diseases and external causes. Malnutrition was also only identified as a cause of mortality, but not production losses (Table 5).

Table 5. Health problems mentioned by the experts that caused losses in beef cattle in East Java

Age group	Health problems	Mortality loss related	Productivity loss related

Juvenile cattle	Infectious diseases	Anthrax; Aspiration Pneumonia; Infectious digestive diseases	Infectious digestive diseases
	Non-infectious diseases	No comments on specific diseases/problems	No comments on specific diseases/problems
	Outside stress	Poor management	No comments on specific problems
Subadult	Infectious diseases	No comments on specific diseases/problems	Infectious diseases that can delay growth
	Non-infectious diseases	Malnutrition	No comments on specific diseases/problems
	Outside stress	No comments on specific diseases/problems	No comments on specific diseases/problems
Adult females	Infectious diseases	Reproductive diseases	No comments on specific diseases/problems
	Non-infectious diseases	Malnutrition	Ovarian hypofunction
	Outside stress	No comments on specific diseases/problems	No comments on specific problems
Adult males	Infectious diseases	Infections of the genital tract	Infectious digestive diseases; diseases that can lead to sterility
	Non-infectious diseases	Genetic issues	Non-infectious digestive diseases
	Outside stress	Accident	No comments on specific problems

4. Discussion

This study has identified potential losses of 961 million USD due to animal health issues in the East Java beef herd in 2021. These losses are equivalent to approximately 12% of the value of the total beef value in East Java and 4% of national beef production. Given the importance of beef production to local livelihoods and food security, these findings indicate the need for increased and targeted investment in beef cattle health and husbandry.

Our results showed that improving cattle health would mainly increase the herd value and would reduce the labour cost. The increased herd value was due to the increased population as no mortality and the increased liveweights of cattle of different ages. The labour input on animal health tasks such as treatment to sick animals was also saved in Ideal Health scenario.

While production losses in beef cattle production have previously been identified in East Java, the value of these losses has not been quantified or attributed to specific causes or syndromes. Previous studies have reported the presence of gastrointestinal parasites, liver fluke and reproductive disease (infectious bovine rhinotracheitis, bovine viral diarrhoea, chlamydiosis) in Java, though they rarely report on production impacts (Priyanti et al., 2012a; Dahlanuddin et al., 2017; Nugroho et al., 2020; Subekti et al., 2021; Zalizar et al., 2021; Hastutiek et al., 2022). Some of the health problems mentioned in the literature were also identified during our expert elicitation process, though specific diseases or pathogens were rarely highlighted. Additional health problems not identified in our review of literature, such as aspiration pneumonia and anthrax, were also mentioned. The lack of specific diseases mentioned during the expert elicitation process may reflect low mortality and morbidity rates associated with infectious causes in East Java production systems or could be an artifact of the elicitation process.

In contrast to our findings, previous studies (e.g., Mayberry et al 2016) have reported correlations between inadequate nutrition and sub-optimal mating management with low growth and reproduction rates. While malnutrition and poor management were mentioned by participants during the expert elicitation process, their contribution to production and mortality losses was considered small, with total losses attributable to external causes less than 30%

across all groups. This finding may reflect the expertise and bias of the participants towards "diseases". Alternatively, the current levels of nutrition and management may be considered adequate or not changeable. Improved data on production losses from both diseases and other causes would therefore help to clarify the main causes of production and mortality losses and provide a more accurate estimate of disease burdens.

Similar findings on the AHLE and its attribution were found in GBADs case studies in other countries. An analysis of the AHLE in small ruminants in Senegal reported that the production loss was higher than the mortality loss (Meyer et al., 2025a), which is the same in this Indonesian case study. Similarly, the attributions of losses from experts were similar to the attributions in other GBAD case study countries. For example, the infectious disease was believed to be the most important driver for both mortality and production loss in the crop livestock mixed system in Ethiopia (a beef system similar to the small holder beef sector in East Java), while the external causes were the least important reason for losses (Larkins et al., 2023). However, the attributions of losses due to infectious diseases in different age groups were different between the two countries. For example, when comparing between age/sex groups, the infectious diseases caused the highest mortality in calves in Ethiopia. Although in Indonesia the infectious diseases caused the highest mortality in cows compared to the other age/sex groups. These findings between different countries suggest that the production loss are more important comparing to the direct mortality loss, and the disease dynamics in different countries would determine the different loss attributions between high-level causes. To support evidence-based animal health investment, systematic and timely analysis of AHLE is needed in a country.

Findings in this study could be used by the Indonesian government and industry stakeholders to inform animal health investments. Infectious diseases were identified by the expert group as an important cause of losses in beef production systems. Thus, biosecurity should be given priority by local animal health stakeholders. It is therefore more justifiable to invest on preventing infectious diseases, particularly foot and mouth disease and lumpy skin disease, which have heavily affected the country since 2022 (Susanti et al., 2023; Zainuddin et al., 2023). Non-infectious diseases, which are often overlooked, were also a major cause of losses, especially in calves. In particular, poor nutrition can exacerbate the impacts of diseases on both productivity and mortality.

It is worth noting that experts mentioned different problems for different age/sex groups, which would support specific interventions to different cattle subgroups. For example, this study showed that infectious digestive diseases in calves are of concern, while reproductive problems in cows seems more important than other disease – presumably reflecting the importance of cows for breeding in these production systems. Thus, local animal health authorities and farmers should give priority to the control of relevant diseases in calves such as gastrointestinal nematodes (Strydom et al., 2023), and reproductive disease in cows such as bovine viral diarrhoea, brucellosis and ovarian hypofunction (Dubovi, 1994; Muflihanah et al., 2013; Salman et al., 2021).

In addition, there may be other socio-cultural restrictions on the current beef production in East Java, although this is out of the scope of this study. The investment on local beef health should also consider farmer aspirations and local social-cultural drivers for improved productivity in the beef sector in the province. Some studies showed that indigenous Bali cattle are preferred by farmers due to their superior dressing rate and meat quality, and European crossbreds are 20-50% more expensive due to their better productivity (Purwantara et al., 2012). However, consumers rarely pay different prices for meat from different breeds of cattle because they generally cannot distinguish breed origins at the point of purchase. (Wankar et al., 2023). Cultural resistance to change remains significant, as delivered cattle development programs have had little impact on increasing the cattle population. Hilmiati et al. (2024) argued that traditional cultural values and practices continue to influence production systems more than modern interventions. Local farmers often raise cattle for cash to pay school fees and other costs, and they have difficulties in borrowing money from banks to invest in cattle production.

While this study provides an initial estimate of the burden of disease for beef cattle in East Java, the accuracy of our results is limited by issues associated with the availability and granularity of published data. For example, the GBADs population dynamic model requires parameters on population size and productivity by age/sex group, but official livestock statistics are often only reported at the population level. In particular, while the official statistics report the number of male and female cattle slaughtered, they do not provide data on animal age, and we had to make assumptions around the demographics of slaughter cattle. The beef cattle in the province were considered a population and averaged values such as liveweight were used in the model. The diversity of beef cattle farms among regions in the province was overlooked due to data gaps in beef cattle systems in these regions. In addition, other assumptions on ideal production performance were made in this study, such as "same growth periods of different age/sex groups in the Ideal Health scenario as in the current scenario" and "same offtake rates of different age/sex groups in the Ideal Health scenario". However, it is challenging to validate each of these assumptions. In the future, GBADs are aiming to provide a comprehensive dataset and a data sharing platform to meet the need of systematic disease burden analysis.

While the Ideal Health Scenario is helpful to quantify production and mortality losses caused by production issues, we recognise that it cannot occur in the real world. An alternative approach would be to use a "benchmark method" comparing productivity of the top 5% of producers with the Current Scenario. However, this approach also comes with limitations. Firstly, even the best producers incur production losses due to disease burdens, especially losses due to non-infectious diseases, so this approach would lead to an underestimate the total disease burden. Secondly, it is challenging to define the top producers, and there is often a data gap on the subgroup-specific performance.

The calculation of the AHLE and attribution to infectious, non-infectious and external causes relied on data captured through the expert elicitation process, and the accuracy of these estimations is subject to the knowledge and biases of the expert group. For example, veterinarians or epidemiologists in charge of disease surveillance may give greater weighting to infectious diseases as the most important reason for livestock production loss. While we invited experts from diverse backgrounds to participate in the expert elicitation process, the small group size may have limited the diversity of experience and introduced bias to the parameter estimation. In addition, the animal health context of cattle production has changed significantly between 2021 (our focus year) and 2024 (when the expert elicitation process was conducted) due to the outbreak of lumpy skin and foot and mouth disease. This may have altered our expert's perception of the relative importance of infectious diseases in 2021. Finally, there is lack of validation for the attribution results from experts due to data gaps. Despite these limitations, this approach can be taken as a pilot study and results cross-checked when data-based methods become available in the future (Larkins et al., 2023).

To address these limitations, a new data-driven method on loss attribution is under development in GBADs programme. In the future, incidences of health problems and their impacts on mortality and productivity will be put into the model to estimate losses due to different health problems. It will be helpful that the surveillance data can be explored to understand better the health problem incidences and their impacts. In this study, the total health loss was attributed at a very general level by experts, although disease specific loss analysis was attractive to many. Disease-specific loss should be explored with data-driven approaches in the future.

Conclusions

The current study estimated the total animal health burden in the Indonesian beef sector using the GBADs methodology, in which the current gross margin of the sector was compared to a theoretical Ideal Scenario. This study indicated that the total health loss of beef cattle in East Java in 2021 was 962 million USD. This was 43% of the ideal gross margin of local beef cattle sector. The production loss, mortality loss and health expenditure were 736 million USD, 197 million USD and 27.8 million USD, respectively. According to the knowledge of local livestock experts, infectious diseases were the major cause of loss, followed by non-infectious diseases and external causes. The identified contributors provide insights for policy makers and serve as a foundation for informed health investment in East Java's beef cattle industry.

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Ethics

The study was approved by the CSIRO Social and Interdisciplinary Science Human Research Ethics Committee (approval ID 122/22) and the National Research and Innovation Agency (BRIN).

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